

Faculty of Resource Science and Technology

Systematics and Phylogeny of the Short-horned Grasshoppers and Locusts (Orthoptera: Acrididae) of Malaysian Borneo

Farah Nabillah binti Abu Hasan Aidil Fitri

Master of Science
2023

Systematics and Phylogeny of the Short-horned Grasshoppers and Locusts (Orthoptera: Acrididae) of Malaysian Borneo

Farah Nabillah binti Abu Hasan Aidil Fitri

A thesis submitted

In fulfillment of the requirements for the degree of Master of Science

(Entomology)

Faculty of Resource Science and Technology
UNIVERSITI MALAYSIA SARAWAK
2023

DECLARATION

I declare that the work in this thesis was carried out in accordance with the regulations of Universiti Malaysia Sarawak. Except where due acknowledgements have been made, the work is that of the author alone. The thesis has not been accepted for any degree and is not concurrently submitted in candidature of any other degree.

……

Signature

Name: Farah Nabillah binti Abu Hasan Aidil Fitri

Matric No.: 17020207

Faculty of Resource Science and Technology

Universiti Malaysia Sarawak

Date :

ACKNOWLEDGEMENT

In the name of Allah, the Most Gracious and the Most Merciful.

Alhamdulillah, all praises to Allah s.w.t. and His blessings for the completion of this thesis. This study would not have been possible without the guidance and abundance of help from several individuals and institutions which in one way or another contributed to the preparation and completion of this thesis.

Prima facie, I offer my sincerest gratitude to my supervisors, Dr. Siti Nurlydia binti Sazali @ Piksin and Ms. Ratnawati binti Hazali, for the invaluable guidance and advice, as well as the immense support and trust towards me in giving the opportunity to work in my own way throughout this journey. I attribute my success in completing this master's degree to the encouragement, effort, and patience I received from both women whom I respect.

I would like to express my gratefulness to Universiti Malaysia Sarawak, especially UNIMAS Insect Reference Collection (UIRC) of Faculty Resource Science and Technology for the authorisation to use the research facilities and assessing the specimens that are crucial for my project. This study was also partially funded by UNIMAS under the Special Top-Down Grant (F07/SpTDG/1766/2018) awarded to Dr. Siti Nurlydia binti Sazali, Ms. Ratnawati binti Hazali and Mdm. Wan Nurainie binti Wan Ismail. Special thanks to the faculty's personnel, especially Mdm. Wan Nurainie binti Wan Ismail, Mr. Mohamad Jalani bin Mortada and Mr. Wahap bin Marni for their assists in the laboratory and guidance during samples collection in the fields.

I wish to extend my greatest gratitude and gratefulness to Research, Development and Innovation Division of Forest Department Sarawak, as well as three reputable institutions in Sabah, namely Sabah Museum, Sabah Parks Natural History Museum, and Institute of Tropical Biology and Conservation of Universiti Malaysia Sabah for granting access to their establishments and authorising the examination of their insects' collections. With great cooperation from these bodies of organisations, my thesis was able to incorporate and elaborate on more inclusive data encompassing the Malaysian Borneo region.

A world of gratitude and love to my backbones; my father and mother, Abu Hasan Aidil Fitri bin Shafee and Yakhamiah binti Adenan, my sisters, families, and Muhammad Afiqfaqihuddin bin Siddek Maulana for their endless support in all forms throughout my journey in completing the thesis. Their love, faith, prayers, and understanding have made me stronger each day, especially when I am at my lowest. This master's degree is dedicated especially to them.

Not to forget my systematics duo, Ahmad Irfan bin Abdul Razak, for all the knowledge (and tea) shared, words of encouragement and fun times while working on this project. Special shoutout to my PG room clique, Marcellinus Isaac Stia, Nurhanis Hafizah binti Hanafiah, Anisa Grace Robert Galang, and Mohamad Norsyahizi Haikal bin Mansor, for all the stress-relieving activities and merriness in the post-graduate room. My thoughts and love also goes to my best friends, Noorzaileen Eileena binti Zaidi, and the GAJAH; Nur Dania binti Haris, Megat Muhammad Nadzrin bin Norizan, and Muhamad Affan bin Ab Azid for always cheering me on and encouraging me to complete my thesis.

Last but never the leasr, I would love to express my thanks to F.R.I.E.N.D.S and its casts, as well as The Weeknd (Abel Tesfaye) and blackbear, as they were part of what keeps my sanity while I was working alone in the museum and working towards the completion of this thesis. I thank everyone wholeheartedly and I pat myself on the back for finally crossing the finish line. Adieu. *As-salamu'alaykum*.

ABSTRACT

Family Acrididae encompassed of the short-horned grasshoppers and locusts belonging to the suborder Caelifera with over 28 subfamilies, 1,400 genera and 6,700 valid species described, distributed across the world. However, knowledge on the phylogeny and systematics of the family were still lacking in the Bornean region, although other documentations relation to their composition, diversity and ecology have been reported. Most studies on phylogeny and systematics of Acrididae were centralised on the Western world. Plus, the relationship between members of the family had always been ambiguous as family Acrididae were used as the taxonomic dumping group for aberrant species, thus leading to conflicting taxonomic theories by different researchers. Thus, the goal of this study is to describe the species within family Acrididae in Malaysian Borneo, record their distributions and build taxonomic keys for the family represented by the eastern region of Malaysia. Next, this study aims to construct the phylogeny within subfamilies of Acrididae from Malaysian Borneo by using morphological data. The systematics study was based on an examination of voucher specimens from several different institutions in Malaysian Borneo, as well as new collections. A total of 1,216 acridoid specimens represented by 28 species of 20 genera from five subfamilies were successfully examined, with no new species recorded. Phylogenetic analysis using neighbour-joining and maximum parsimony consisting of 100 morphological characters coded based on 28 ingroups and two outgroups (Pyrgomorphidae) were performed using Phylogenetic Analysis Using Parsimony (*and Other Methods) (PAUP*) and Tree Analysis Using New Technology (TNT) software. The result deduced a monophyletic Acrididae when rooted with the sister group, Pyrgomorphidae, although paraphyly were rampant throughout subfamily Acridinae, Catantopinae, Cyrtacanthacridinae, and Oedipodinae, while Oxyinae was deduced to be

monophyletic on the basal position of the clade. Additionally, systematics revision based on 28 species of 20 genera were presented. Dichotomous key to the subfamilies of Acrididae based on comparative morphology study, as well as habitus-coloured photographs and geological distribution maps for all species documented in Malaysian Borneo were provided. The outcomes of this study were hoped to benefit in providing baseline data for taxon sampling in future studies, adding new insights on the phylogenetic relationships between subfamilies of Acrididae based on sampled taxa in Malaysian Bornean region, as well as revising the documentation of the family recorded from Sabah and Sarawak while contributing worthwhile knowledge to the studies of Acrididae worldwide.

Keywords: Acrididae, phylogeny, Sarawak, short-horned grasshoppers, systematics

Sistematik dan Filogeni Belalang Tanduk Pendek dan Belalang Juta (Orthoptera: Acrididae) dari Malaysia Timur

ABSTRAK

*Famili Acrididae merangkumi belalang tanduk pendek dan belalang juta daripada suborder Caelifera merangkumi 28 subfamili, 1,400 genus dan 6,700 spesies sah yang telah dilaporkan dengan populasi menyeluruh di serata dunia. Namun begitu, pengetahuan mengenai filogeni dan sistematik famili ini masih sangat terbatas di wilayah Borneo, walaupun maklumat lain mengaitkan komposisi, kepelbagaian spesies dan ekologi famili tersebut telah direkodkan. Kebanyakan kajian mengenai filogeni dan sistematik famili Acrididae hanya bertumpu di dunia Barat. Tambahan pula, hubungan di antara ahli dalam famili ini sentiasa tidak jelas kerana selalu digunakan sebagai kumpulan lambakan taksonomi untuk spesies aberan, sekaligus menyumbang kepada percanggahan teori taksonomi dalam kalangan penyelidik. Oleh itu, matlamat kajian ini adalah untuk menerangkan spesies dalam famili Acrididae di Malaysia Timur, merekodkan taburan dan membina kekunci taksonomi bagi famili ini yang diwakili oleh wilayah timur Malaysia. Seterusnya, kajian ini juga bertujuan untuk membina filogeni di antara subfamili dalam Acrididae dari Malaysia Timur dengan menggunakan data morfologi. Kajian sistematik ini dijalankan berdasarkan pemeriksaan spesimen baucar dari beberapa institusi di Malaysia Timur, serta pengumpulan spesimen tambahan. Sebanyak 1,216 spesimen diwakili oleh 28 spesies daripada 20 genus dan lima subfamili telah berjaya diperiksa, tanpa ada rekod mengenai spesies baharu. Analisis filogenetik menggunakan kelompok kejiranan dan parsimoni maksimum menerusi 100 ciri morfologi yang disenaraikan berdasarkan 28 spesies dalam kumpulan dan dua spesies di luar kumpulan (Pyrgomorphidae) dicapai melalui perisian Phylogenetic Analysis Using Parsimony (*and Other Methods) (PAUP*)*

dan Tree Analysis Using New Technology (TNT). Hasil kajian menunjukkan hubungan monofiletik famili Acrididae sekiranya kumpulan terdekat, famili Pyrgomorphidae digunakan sebagai kumpulan luar bagi pembinaan topologi pohon. Parafili pula meluas dalam subfamili Acridinae, Catantopinae, Cyrtacanthacridinae, dan Oedipodinae, sementara Oxyinae disimpulkan sebagai monofiletik yang terletak di tapak klad. Tambahan pula, semakan sistematik berdasarkan 28 spesies diwakili oleh 20 genus telah disediakan. Kekunci dikotomi kepada famili Acrididae berdasarkan morfologi perbandingan, serta fotograf habitus berwarna dan peta taburan geologi untuk semua spesies yang direkodkan di Malaysia Timur juga telah disediakan. Hasil kajian ini diharap dapat membantu untuk menyediakan data asas bagi pensampelan taksa untuk kajian akan datang, menguatkan fahaman ke atas hubungan filogeni antara subfamili dalam Acrididae berdasarkan taksa sampel di kawasan Malaysia Timur, dan mengemaskini dokumentasi famili tersebut yang direkodkan di Sabah dan Sarawak, serta menyumbang kepada pengetahuan tentang kajian ke atas Acrididae di serata dunia.

Kata kunci: *Acrididae, filogeni, Sarawak, belalang tanduk pendek, sistematik*

TABLE OF CONTENTS

		Page
DECLARATION		i
ACKNOWLEDGEMENT		ii
ABSTRACT		v
ABSTRAK		vii
TABLE OF CONTENTS		ix
LIST OF TABLES		xii
LIST OF FIGURES		xiii
LIST OF ABBREVIATIONS		xviii
CHAPTER 1: GENERAL INTRODUCTION		1
1.1	Research Background	1
1.2	Problem Statement	4
1.3	Objectives	7
CHAPTER 2: LITERATURE REVIEW		8
2.1	Acrididae MacLeay, 1821	8
2.1.1	Taxonomic History	8
2.1.2	Orthoptera Species File (OSF)	12
2.1.3	Family Acrididae	14

2.1.4 Morphological Descriptions 16

2.1.5 Developmental Stages 25

2.1.6 Roles in Ecosystem 29

2.2 Acrididae in Malaysian Borneo 33

2.3 Comparative Morphology of Acrididae 41

2.4 Phylogeny of Acrididae 43

CHAPTER 3: SYSTEMATICS OF FAMILY ACRIDIDAE MACLEAY, 1821 (ORTHOPTERA: ACRIDIDAE) FROM MALAYSIAN BORNEO 46

3.1 Introduction 46

3.2 Methodology 49

3.2.1 Materials 49

3.2.2 Preservation and Curation of Samples 50

3.2.3 Species Identification, Nomenclatural Data and Type Specimens 53

3.2.4 Character Sampling 54

3.2.5 Morphometric Measurements 55

3.2.6 Imaging 55

3.2.7 Distribution Maps 56

3.3 Results 56

3.3.1 Species Identification 56

3.3.2 Species Abundance and Composition 57

3.3.3 Species Description 60

3.4 Conclusion 230

CHAPTER 4: PHYLOGENY OF FAMILY ACRIDIDAE MACLEAY, 1821 IN MALAYSIAN BORNEO BASED ON MORPHOLOGICAL DATA 231

4.1 Introduction 231

4.2 Methodology 234

4.2.1 Taxa Sampling 234

4.2.2 Character Sampling 236

4.2.3 Morphometric Measurement 247

4.2.4 Phylogenetic Analyses 247

4.3 Results and Discussion 248

4.3.1 Character Homology and Terminology 248

4.3.2 Phylogenetic Interpretations 265

4.4 Chapter Summary 272

CHAPTER 5: CONCLUSION AND RECOMMENDATIONS 274

5.1 Conclusion 274

5.2 Recommendations 275

REFERENCES 277

APPENDICES 306

LIST OF TABLES

		Page
Table 2.1	List of acridids species documented in Malaysia based on literature records.	17
Table 2.2	List of acridids species documented in Malaysian Borneo based on literature records.	36
Table 2.3	List of species recorded in Sarawak from 1938 – 2020 by different authors according to current classification system. Subfamilies in Willemse (1938) raised to family level were omitted from current record.	39
Table 3.1	List of species with the repositories, number of individuals and relative abundance of Acrididae examined from Malaysian Borneo. Abbreviations are as follows: UIRC: UNIMAS Insect Reference Collection, RDID: Research Development and Innovation Division of Forest Department Sarawak, SM: Sabah Museum, SPM: Sabah Parks Natural History Museum, and ITBC: Institute of Tropical Biology and Conservation of Universiti Malaysia Sabah.	58
Table 4.1	List of species from family Acrididae documented from Malaysian Borneo.	235
Table 4.2	List of morphological characters and character states used in the phylogeny analysis.	237
Table 4.3	Data matrix for family Acrididae.	241

LIST OF FIGURES

Page

Figure 2.1 The current status on the knowledge of grasshopper fauna in terms of countries. White on the map represents countries that were extensively studied, light gray represents countries that were moderately studied, dark grey represents countries that were poorly studied, and black on the map represents countries that has not been studied and explored at all. Adapted from "Grasshopper systematics: Past, present and future," by H. Song, 2010, *Journal of Orthoptera Research*, *19*(1), 57-68. 15

Figure 2.2 Anatomy of an acridid from lateral view. Adapted from Grasshoppers of Wyoming and the West, by University of Wyoming, n.d. (http://www.uwyo.edu/entomology/grasshoppers/colorado/indentification.html). 21

Figure 2.3 Front view of the head of an acridid. Adapted from Grasshoppers of Wyoming and the West, by University of Wyoming, n.d. (http://www.uwyo.edu/entomology/grasshoppers/colorado/indentification.html). 22

Figure 2.4 Anatomy of an acridid from dorsal view. Adapted from Grasshoppers of Wyoming and the West, by University of Wyoming, n.d. (http://www.uwyo.edu/entomology/grasshoppers/colorado/indentification.html). 23

Figure 2.5 Ventral view of the thorax of an acridid. Adapted from Grasshoppers of Wyoming and the West, by University of Wyoming, n.d. (http://www.uwyo.edu/entomology/grasshoppers/colorado/indentification.html). 23

Figure 2.6 Lateral view of the abdominal segments of an acridid. Adapted and modified from Locusts and Grasshoppers of the U.S.S.R. and Adjacent Countries (Part I) (p. 11), by G. Bei-Bienko & L. Mishchenko, 1963, Israel Program for Scientific Translations Ltd. 24

Figure 2.7 Saltatorial leg of a grasshopper, adapted for jumping. Adapted and modified from Locusts and Grasshoppers of the U.S.S.R. and Adjacent Countries (Part I) (p. 11), by G. Bei-Bienko & L. Mishchenko, 1963, Israel Program for Scientific Translations Ltd. 24

Figure 2.8 (a) Lateral view of the male external reproductive organ; (b) Dorsal view of the male external reproductive organ. Adapted and modified from Grasshoppers of Wyoming and the West, by University of Wyoming, n.d.

(http://www.uwyo.edu/entomology/grasshoppers/colorado/indentification.html). 26

Figure 2.9 Lateral view of the female external reproductive organ. Adapted and modified from Grasshoppers of Wyoming and the West, by University of Wyoming, n.d. (http://www.uwyo.edu/entomology/grasshoppers/colorado/indentification.html). 26

Figure 2.10 Development of grasshopper's wings from the 1st to the 5th instars. Adapted from Grasshopper control, by Utah State University, n.d. (https://extension.usu.edu/pests/ipm/notes_ag/veg-grasshopper-control). 29

Figure 3.1 The correct height for the distance of sample's body to the top of the pin with the position of labelling data. 51

Figure 3.2 Entomological cabinet used to store insect specimens. 52

Figure 3.3 Entomological storebox used to store insect specimens. 53

Figure 3.4 Lateral view of *Traulia azureipennis* focusing on some of the external morphological characters assessed in morphometrical measurements. 56

Figure 3.5 *Phlaeoba antennata*, ♂. **A.** Dorsal view of type; **B.** Lateral view of type. Scale = 5 mm. 68

Figure 3.6 *Phlaeoba infumata*, ♀. **A.** Dorsal view of type; **B.** Lateral view of type. Scale = 5 mm. 72

Figure 3.7 Distribution map of subfamily Acridinae in Malaysian Borneo. 73

Figure 3.8 *Apalacris varicornis*, ♂. **A.** Dorsal view of type; **B.** Lateral view of type. Scale = 5 mm. 78

Figure 3.9 *Coloracris azureus*, ♂. **A.** Dorsal view of type; **B.** Lateral view of type. Scale = 5 mm. 82

Figure 3.10 *Coloracris coerulescens*, ♀. **A.** Dorsal view of type; **B.** Lateral view of type. Scale = 5 mm. 86

Figure 3.11 *Coloracris* sp., ♂. **A.** Dorsal view of type; **B.** Lateral view of type. Scale = 5 mm. 90

Figure 3.12 *Craneopsis olivacea*, ♂. **A.** Dorsal view of type; **B.** Lateral view of type. Scale = 5 mm. 94

Figure 3.13 *Meltripata* sp. 1, ♂. **A.** Dorsal view of type; **B.** Lateral view of type. Scale = 5 mm. 98

Figure 3.14 *Meltripata* sp. 2, ♀. **A.** Dorsal view of type; **B.** Lateral view of type. Scale = 5 mm. 102

Figure 3.15 *Perakia borneensis*, ♂. **A.** Dorsal view of type; **B.** Lateral view of type. Scale = 5 mm. 106

Figure 3.16 *Phalaca waterstradti*, ♂. **A.** Dorsal view of type; **B.** Lateral view of type. Scale = 5 mm. 110

Figure 3.17 *Stenocatantops splendens*, ♂. **A.** Dorsal view of type; **B.** Lateral view of type. Scale = 5 mm. 116

Figure 3.18 *Traulacris grandis*, ♀. **A.** Dorsal view of type; **B.** Lateral view of type. Scale = 5 mm. 121

Figure 3.19 Distribution map of genera *Coloracris* and *Meltripata*, including *Craneopsis olivacea*, *Perakia borneensis*, *Phalaca waterstradti* and *Traulacris grandis* from subfamily Catantopinae in Malaysian Borneo. 122

Figure 3.20 *Traulia azureipennis*, ♂. **A.** Dorsal view of type; **B.** Lateral view of type. Scale = 5 mm. 131

Figure 3.21 *Traulia borneensis*, ♀. **A.** Dorsal view of type; **B.** Lateral view of type. Scale = 5 mm. 136

Figure 3.22 *Traulia sanguinipes sanguinipes*, ♂. **A.** Dorsal view of type; **B.** Lateral view of type. Scale = 5 mm. 141

Figure 3.23 Distribution map of genus *Traulia* from subfamily Catantopinae in Malaysian Borneo. 142

Figure 3.24 *Xenocatantops humilis*, ♀. **A.** Dorsal view of type; **B.** Lateral view of type. Scale = 5 mm. 150

Figure 3.25 Distribution map of *Apalacris varicornis*, *Stenocatantops splendens* and *Xenocatantops humilis* from subfamily Catantopinae in Malaysian Borneo. 151

Figure 3.26 *Patanga luteicornis*, ♀. **A.** Dorsal view of type; **B.** Lateral view of type. Scale = 5 mm. 158

Figure 3.27 *Patanga succincta*, ♀. **A.** Dorsal view of type; **B.** Lateral view of type. Scale = 5 mm. 164

Figure 3.28 *Valanga nigricornis*, ♂. **A.** Dorsal view of type; **B.** Lateral view of type. Scale = 5 mm. 174

Figure 3.29 Distribution map of subfamily Cyrtacanthacridinae in Malaysian Borneo. 175

Figure 3.30 *Aiolopus thalassinus tamulus*, ♂. **A.** Dorsal view of type; **B.** Lateral view of type. Scale = 5 mm. 182

Figure 3.31 *Gastrimargus marmoratus*, ♀. **A.** Dorsal view of type; **B.** Lateral view of type. Scale = 5 mm. 189

Figure 3.32 *Heteropternis obscurella*, ♂. **A.** Dorsal view of type; **B.** Lateral view of type. Scale = 5 mm. 193

Figure 3.33 *Locusta migratoria manilensis*, ♂. **A.** Dorsal view of type; **B.** Lateral view of type. Scale = 5 mm. 199

Figure 3.34 *Trilophidia annulata*, ♂. **A.** Dorsal view of type; **B.** Lateral view of type. Scale = 5 mm. 206

Figure 3.35 Distribution map of subfamily Oedipodinae in Malaysian Borneo. 207

Figure 3.36 *Oxya hyla intricata*, ♂. **A.** Dorsal view of type; **B.** Lateral view of type. Scale = 5 mm. 213

Figure 3.37 *Oxya japonica japonica*, ♂. **A.** Dorsal view of type; **B.** Lateral view of type. Scale = 5 mm. 222

Figure 3.38 *Pseudoxya diminuta*, ♂. **A.** Dorsal view of type; **B.** Lateral view of type. Scale = 5 mm. 229

Figure 3.39 Distribution map of subfamily Oxyinae from Malaysian Borneo. 230

Figure 4.1 Variation of head structures in Acrididae. **A.** *Phalaca waterstradti*; **B.** *Patanga succincta*; **C.** *Craneopsis olivacea*; **D.** *Perakia borneensis* (dorsal view); **E.** *P. borneensis* (left lateral view); **F.** *Coloracris coerulescens*; **G.** *Meltripata* sp. 2; **H.** *Coloracris* sp.; **I.** *Meltripata* sp. 1; **J.** *C. azureus*; **K.** *Phlaeoba infumata*. Scale = 5 mm. 253

Figure 4.2 Variation of prosternal process in Acrididae. **A.** *Coloracris coerulescens*; **B.** *Patanga luteicornis*; **C.** *Craneopsis olivacea*. 254

Figure 4.3 Variation of pronotal structures in Acrididae. **A.** *Craneopsis olivacea*; **B.** *Coloracris coerulescens*; **C.** *Patanga succincta*; **D.** *Meltripata* sp. 2; **E.** *P. succincta* (right lateral view); **F.** *Gastrimargus marmoratus*; **G.** *P. succincta* (ventral view); **H.** *Perakia borneesis* (ventral view); **I.** *Traulia borneensis* (ventral view). Scale = 5 mm. 259

Figure 4.4 Variation of leg structures in Acrididae. **A.** *Perakia borneensis*; **B.** *Craneopsis olivacea*; **C.** *Coloracris coerulescens*; **D.** *Phalaca waterstradti*; **E.** *P. borneensis* (left dorsal view); **F.** *C. azureus* (left dorsal view). Scale = 5 mm. 261

Figure 4.5 Variation of male external genital structures in Acrididae from lateral view; **A.** *Perakia borneensis*, **B.** *Meltripata* sp. 1, **C.** *Craneopsis*

olivacea, and dorsal view; **D.** *Coloracris azureus*, **E.** *Coloracris* sp., **F.** *Meltripata* sp. 1. Scale = 1 mm. 263

Figure 4.6 Variation of female external genitalia structures in Acrididae; **A.** *Meltripata* sp. 2 (lateral view); **B.** *Meltripata* sp. 2 (dorsal view); **C.** *Coloracris coerulescens* (ventral view) and **D.** *Patanga succincta* (ventral view). Scale = 1 mm. 265

Figure 4.7 Topology of Acrididae based on neighbour-joining analysis with bootstrapping measure of 1,000 replicates. Branch numbers indicates bootstrap values. Only bootstrap values of more than 50% were shown on the branch. 271

Figure 4.8 Consensus tree of 24 most parsimonious trees of 28 species of Acrididae including the outgroup representatives of Pyrgomorphidae based on 100 morphological structures according to TNT (length = 484; consistency index = 0.36; retention index = 0.55). Number above branches (x/y/z) represents symmetric resampling, standard bootstrap and jacknifing respectively. Only bootstrap values of more than 50% were shown on the branch. 272

LIST OF ABBREVIATIONS

%	Percent
BMNH	British Museum (Natural History)
BS	Bootstrap
CI	Consistency index
CIS	Centre for Insect Systematics
COPR	Centre for Overseas Pest Research
FAO	Food and Agriculture Organization
FDS	Forest Department Sarawak
FRC	Forest Research Centre
GIS	Global Information System
HI	Homoplasy index
HoB	Heart of Borneo
ICZN	International Commission on Zoological Nomenclature
ITBC	Institute of Tropical Biology and Conservation
km^2	Square kilometre
MCSN	Museo Civico di Storia Naturale “Giacomo Doria”
MP	Maximum parsimony
mya	Million years ago
NHRS	Naturhistoriska Riksmuseet / Swedish Museum of Natural History
NJ	Neighbour-joining
OSF	Orthoptera Species File
OUMNH	Oxford University Museum of Natural History

PAUP*	Phylogenetic Analysis Using Parsimony (*and Other Methods)
PFE	Permanent Forest Estate
QGIS	Quantum Geographic Information System
RDID	Research, Development and Innovation Division
rDNA	Ribosomal deoxyribonucleic acid
RI	Retention index
RNA	Ribonucleic acid
SL	State Land
SM	Sabah Museum
sp.	Species
SPM	Sabah Parks Natural History Museum
SMSM	Sarawak Museum
TNT	Tree Analysis Using New Technology
TPA	Totally Protected Area
UIRC	UNIMAS Insect Reference Collection
UKM	Universiti Kebangsaan Malaysia
UNIMAS	Universiti Malaysia Sarawak

CHAPTER 1

GENERAL INTRODUCTION

1.1 Research Background

The family Acrididae, commonly recognised as the short-horned grasshoppers and locusts, belongs to the suborder Caelifera within the order Orthoptera with over 9,000 valid species have been described (Hill & Abang, 2010). The family name was first used by Krauss (1890) based on the type genus *Acrida* Linnaeus (1758) with priority for family-group names based on *Acrida* deriving from Acridina MacLeay, 1821. Proof of the family's ancestral lineage dated back in the Late Cretaceous era and diversification of the family line happened after Cretaceous-Paleogene boundary, going early into the Cenozoic era (Flook & Rowell, 1997; Song et al., 2015, 2018).

Acrididae is by far the most well-known and diverse acridoid family dispersed along the natural and anthropogenic habitats such as grasslands, tropical forests, shrublands, deserts, wetlands and alpine regions all over the world (Latchininsky et al., 2011; Song et al., 2018). They serve numerous significant roles in the ecosystem such as a crucial source of nutrition for vertebrates (Gandar, 1982) and invertebrates (Joern et al., 2006), excellent bioindicators (Bazelet & Samways, 2014) and play a part in terms of nutrient cycling (Mitchell & Pfadt, 1974; Rodell, 1977; Belovsky & Slade, 1993).

Richards and Davies (1977) reported that some species in the family, commonly known as locusts, have the ability to transform into two different phases; migratory and sedentary, and this phase polyphenism is heavily dependent on the population density (Song & Wenzel, 2007). Sedentary phases describes species in solitary, which typically does not

swarm or congregate as population density increases, inhabiting the same locality throughout life (Song & Wenzel, 2007), and generally unable to express obvious density-dependent plasticity behaviour compared to migratorial species (Kilpatrick et al., 2019). Locust phase polyphenism is often exhibited by gregarious species and could be seen as an expression of numerous phenotypically plastic responses often affected by the change of local population density (Song & Wenzel, 2007; Song, 2011; Kilpatrick et al., 2019).

These extreme changes in phenotypes not only changes the colour and behaviour of the species but also affect the biochemical, ecological, molecular, physiology of the population, and morphology of the individuals, such as the nymphal colour pattern, body size and morphometric ratio (Song et al., 2017; Kilpatrick et al., 2019). Due to these changes, grasshoppers and locusts are notorious in their role as economic pest. Some species voraciously devours paddy (Reissig et al., 1986) and other economically important plants (Nair, 2001; Willemse, 2001; Siwi et al., 2005). Nevertheless, with the advancement in pest control measurements, most of the species were found to be non-swarming which would cause less damage to the plantations and less outbreaks have been reported due to anthropogenic factors which disrupt the natural habitats and feeding spots of the family (Reissig et al., 1986; Willemse, 2001).

The most prominent characters that differentiate Acrididae from the rest of the families are: (i) short antennae with less than 30 segments and are almost always shorter than the combined length of head and pronotum; (ii) non-elongated ovipositors consisting of four short valves; (iii) hearing organ (tympanum) located on the first abdominal tergite; (iv) stouter in shape with thicker forewings; (v) usually more bright and cryptically coloured; (vi) tarsi divided into three segments; (vii) lacks fastigial furrow with wide frontal ridge,

foveola may be present or absent, with slight to deep median depression dorsally; and, (viii) eggs are usually in clusters and deposited into the soils (Ball et al., 1942; Willemse, 2001; Smith et al., 2004; Tan, 2012a; Chapman, 2013; Tan & Kamaruddin, 2014; Ali & Panhwar, 2017; Gardiner, 2018).

The phylogenetic relationship between subfamilies of Acrididae in Malaysian Borneo is still in its infancy. There had never been any extensive phylogenetic studies conducted on the family documented in the Bornean region. Most of the studies focused on higher-level orthopterans in Africa, Eurasia, Europe, and North America. Thus, the outcome of those studies were only documented based on species collected from the regions (Bei-Bienko & Mishchenko, 1963). Additionally, most of these researchers concentrated on deducing phylogenetic relationships within subfamily or genera level using molecular and morphological data (Cigliano et al., 1996; Song, 2004; Colombo et al., 2005; Song & Wenzel, 2007; Marquier, 2010; Li et al., 2011; Husemann et al., 2012; Song et al., 2015).

One of the most comprehensive study on higher-level acridids had been presented by Liu et al. (2008) using 12S and 16S rDNA genome sequences to reassess the phylogenetic relationships of the family and resulted in a monophyletic Oedipodinae, suggesting that this subfamily is a relatively primitive subfamily within family Acrididae. The study also revealed that subfamilies Catantopinae and Acridinae appeared to be non-monophyletic, and due to these discrepancies in the phylogeny within the subfamilies, Liu et al. (2008) suggested that more information is required to resolve the phylogenetic relationships of the family.

1.2 Problem Statement

As one of the largest family in suborder Caelifera, acridids are found to be abundant and capable of adapting to different ecosystems as a method of survivability (Song et al., 2018). Due to this highly adaptive characteristic, acridids have also become well known as ecological indicator and agricultural pests (Arya et al., 2015), albeit their minor impact especially in Malaysian Borneo. As documented by Adu-Acheampong and Samways (2019), the sensitivity of these grasshoppers to environmental changes, coupled with their functional importance and high diversity which leads to the ease of sampling had proven their usefulness as a good bioindicator. This was strengthen by Andersen et al. (2001), in their research on of species extinction from the agricultural expansion in the natural areas by using grasshoppers as model organism and their results corresponds to the study by Fartmann et al. (2012) which showed the response by grasshoppers for succession in steppe grasslands. From their study, species richness was found to be the highest at the earliest successional stages, presumably due to the microclimatic conditions and bare grounds that are suitable as breeding sites.

Nair (2001) discussed on the destructive role of acridids as pest of exotic trees in Southeast Asian countries with their tendency to rise in populations. As stated by Joern (1979), grasshoppers have a species-specific variation in their feeding behaviour and the theory was proven by Nair (2001) when the leaf-feeding *Valanga nigricornis* were often observed feeding on eucalyptus species and *Acacia mangium* in Malaysia and Indonesia. From the study, *V. nigricornis* were also linked to the declining number of plants in nursery sites and young plantations in Indonesia.

As such, east of Malaysia would be wise to take precautionary steps on controlling the population of these acridids as they occupy the same land as Indonesia and shared similar types of vegetations that might attract overcrowding of species. Certain species with phenotypic plasticity shows higher tendency for overcrowding and causes damage to the area (Kilpatrick et al., 2019). Over time, these species will acclimatise and become serious pests as insects have shorter generation time and life cycle in comparison with the plants they attacked. Plus, Nair (2001) debated that these acridids can adapt quicker to their environment, while plants in general have a lower chance to develop resistance mechanisms through natural selection as they have longer generation time.

Additionally, knowledge on family Acrididae is still limited as no intensive and published studies have been done on the systematics and phylogeny of the family in Malaysia. Previous published works focusing solely on acridids carried out in Malaysia, in particular the states of Sabah and Sarawak, were based on studies done by western researchers such as Miller (1937) and Willemse (1938), while some works were also conducted in the neighbouring countries such as Brunei (Tan & Wahab, 2018), the Philippines (Bruner, 1915; Rehn & Rehn, 1940) and Singapore (Tan, 2010a, 2010b, 2012a, 2012b; Tan & Wang, 2012; Tan et al., 2012; Tan, 2013; Tan et al., 2013; Tan, 2019). However, studies undertaken by these western researchers dated back to the 1930's on the account of the several expeditions held in Malaysian Borneo, thus emphasising the need for further updated and holistic approach to assemble a functional system of recognising the family.

Moreover, the relationships between members of the family had always been problematic and unstable due to the conflicting taxonomic theories that were based on

different morphological sets such as wing venation, internal organs, external morphology and the male phallic complex, as disputed by Song et al. (2015). Besides, the family had long been the taxonomic dumping ground for aberrant species and used by researchers to group species when faced with classification problems (Song et al., 2018). This was elucidated by Roberts (1941) as his study on male phallic structures treated the current families Ommexechidae, Pamphagidae, Pyrgomorphidae, Romalidae as subfamilies of Acrididae, although through recent studies they were proven to be distinct families.

The main research gap of understanding the biology and relationships on family Acrididae was that most of the studies conducted on acridids were focused on the African, Australian, European, North American, South American, South Asian and Temperate Asian regions (Liu & Li, 1995; Cigliano & Otte, 2003; Smith et al., 2004; Cigliano & Amedegnato, 2010; Li et al., 2011; Cigliano et al., 2011; Khan & Usmani, 2016; Mobin et al., 2017; Rahaman & Usmani, 2017; Song et al., 2018). Therefore, the systematics and phylogeny with the use of morphological data of family Acrididae will be the major disciplines of this study which was carried out in the Malaysian Borneo region of Malaysia.

Being one of the Sundaland biodiversity hotspot areas, it is expected that the knowledge extracted from this study would benefit in providing a baseline data for taxon sampling in future studies concerning the phylogeny and taxonomy of the family, as well as updating the documentation of family Acrididae with the addition of new insights on the phylogenetic relationships between subfamilies of acridids based on sampled taxa recorded from Malaysian Borneo. Furthermore, the outcome of this study is hoped to help in the management of agricultural pests and other ecological studies, as well as serving worthwhile knowledge to the studies of Acrididae globally.

1.3 Objectives

The objectives of this study are as follows:

i) To describe the species within family Acrididae, record the distribution of the family in Malaysian Borneo, and build the taxonomic keys for the family; and

ii) To construct the phylogeny within subfamilies in family Acrididae in Malaysian Borneo using morphological data.

.

CHAPTER 2

LITERATURE REVIEW

2.1 Acrididae MacLeay, 1821

2.1.1 Taxonomic History

The family group name Acrididae was first used by Krauss (1890) based on the type genus *Acrida* Linnaeus (1758). The precedence of denoting the family-group names was also based on *Acrida* originating from Acridina MacLeay, 1821. In the early years of scientific research, the imposition of species nomenclature although crucial as a fundamental first stage of any scientific study has not been taken seriously or even acknowledged as stated by Kirby (1825), as a result of the escalating numbers of researchers carrying out new research at different times without a comprehensive system of classification as a guidance.

The common name short-horned grasshoppers and locusts were used to describe the family Acrididae. In 1802, Latreille first acknowledged Acridites (Acrididae) and Locustariæ (Locustidae) as families of the order Orthoptera while further categorising Criquet, Gomphocère, Oedipode, Pneumore, Podisme, Proscopie, Tétrix, Truxale and Xyphicère as subfamilies of Acridites and Anisoptère, Conocèphale, Éphippigère, Pennicorne and Sauterelle as subfamilies of Locustariæ in his later publication. In Familles Naturelles du Règne Animal, he very briefly discussed the grouping of Orthoptera into three separate sections according to their general morphology and behaviour (Latreille, 1825). The first section includes four families, Blattaires (Blattidae), Forficulaires (Forficulidae), Mantides (Mantidae) and Spectres (Phasmidae), characterised by having: (i) horizontal elytra and wings; (ii) legs suitable for running; and (iii) no stridulating organ. The second section comprises of two families, Grilloniens (Gryllotalpidae) and Locustaires

(Locustidae), described as having: (i) roof-like elytra and wings; (ii) legs suitable for jumping, with very large thighs; (iii) male producing chirping sound by rubbing inner part of legs together against the elytra; (iv) first abdominal segment without tympanum; and (v) females with protruding, sword-shaped ovipositor and burying their eggs without the envelope. The last section composes of only one family, Acridiens (Acrididae), represented by: (i) roof-like elytra and wings; (ii) posterior legs used for jumping and tarsi composed of five articles; (iii) male and female producing chirping sound by rubbing inner part of legs together against the elytra; (iv) drum (tympanum) on each side of first abdominal segment can be distinguished externally by a membranous operculum, circular or lunular; (v) tare comprised of four hooked pieces which formed a small protrusion; (vi) antennae sometimes sword-shaped, subulate, filiform or club-shaped in both sexes or in males only; (vii) eggs are enclosed in envelope or cohesively covered with frothy and viscous material; and (viii) eggs pods are buried in the sand.

MacLeay (1821) conceded Acridina and Locustina as tribes under the order Orthoptera in Horæ Entomologicæ or Essays on the Annulose Animals. This was supported by Kirby (1825), as he adopted the nomenclature system by Linnaeus where species with obtuse head and straight ovipositor would be identified as *Acrida*, while species with conical head belonged to *Conocephalus* and species with tegmina imitating plants and recurved ovipositors would be recognised as *Pterophylla*, further debunking Fabricius' classification from Systema Entomologiae in which Fabricius (1775) rejected three of Linnaeus' nomenclatural structure by turning *Acrida* into *Truxalis*, *Bulla* into *Acrydium*, and *Locusta* into *Gryllus*, while retaining *Acheta* and *Tettigonia*.

In 1893, Brunner retained the division into tribes system that was established by Stål (1873) with minimal modifications. Oedipodidae was still recognised as its own subfamily under the family Acridiodea, separate from Acrididae, and concurring to the classification by Saussure (1884) in Prodromus Oedopodiorum Insectorum ex Ordine Orthopterorum. The subfamilies recognised under family Acridiodea in this monograph includes Acrididae, Mastacidae, Oedipodidae, Pamphagidae, Pneumoridae, Proscopidae, Pyrgomorphidae, Tettigidae and Tryxalidae. At this point of time, Brunner (1893) separated Locustodea into a higher rank of family level, with 15 different subfamilies under its division, which includes Conocephalidae, Locustidae, Meconemidae, Mecopodidae and Phaneropteridae to name a few. This nomenclature system was adopted by Kirby (1914) with slight modifications, including the adjustment of the family name from Acridiodea to Acridiidae, and excluding two of the subfamilies, Pneumoridae and Proscopidae, in his publication as they were exclusively constricted in the South African and Tropical American regions respectively. Additionally, he decided to reconstruct the suffix of the subfamilies from *-idae* to *-inae*. Thus, the subfamilies of the Indian Acridiidae as mentioned in his monograph were converted to Acrydiinae, Batrachotetriginae, Catantopinae, Eumastacinae, Oedipodinae, Pamphaginae, Pyrgomorphinae and Tryxalinae. In relation to the family Locustodea mentioned above, Kirby (1914) has further lowered the rank of these locusts into genera level of the subfamily Oedipodinae.

However, Lucas (1920) in "A Monograph of the British Orthoptera" raised the rank of the subfamilies into the families under suborder Acridiodea, which includes Acridiidae, Mastacidae, Oedipodidae, Pamphagidae, Pneumoridae, Proscopiidae, Pyrgomorphidae, Tetrigidae and Truxalidae. He agreed with Kirby (1914) on the fact that true locusts are known as the short-horned grasshoppers, thus belonged to Acridiodea. In spite of that, he

still retained the sub-order Locustodea as a category for the long-horned grasshoppers as he upheld the nomenclature system established by Brunner (1893).

The confusion over the group Locusta were due to the fact that most European authors were following Geoffroy's (1762) nomenclature system for *Locusta* where he assigned *Locusta* to the long-horned grasshoppers or katydids of the family Tettigoniidae and assigning the true locusts to *Acrydium*. As such, Pierre André Latreille, Brunner von Wattenwyl, William John Lucas and other entomologists from the continental European region defined *Locusta* as Orthoptera with longer hindlegs as opposed to the forelegs and midlegs, tympanum on fore tibiae below the knee, antennae slender and very long surpassing the total body length and long, sword-shaped ovipositors. This was debated by Krauss (1902) as he raised the issue regarding the introduction of old names which followed Linnaeus (1758). He explained that the idea of nomenclature classification proposed by Linnaeus was not followed by his immediate successors, thus the complete vision of the idea was almost completely blurred. His arguments was supported by Uvarov (1921a) as he stated that Linnaeus (1758) in Systema Naturæ had intended the name *Locusta* for the short-horned grasshoppers and swarming locusts as written by the old Romans.

The reintroduction of *Locusta* to the true locusts was made by Leach (1815) in the spirit of Linnaeus as he also restore all the names associated to family Locustidae. The restoration of the name *Locusta* was accepted by most of the English authors including James Francis Stephens, John Obadiah Westwood and William Forsell Kirby, although other French and German authors preferred keeping the name introduced by Geoffroy (Krauss, 1902). Other significant statements discussed in Zoologisher Anzeiger by Krauss (1902) includes the construction of nomenclature system that was still in its infancy in the 19th

century. He criticised the formation of the nomenclature system which provides no uniformity to the community. This view was long condemned by Kirby (1825) as he commented that Linnaeus was successful in establishing the names of genera in Philosophia Botanica but did not manage to provide a regular system of nomenclature, although he succeeded in giving a uniform termination to the orders in Entomology. This was followed by Latreille (1802) as he divided the orders into various smaller sections. However, his system was rather confusing since he disregarded the general rule in construction and application of nomenclature system. Kirby (1825) also noted on his plan in adopting the patronymic names of the same termination for the insect orders but stated that he did not act further on the idea, but MacLeay (1821) in Horæ Entomologicæ adopted and improved on his idea by dividing the primary sections of the orders with the same termination, *-ina*. As the International Commission on Zoological Nomenclature (ICZN) was founded in 1895, Krauss (1902) pointed out that the final standardisation on the old basis following Linnaeus was adopted and certain uniformity gradually took place in the system of nomenclature. This international nomenclature system is principally used globally as a guide to labelling insects, thus avoiding confusion and unstandardised classification arrangements in the future.

2.1.2 Orthoptera Species File (OSF)

Taxonomists and systematics have always been in a debate regarding the taxonomic status of certain grasshopper species, leading to the erection of new subfamilies, and at times new family altogether (Louveaux et al., 2013; Song et al., 2015). The aforementioned state in the late 18th century and early 19th century have progressively made the nomenclature system chaotic within the orthopteran community, as most taxonomists were in disagreement on the classification structure (Geoffroy, 1762; Leach, 1815; Kirby, 1825; Brunner, 1882; Lucas, 1920). Due to these inconsistencies in the system, Chinese taxonomists resolved to

adopting their own classification system based on the species collected and recorded in China, that is still being used to date (Zheng, 1993; Xia, 1994; Zheng & Xia, 1998; Yin & Xia, 2003; Liu et al., 2008; Li et al., 2011). The difference in classification scheme used was illustrated in the categorisation of subfamily Oxyinae that is internationally classified under family Acrididae, but was raised in Xia's (1994) classification system to family level, Catantopidae, along with members of Arcypteridae, Gomphoceridae and Oedipodidae (Flook & Rowell, 1997; Liu et al., 2008).

Following these problematic classifications, Daniel Otte (1994-2000) came up with an eight-volume series of "Orthoptera Species File" (OSF) which compiled all information on Orthoptera at the time. The first volume of the series provided knowledge on Grylloidea that builds up to covering the whole order throughout the eight volume publications, and later developed its first online version in 1997 with the joint effort of Otte and Piotr Naskrecki (Song, 2010; Li et al., 2011; Song, 2018). The first version of OSF compiled all updated information from the first seven publications and includes images and sound recordings on species collected throughout the years (Eades, 2001; Cigliano et al., 2021).

An extension of Otte's work was undertaken by Eades (2001), where he first took the approach of digitalising all the materials into Version 2 of Orthoptera Species File Online with the intentions of making the information accessible worldwide, thus assisting other researchers to partake in updating the database at ease. The website is currently maintained and expanded by Cigliano et al. (2021) with the cooperation and support from the Orthopterists' Society where all important information, references, geological data and images could be easily accessed owing to the contributions of orthopterists around the globe. They have also provided literature citations, keys, ecological data, and other useful

information on species that are geared towards enlightening other researchers in other fields to prospective interests that could possibly be of important value. Additionally, this uniformed classification schemes by Otte (1981) was universally adopted and accepted by most orthopterists (Song et al., 2018), and due to heavy participation of researchers worldwide, the reputation and reliability of the website is strengthened (Cigliano et al., 2021).

2.1.3 Family Acrididae

Members of family Acrididae, classified under the superfamily Acridoidea were hypothesised to have emerged roughly around 66 million years ago, and were found worldwide with approximately 8,721 species, 2,000 genera and 88 subfamilies that had been documented (Song et al., 2018; Cigliano et al., 2021; David & Gautam, 2021). Among the 88 subfamilies recorded within Acrididae, 26 were recognized as valid subfamilies; the correct and accepted scientific names, with only Acridinae, Cyrtacanthacridinae, Gomphocerinae, Melanoplinae and Oedipodinae determined to have a cosmopolitan distribution, while the rest of the subfamilies were distributed in a more restricted areas (Song, 2018; Cigliano et al., 2021). In the opinion of Song et al. (2018), among the remaining subfamilies with the more restricted distributions, 14 are found particularly in the Old World, consisting of the African, Asian and European region, while seven of the subfamilies appeared to be distributed in the New World region, mainly in the Central and South America.

According to Song (2010), grasshopper fauna in the Old World; Paleartic, and New World; Neartic and Neotropic regions were extensively studied, although certain parts of Central America does not receive much attention and are in need of further exploration. His

arguments include the state of grasshopper fauna in western Tropical Asia that were also insufficiently studied as opposed to the other parts in eastern Africa. He further stated that the understanding in the taxonomy of acridids in tropical Southeast Asia were still at scarce as the grasshopper fauna has not been systematically studied, especially in countries such as Vietnam, Laos and Cambodia (Song, 2010). Figure 2.1 depicts the current status on the knowledge of grasshopper systematics in terms of countries as discussed heavily by Song (2010), revealing countries that were not studied due to circumstances such as inadequate researchers or environmental and ecological factors of the regions, to countries that have sufficient data and knowledge on grasshopper fauna.

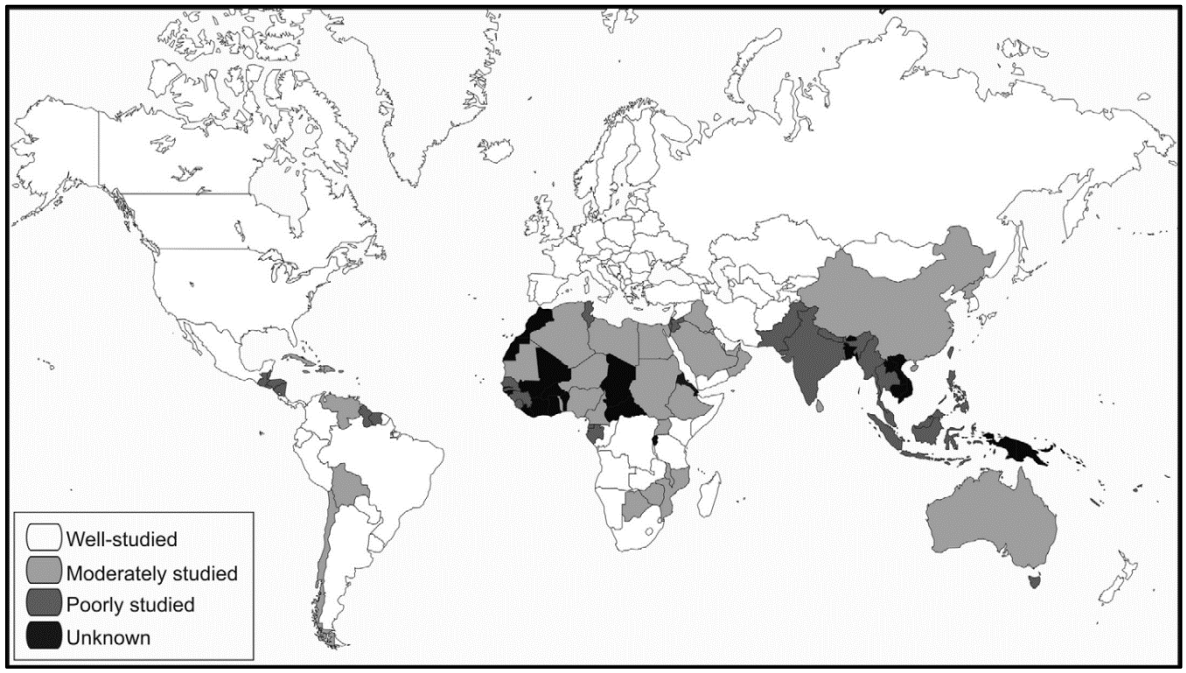


Figure 2.1: The current status on the knowledge of grasshopper fauna in terms of countries. White on the map represents countries that were extensively studied, light gray represents countries that were moderately studied, dark grey represents countries that were poorly studied, and black on the map represents countries that has not been studied and explored at all. Adapted from "Grasshopper systematics: Past, present and future," by H. Song, 2010, *Journal of Orthoptera Research*, *19*(1), 57-68.

Subsequently, species composition of the family in the Southeast Asia recorded approximately 1,968 species, while 75 species from 43 genera and 11 subfamilies were currently documented in Malaysia as listed in Table 2.1 (C. Willemse, 1938; L. Willemse, 2001; Chai, 2007; Mahmood et al., 2007, 2008; Tan & Kamaruddin, 2014, 2016; Farah Nabillah et al., 2020; Chung et al., 2021; Cigliano et al., 2021).

2.1.4 Morphological Descriptions

The order Orthoptera, that was derived from the Greek, "ortho" which means straight and "ptera" which means wings, represents one of the polyneopteran group of the insect orders (Song et al., 2015; Wipfler et al., 2019). The order Orthoptera is divided into two suborders, known as Caelifera and Ensifera. Members of suborder Caelifera, otherwise recognized as the "short-horned grasshoppers" are characterized as having robust antennae with less than 30 segments, asymmetrical mandibles specialised for consuming monocots foliage, thoracic pleura mostly visible, tympanum located on the first abdominal segments, having three or fewer tarsal segments and are diurnal (Song, 2018).

The model organism of this study shares similar morphological characteristics in general as shown in Figure 2.2. The body is divided into three major segments, namely head thorax and abdomen. The head consists of vertex, frontal costa, eyes, antennae, and mouthparts. Vertex refers to the surface area on top of the head, while frontal costa covers the area of the face when examined from the front view (Figure 2.3). Acridids possessed a pair of compound eyes, an ocellus situated approximately in the middle of the frontal ridge, and a pair of ocelli located just above the antennal base that holds the antennal segments. Acridids have relatively short antennae, consisting of not more than 26 to 28 segments equalling to approximately the length of head to pronotum. Most species in this study have

Table 2.1: List of acridids species documented in Malaysia based on literature records.

Subfamily	Genus	Species	Reference(s)
Acridinae	*Acrida*	*Acrida cinerea*	Mahmood et al. (2007)
		Acrida willemsei	Willemse (2001)
		Acrida sp.	Chung et al. (2021)
	Phlaeoba	*Phlaeoba antennata*	C. Willemse (1938), L. Willemse (2001), Chai (2007), Tan & Kamaruddin (2014), Farah Nabillah et al. (2020)
		Phlaeoba antennata malayensis	Mahmood et al. (2007), Tan & Kamaruddin (2016)
		Phlaeoba fumosa	Willemse (2001)
		Phlaeoba infumata	Willemse (2001), Mahmood et al. (2007), Tan & Kamaruddin (2014, 2016), Farah Nabillah et al. (2020)
	Vitalisia	*Vitalisia bangiensus*	(Mahmood et al., 2007)
Catantopinae	*Althaemenes*	*Althaemenes maculalutea*	Chai (2007)
	Anacranae	*Anacranae nuda*	Tan & Kamaruddin (2014)
	Apalacris	*Apalacris varicornis*	Willemse (2001), Chai (2007), Mahmood et al. (2007), Tan & Kamaruddin (2016), Farah Nabillah et al. (2020)
	Coloracris	*Coloracris azureus*	Willemse (1938)
		Coloracris coerulescens	Willemse (1938), Chai (2007), Farah Nabillah et al. (2020)
		Coloracris viridis	Willemse (1938)
		Coloracris sp.	Farah Nabillah et al. (2020)
	Craneopsis	*Craneopsis olivacea*	Farah Nabillah et al. (2020)
	Eritrichius (?)	*Eritrichius* (?) cf. *modiglianii*	Tan & Kamaruddin (2014, 2016)
	Meltripata	*Meltripata antennata*	Mahmood et al. (2007), Tan & Kamaruddin (2014)
		Meltripata bolivari	Mahmood et al. (2007)
		Meltripata cauta	Tan & Kamaruddin (2016)
		Meltripata picta	Mahmood et al. (2007)
	Pagdenia	*Pagdenia rufipes*	Mahmood et al. (2007)
	Pareuthymia	*Pareuthymia brevifrons*	Chai (2007)
		Pareuthymia maculata	Mahmood et al. (2007)
		Pareuthymia obscura	Willemse (1938)
	Peitharchicus	*Peitharchicus fasciatus*	Chai (2007)

Table 2.1 continued.

Subfamily	Genus	Species	Reference
	Perakia	*Perakia borneensis*	Farah Nabillah et al. (2020)
	Phalaca	*Phalaca sarawakensis*	Willemse (1938)
		Phalaca waterstradti	Farah Nabillah et al. (2020)
	Sedulia	*Sedulia perakensis*	Mahmood et al. (2007)
		Sedulia specularia	Tan & Kamaruddin (2016)
	Stenocatantops	*Stenocatantops splendens*	C. Willemse (1938), L. Willemse (2001), Chai (2007), Mahmood et al. (2007), Tan & Kamaruddin (2014), Farah Nabillah et al. (2020), Chung et al. (2021)
	Tauchira	*Tauchira karnyi*	Mahmood et al. (2007)
		Tauchira polychroa	Mahmood et al. (2007), Tan & Kamaruddin (2014, 2016)
		Tauchira rufotibialis	Mahmood et al. (2007), Tan & Kamaruddin (2016)
	Theomolpus	*Theomolpus* sp.	Chung et al. (2021)
	Traulia	*Traulia antennata*	Tan & Kamaruddin (2016)
		Traulia azureipennis	C. Willemse (1938), L. Willemse (2001), Chai (2007), Mahmood et al. (2007), Farah Nabillah et al. (2020)
		Traulia brunneri	Mahmood et al. (2007)
		Traulia flavoannulata	Chai (2007)
		Traulia hosei	Willemse (1938)
		Traulia sanguinipes sanguinipes	Farah Nabillah et al. (2020)
	Utanacris	*Utanacris flavifrons*	Tan & Kamaruddin (2014)
		Utanacris pulchra	Mahmood et al. (2007)
	Xenocatantops	*Xenocatantops humilis*	C. Willemse (1938), L. Willemse (2001), Chai (2007), Mahmood et al. (2007), Tan & Kamaruddin (2016), Farah Nabillah et al. (2020)
Coptacrinae	*Eucoptacra*	*Eucoptacra minima*	Mahmood et al. (2007)
Cyrtacanthacridinae	*Chondracris*	*Chondracris rosea*	Willemse (2001)
	Cyrtacanthacris	*Cyrtacanthacris tatarica*	Willemse (2001)
	Patanga	*Patanga luteicornis*	C. Willemse (1938), L. Willemse (2001), Farah Nabillah et al. (2020)

Table 2.1 continued.

Subfamily	Genus	Species	Reference
		Patanga succincta	C. Willemse (1938), L. Willemse (2001), Chai (2007), Farah Nabillah et al. (2020)
	Valanga	*Valanga nigricornis*	Willemse (2001), Chai (2007), Mahmood et al. (2007), Chung & Majapun (2013), Tan & Kamaruddin (2014), Chung & Tangah (2015), Farah Nabillah et al. (2020), Chung et al. (2021)
Eyprepocnemidinae	*Choroedocus*	*Choroedocus violaceipes*	Mahmood et al. (2007)
Gomphocerinae	*Gonista*	*Gonista bicolor*	Mahmood et al. (2007), Willemse (2001)
Hemiacridinae	*Willemsella*	*Willemsella bicolor*	Tan & Kamaruddin (2014, 2016)
Incolacridinae	*Bettotania*	*Bettotania festiva*	Mahmood et al. (2007)
Oedipodinae	*Aiolopus*	*Aiolopus tamulus*	Willemse (1938)
		Aiolopus thalassinus tamulus	Willemse (2001), Chai (2007), Mahmood et al. (2008), Tan & Kamaruddin (2014), Farah Nabillah et al. (2020)
	Gastrimargus	*Gastrimargus marmoratus*	Willemse (2001), Chai (2007), Mahmood et al. (2008), Farah Nabillah et al. (2020)
	Heteropternis	*Heteropternis respondens*	Willemse (2001), Mahmood et al. (2008)
		Heteropternis sarimahii	Mahmood et al. (2008)
	Locusta	*Locusta migratoria manilensis*	Willemse (2001), Chai (2007), Mahmood et al. (2008), Farah Nabillah et al. (2020)
	Pternoscirta	*Pternoscirta caliginosa*	Willemse (2001), Mahmood et al. (2008), Tan & Kamaruddin (2014, 2016)
	Trilophidia	*Trilophidia annulata*	C. Willemse (1938), L. Willemse (2001), Chai (2007), Mahmood et al. (2008), Tan & Kamaruddin (2014, 2016), Farah Nabillah et al. (2020)
Oxyinae	*Gesonia*	*Gesonia punctifrons*	Willemse (1938)
	Gesonula	*Gesonula mundata mundata*	Mahmood et al. (2007)
		Gesonula mundata pulchra	Willemse (2001)
	Lucretilis	*Lucretilis bolivari*	Tan & Kamaruddin (2014)
		Lucretilis splendens	Mahmood et al. (2007)
		Lucretilis uvarovi	Mahmood et al. (2007)

Table 2.1 continued.

Subfamily	Genus	Species	Reference
	Oxya	*Oxya chinensis*	Willemse (1938)
		Oxya hyla intricata	Willemse (2001), Chai (2007), Mahmood et al. (2007), Tan & Kamaruddin (2016), Farah Nabillah et al. (2020)
		Oxya japonica japonica	Willemse (2001), Chai (2007), Mahmood et al. (2007), Tan & Kamaruddin (2014, 2016), Farah Nabillah et al. (2020)
	Pseudoxya	*Pseudoxya diminuta*	Willemse (2001), Chai (2007), Mahmood et al. (2007), Tan & Kamaruddin (2014, 2016), Farah Nabillah et al. (2020)
Spathosterninae	*Spathosternum*	*Spathosternum prasiniferum*	Willemse (2001)
		Spathosternum sp.	Chung et al. (2021)
TOTAL	**43**	**75**	

filiform antennae, while some species possessed ensiform antennae (sword-shaped). Mouthparts of an acridid consists of the mandibles which is located on the side of the head under the gena, bearing the maxillae and labium. According to Bei-Bienko & Mishchenko (1963), the mandibles bear a pair of segmented maxillae consisting of five-segmented palp, and a segmented labium consisting of a pair of three-segmented palpi. Clypeus and labrum of an acridid serves as an upper lip needed to contain food consumed daily.

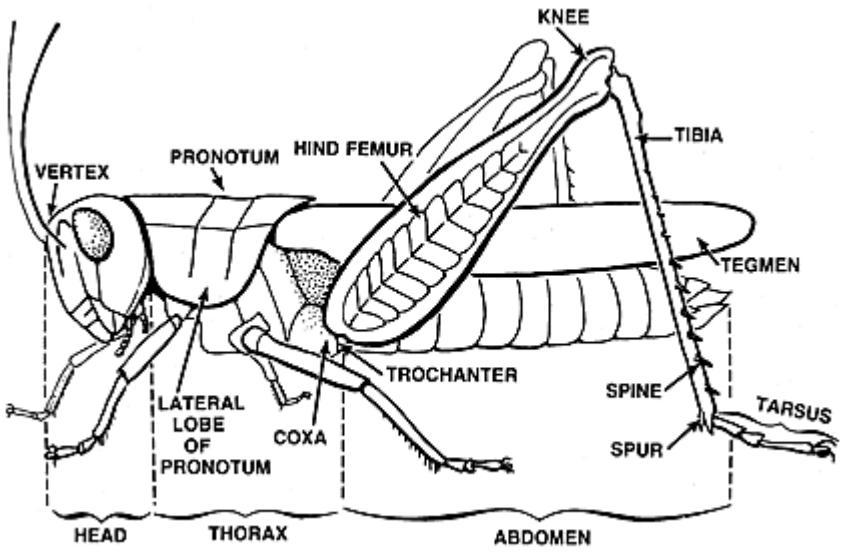


Figure 2.2: Anatomy of an acridid from lateral view. Adapted from Grasshoppers of Wyoming and the West, by University of Wyoming, n.d. (http://www.uwyo.edu/entomology/grasshoppers/colorado/indentification.html).

Thorax of an acridid viewed dorsally is covered from top to the sides of the body, known as the pronotum. The pronotum is divided into three segments, namely prothorax, mesothorax and metathorax. Prothorax of an acridid is more expanded than the meso- and metathorax, and these segments are divided by lines known as the transverse sulci, although it may not be visible in certain species (Figure 2.4). Median carina, which divides the surface of the pronotum into half, and lateral carina, which separates the dorsal surface from the sides of the lateral lobes, may also be visible in certain species as exhibited in Figure 2.4.

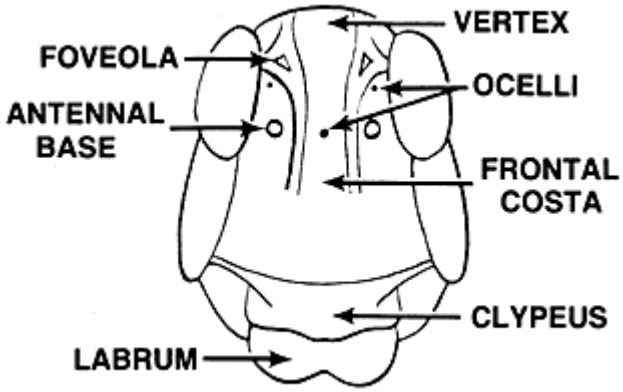


Figure 2.3: Front view of the head of an acridid. Adapted from Grasshoppers of Wyoming and the West, by University of Wyoming, n.d. (http://www.uwyo.edu/entomology/grasshoppers/colorado/indentification.html).

When viewed ventrally, the thorax is also divided into three segments, the prosternum, mesosternum and metasternum, and each segments bear a pair of legs for the acridid as shown in Figure 2.5. Shape of mesosternal space is useful in identifying members of subfamily Cyrtacanthacridinae as the inner angle of the lobe is rectangular to acutely angular as opposed to members of other subfamilies (Song & Wenzel, 2007). Contact between the metasternal space is also used in separating subfamilies as subfamily Oedipodinae have metasternal space that are separated, while subfamily Cyrtacanthacridinae have metasternal space that are contiguous.

Figure 2.6 revealed part of the abdominal segments of an acridid from lateral view. Tympanum, or the hearing organs of an acridids and other caeliferans are located on the first abdominal tergite (Bei-Bienko & Mishchenko, 1963).

Hind legs of a grasshopper are known as saltatorial legs and have been modified for jumping, which is characterised by the elongated femur and tibia as elucidated in Figure 2.7. Major parts of the leg constitute of the femur, tibia, and tarsi. The socket connecting the

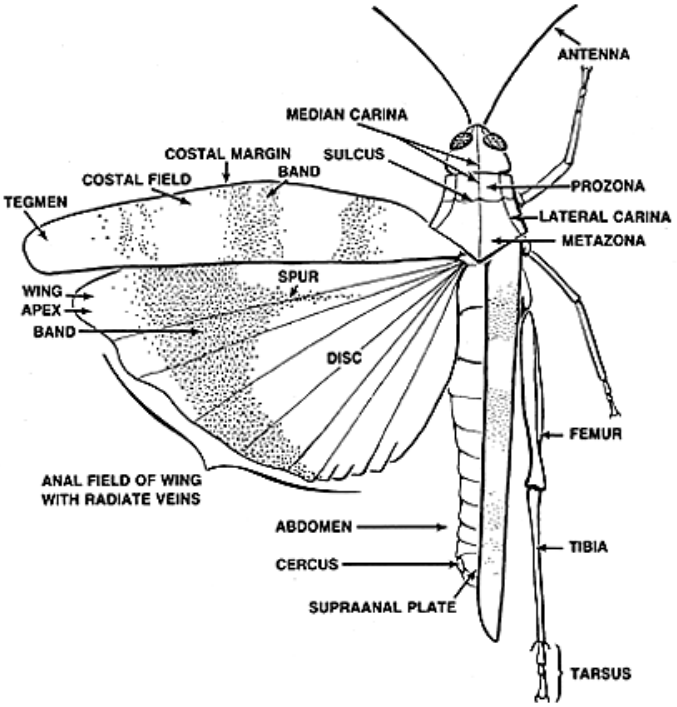


Figure 2.4: Anatomy of an acridid from dorsal view. Adapted from Grasshoppers of Wyoming and the West, by University of Wyoming, n.d. (http://www.uwyo.edu/entomology/grasshoppers/colorado/indentification.html).

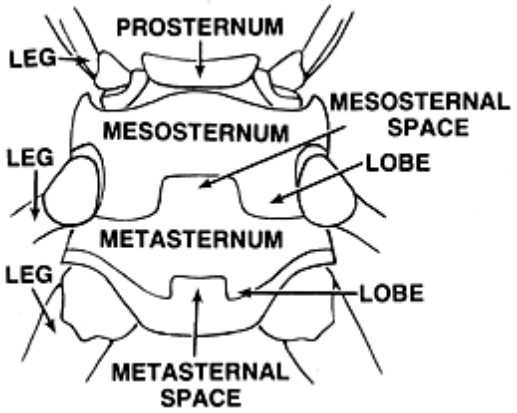


Figure 2.5: Ventral view of the thorax of an acridid. Adapted from Grasshoppers of Wyoming and the West, by University of Wyoming, n.d. (http://www.uwyo.edu/entomology/grasshoppers/colorado/indentification.html).

legs to the body of an acridid is known as coxa (Figure 2.6), along with a small and barely perceptible trochanter (Figure 2.2), which connects the coxa to the femur. Along the dorsal margin of hind femora is the dorsal carina, where in some species it appears to be serrated,

while the others are smooth. Ventral margin of the hind femora is known as the ventral carina, while the genicular lobes are located apically, nearing the knee of hind tibia (Jago, 1967). The tibia bears rows of spines on the outer face and inner face of the leg, and a few external spines apically known as spurs, whereas tarsi of an acridid is divided into three segments, which is a diagnostic characteristic of the family (Li et al., 2011).

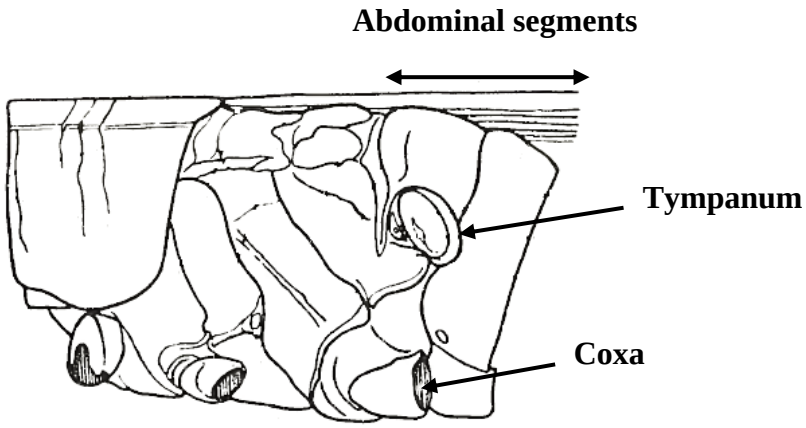


Figure 2.6: Lateral view of the abdominal segments of an acridid. Adapted and modified from Locusts and Grasshoppers of the U.S.S.R. and Adjacent Countries (Part I) (p. 11), by G. Bei-Bienko & L. Mishchenko, 1963, Israel Program for Scientific Translations Ltd.

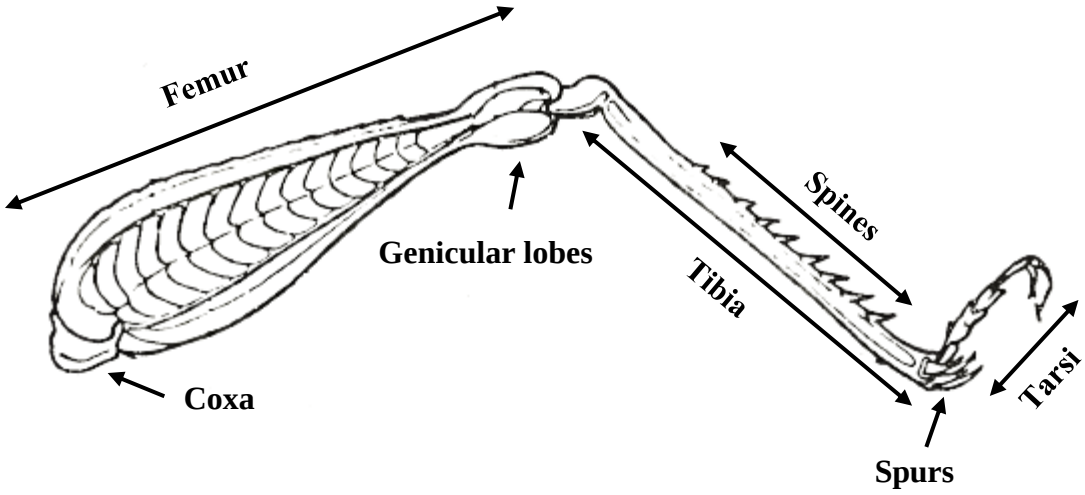


Figure 2.7: Saltatorial leg of a grasshopper, adapted for jumping. Adapted and modified from Locusts and Grasshoppers of the U.S.S.R. and Adjacent Countries (Part I) (p. 11), by G. Bei-Bienko & L. Mishchenko, 1963, Israel Program for Scientific Translations Ltd.

Abdominal segments of an acridid are covered with pliable membranes that is separated into segments. Each segment is enclosed by sclerotised tergum which covers the dorsal and lateral sides of the abdomen while the ventral surface is covered by sclerotised sternum. The end of the abdominal segments is reduced and modified to form the external genitalia in both male and female species. Similarly, the supra-anal plate and subgenital plate are formed apically on the tergum and sternum of both sexes (Jago, 1967).

However, in male species, a pair of projection known as cercus is developed on the sides of the tergites and these projections usually varies in sizes and shapes within subfamilies (Figure 2.8). In addition, another pair of projections evolved dorsally before the last tergite, projecting into a pair of fork called furcula, which also varies in sizes and shapes according to species (Roberts, 1941). Female external genitalia are less distinctive in comparison with its counterparts, as females only bear two pair of valves known as ovipositors as shown in Figure 2.9. The dorsal ovipositor valves may be smooth or serrated on the superior margin depending on the species, while the ventral ovipositor valves may prominently show an external apical tooth when viewed ventrally (Cigliano et al., 1996).

2.1.5 Developmental Stages

Insect wings, which were believed to have evolved approximately 400 million years ago was debated to have originated the term polyneopteran group, thus given rise to the acknowledgement of the most recognised insect group; grasshoppers, crickets and their allies (Wipfler et al., 2019). Grasshoppers represent the oldest and most diverse polyneopteran group of the insect orders (Flook & Rowell, 1998; Naskrecki, 2013), alongside cockroaches and termites (Blattodea), earwigs (Dermaptera), mantids (Mantodea), stick and leaf insects (Phasmatodea) and stoneflies (Plecoptera), as well as the lesser known groups, which

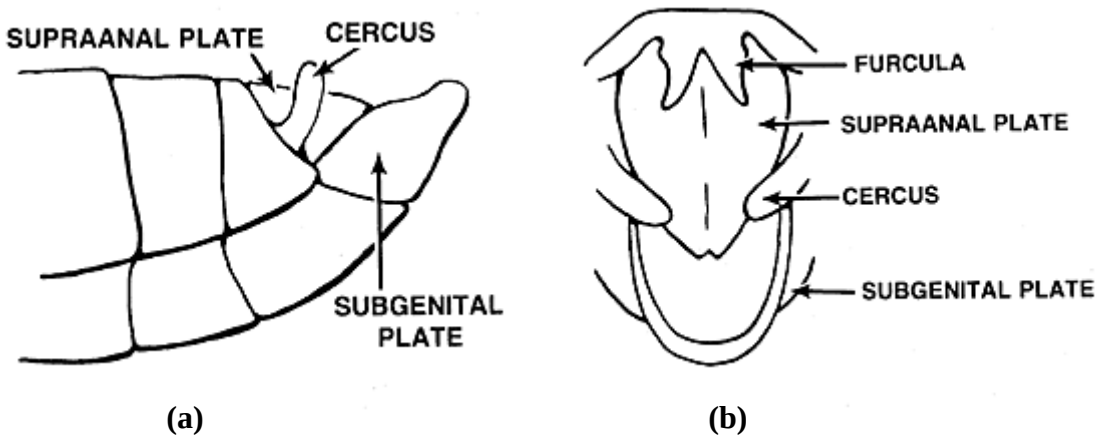


Figure 2.8: (a) Lateral view of the male external reproductive organ; (b) Dorsal view of the male external reproductive organ. Adapted and modified from Grasshoppers of Wyoming and the West, by University of Wyoming, n.d. (http://www.uwyo.edu/entomology/grasshoppers/colorado/indentification.html).

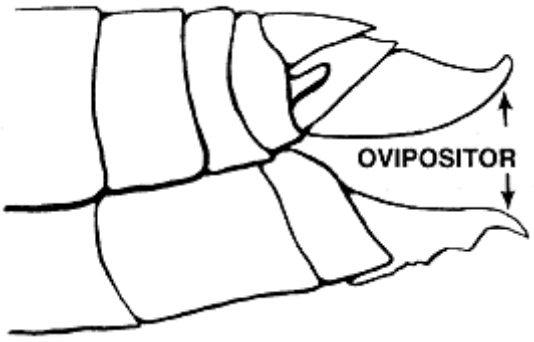


Figure 2.9: Lateral view of the female external reproductive organ. Adapted and modified from Grasshoppers of Wyoming and the West, by University of Wyoming, n.d. (http://www.uwyo.edu/entomology/grasshoppers/colorado/indentification.html).

includes webspinners (Embioptera), ice crawlers (Grylloblattodea), heelwalkers (Mantophasmatodea) and ground lice (Zoraptera) as the major lineage of winged insects (Wipfler et al., 2019).

The life-history strategies of these polyneopteran groups is also known as incomplete metamorphosis or hemimetabolism, where the development of its juvenile resembles the adults with the exception of the development of its wings and genitalia, and the adults

reached a terminal stage preventing them from moulting as opposed to the holometabolous groups (Smith et al., 2004; Truman & Riddiford, 2019). In the opinion of Truman and Riddiford (2019), other orders with similar life cycle alongside Polyneoptera includes, Condylognatha (true bugs, aphids, thrips, bark lice and true lice), and Palaeoptera (dragonflies and mayflies).

Key difference in the developmental stages of the hemimetabolous group is the reduced phases in growth which is egg, nymph and adult, in contrast with the holometabolous group which consists of four phases; egg, larva, pupa and adult (Bei-Bienko & Mishchenko, 1963; Smith et al., 2004). Female grasshoppers would lay their eggs in soils by firstly digging the soil bigger in the bottom compared to the top before depositing the eggs that were covered in frothy and glutinous material which helps in hardening and binding the eggs in the soil (Ball et al., 1942; Bei-Bienko & Mishchenko, 1963). The hole opening is also filled with similar liquid mixed with dirt as a prevention and protection for the egg pods against predators (Ball et al., 1942). According to Capinera and Sechrist (1982), female grasshoppers usually produced four to 25 egg pods and each egg pod generally contain around four to 40 eggs, totalling up to 200 eggs.

Nymph in hemimetabolous group resembles a miniature adult of the species. Nymph instars, referring to the developmental stages of insects between moulting phases, varies from four to seven instars according to different grasshopper species and affected by their physical environment (Bei-Bienko & Mishchenko, 1963; Lockwood et al., 1994). Lockwood et al. (1994) debated on the differences between the ecology of the Inner Mongolian and North American grasshoppers and concluded that in connection with the nymphal stage, Asian species have adapted their timing of hatching to the temporal niches of the grassland

ecosystem, while the North American species have acclimatised to the irregularities of the rangeland through facultative development.

Bei-Bienko and Mishchenko (1963) exhaustively described the development of the nymphal stages in 'Locusts and grasshoppers of the U.S.S.R. and adjacent countries (Part I)'. Generally, first instar describes nymphal grasshopper with antennae not more than 13 segments and lacking wing rudiments, second instar would show growth increment of the antennae with 15 – 17 or 18 – 19 segments and wing rudiments with weak and isolated veins started to grow on the sides of the body, third instar presented with longer antennae from 17 – 22 segments and wing rudiments are visible with numerous veins, although still positioned at the sides of the body, fourth instar defines nymphal grasshoppers with antennae around 21 – 25 segments and wing rudiments finally positioned on the dorsum but still shorter than the length of the pronotum, while fifth instar usually describes nymphal with 23 – 26 antennae segments and wing rudiments grow to the same lengths or longer than the length of pronotum. Figure 2.10 explains the development of wing rudiments across all instars.

Adult stage or imago is a phase where insects reach maturity, occurs after the final moulting, where organs have been fully developed and the nymph turned into an adult insect. However, it would take another one to three weeks for the grasshoppers to be able to reproduce as their reproductive organs were not fully developed in the last instars (University of Wyoming, n.d.). Bei-Bienko and Mishchenko (1963) also believed that within three weeks of developing their reproductive organs, the mass of their body is doubled to reach a normal body weight and they would acquire the normal body shape.

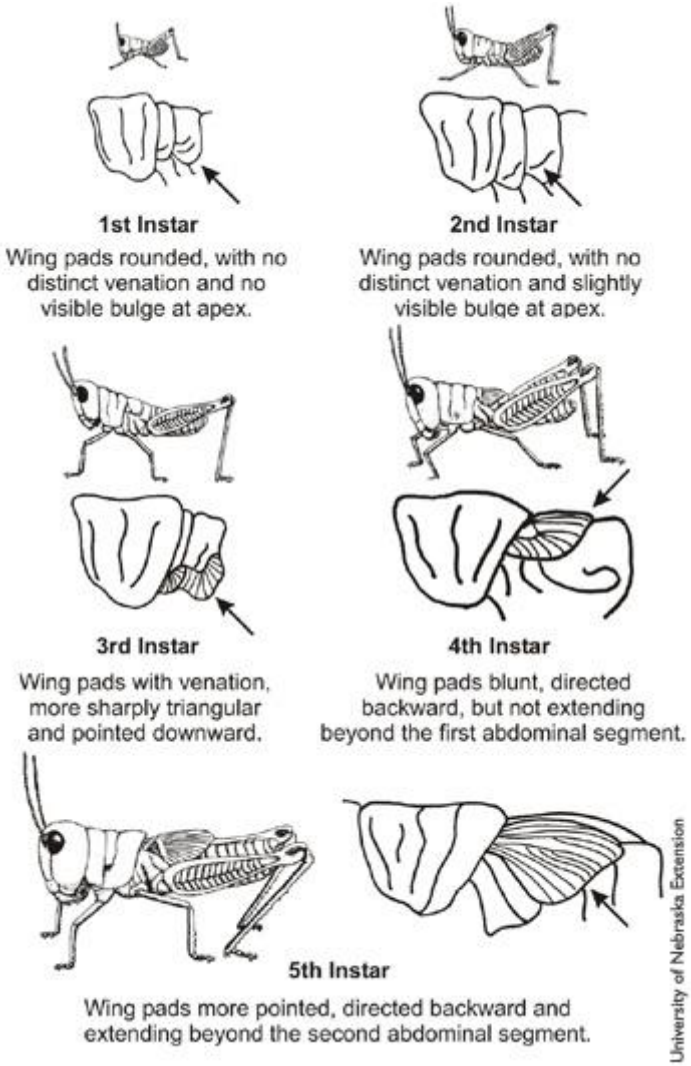


Figure 2.10: Development of grasshopper's wings from the 1st to the 5th instars. Adapted from Grasshopper control, by Utah State University, n.d. (https://extension.usu.edu/pests/ipm/notes_ag/veg-grasshopper-control).

2.1.6 Roles in Ecosystem

The existence of grasshoppers and locusts was believed to have been recorded since the early times of Cenozoic era, and swarming locusts specifically had been mentioned numerous times in the Qur'an and Bible as plagues, serving as blessings or punishments for acts against God (Aharoni, 1938; Roonwal, 1958; El-Mallakh & El-Mallakh, 1994; Song et al., 2006, 2018; le Gall et al., 2019; Pflüger & Bräunig, 2021). As results of their long

existence, acridids have various roles in the ecosystem with both positive and negative influences on the environment.

In relation to the *Homo sapiens*, insects in general have been consumed as food due to their high nutrient value, and in certain parts of the world, serve as an important source of medicine (Chung et al., 2002; Figueirêdo et al., 2015). Entomophagy, the practice of eating edible insects, and entomotherapy, the use of insects as medicinal resources, are uncommon practices in the 21st century but are commonly associated with the cultures in Africa, Asia, Latin America and the Middle East (Chung, 2010; Anankware et al., 2015; Figueirêdo et al., 2015; Tang et al., 2019). Acridids are some of the infamous insects that have been consumed as food and regarded as valuable food resource, especially in areas where source of proteins are scarce (Roonwal, 1958; Mercer, 1997), with notorious species such as *Locusta migratoria* (migratory locust), *Locustana pardalina* (brown locust), *Nomadacris septemfasciata* (red locust) and *Schistocerca gregaria* (desert locust) commonly reported as the most consumed species in Africa, while *Acrida lata*, *Oxya sinuosa*, *O. velox*, *O. yezoensis* and *Patanga succincta* were consumed as snacks in most Asian countries (Pemberton, 1994; Nonaka, 2009; van Huis et al., 2013; Anankware et al., 2015). In Malaysian Borneo, specifically in the state of Sabah, Chung (2010) recorded some species of acridids from genus *Valanga* (*gedoh*) and typical short-horned grasshoppers (*butoh*) were collected in paddy fields to be served as dishes for family consumptions.

Grasshoppers are known as phytophagous insects who devours plants, mainly known as the graminaceous feeders (Dadd, 1963; Franzke et al., 2010; Sun et al., 2015). Some acridids were notorious for their swarming behaviours that led to outbreaks in areas including the deserts and scrub regions, as well as important agricultural plantations and

pastures such as paddy fields and soy fields due to their selective feeding behaviour (Showler, 1995; Nair, 2001; Magrath & Simms, 2005; Siwi et al., 2005). Acridids recognised as agricultural pests are usually termed as locusts from subfamilies Calliptaminae, Cyrtacanthacridinae, Melanoplinae and Oedipodinae (Naskrecki, 2013), with the ability to transform into two different phases known as the solitary phase (*phasis solitaria*) and gregarious phase (*phasis gregaria*) (Richards & Davies, 1977; Mahmood et al., 2008; Cisneiros et al., 2012). The swarming behaviours of these locusts usually caused by overcrowding in the population which takes effect within hours as a response to the rush of serotonin in the metathoracic ganglion thus making the locusts digest food and breed even faster (Song et al., 2017; le Gall et al., 2019; Pflüger & Bräunig, 2021). The Centre for Overseas Pest Research (COPR) and Food and Agriculture Organization (FAO) were among the first organisations to attend to the issue of locusts' infestations as an important agricultural problem. Lomer et al. (2001) believed that the results from various research performed by these organisations prompted theories on the development of plagues, such as the lack of pre-emptive interventions, and failure in control efforts where man-made or natural disasters blocking the access to breeding areas. Methods of control for locusts outbreak focused on the biological and chemical controls that delivered the least aftereffect to environment, people and their belongings (Cunningham & Sampson, 1996). The use of biological control to regulate the locusts assemblages typically involves predation by natural predators such as snakes, birds and robber flies, parasitoids by blister beetle, flies and mites that naturally infest the eggs, and infestation by pathogens such as fungi and protozoans (Lockwood et al., 1994). Contrarily, insecticides and pesticides were utilised to control the upsurge population of locusts. Scientists discovered microbial control that manipulates the host-pathogen relationship to develop entomopathogens by producing biopesticide from the

fungus, *Metarhizium acridum* and microsporidian, *Paranosema locustae* to counter the attack of *L. migratoria* (Capinera & Sechrist, 1982; Belayneh, 2001; Cullen et al., 2017). Nevertheless, as more research progresses, the realisation on the potential harm of pesticides in affecting human health and biodiversity of the ecosystem grows as chemicals used may affect nontarget organisms (Latchininsky et al., 2011), which in turn gave rise to the development of remote sensing and Global Information Systems (GIS) for outbreak forecasting (Showler, 1995; Latchininsky, 2013). Aside from using the geospatial technology in maintaining the locusts' population, a few communities in Asia and Africa resolved to practicing entomophagy. Countries such as Thailand had once started a campaign to encourage the community to utilise locusts as cooking sauce, snacks, and ingredients in crackers (van Huis, 2018), while Pemberton (1994) on one of his travels to South Korea reported that Koreans resorted to rearing the rice-field grasshoppers (*Oxya* spp.), known as *metdugi* to be marketed and sold in supermarkets, where people usually consumed as side dishes, lunch box ingredients and drinking snacks.

However, the destructive effect of locust outbreaks does not diminish other significant ecological impacts made by these acridids to the ecosystems. They served as an excellent bioindicators ecologically due to their great mobility, sensitivity in biome and abundancy in nature (Song et al., 2018). In relation to land management, Andersen et al. (2001) observed the sensitivity of 56 species of grasshoppers, comprising of 40 species of acridids and 16 species from families Eumastacidae, Pyrgomorphidae and Tetrigidae, towards disturbance to grass layers associated with mining. Their research revealed stipulations required to be fulfilled as good bioindicators, which were the ability to provide exclusive and concentrated data on the ecosystem efficiently, and consistent responses to disturbance. Even though it was not proven that species richness changed with level of

disturbance, species composition of grasshoppers strongly correlates with the degree of habitat disturbance, where disturbed area showed sporadic occurrences of various species and undisturbed area were populated by core species (Andersen et al., 2001). Apart from that, grasshoppers are also ecologically known to support other biological components of the ecosystem in terms of nutrient cycling (Song et al., 2018) where food consumptions would be degraded, thus releasing nutrients back to the ecosystem. Mitchell and Pfadt (1974) described the flow of energy from forage plants by three species of acridids, namely *Aulocara elliotti*, *Melanoplus foedus* and *M. sanguinipes*, where the process of grazing accelerates the degradation of cellulose and other materials. Subsequently, the faecal matter of these grasshoppers further helped in increasing the solubility of nutrients into the soil, thus facilitating in plant decomposition and regrowth (Belovsky & Slade, 2000, 2002; Fumy et al., 2020). Ultimately, the role played by grasshoppers in maintaining a balanced ecosystem undoubtedly outweighs the harmful effects they inflicted at times. Plus, the issue regarding locust outbreaks and plagues had not been agriculturally significant compared to what they used to be hundreds of years ago, thus lowering their status as important agricultural pests.

2.2 Acrididae in Malaysian Borneo

Sarawak and Sabah, two of the largest states in Malaysia, are established in a separate land on the island of Borneo, known as the third largest islands after Greenland and New Guinea with an area of 743,330 km^2 (Britannica, 2019; Mitchell, 2019; Hamid et al., 2021). The island is known to be one of the oldest tropical rainforests in the world and its political administrations are divided among three countries with majority of the land belonging to Indonesia (73%) in the central and southern part of the island, and Malaysia represented 26% of the land on the northwest region while Brunei is the smallest country located in between

the states of Sabah and Sarawak which makes up for 1% of the total landmass on the island (Primack & Hall, 1992; WWF, 2007; Smith, 2017; The Borneo Project, 2021).

The rainforests of Sabah and Sarawak are known to be one of the richest biome in terms of species diversity (Meijaard & Nijman, 2003) and is a part of the Heart of Borneo (HoB) initiative that aims to conserve and protect the forests, alongside their neighbours, Brunei and Indonesia, where they accounted for roughly 6% of world's biodiversity (WWF, 2020). Sarawak represents the largest states in Malaysia with the landmass of 124,450 km^2, with 62% forest coverage comprising of the Permanent Forest Estate (PFE), Totally Protected Area (TPA) and State Land (SL) (Forest Department Sarawak, 2021). Three types of forests monopolised the land of Sarawak namely hill mixed dipterocarp forest, peat swamp forest and mangrove forest, while heath forest and montane forest represents the minority of land covered (Hon & Shibata, 2013; Forest Department Sarawak, 2021). The state of Sabah covered 73,631 km^2 of the land, with approximately 65% forest coverage and 52% (38,000 km^2) of the land were gazetted as permanent forest reserves, parks and wildlife conservation areas (FAO, 2020; Sabah Forestry Department, 2021). Six different types of vegetation can be found in Sabah with two major forest types; mixed dipterocarp forest and mossy forest, and five types of edaphic land formations; mangrove forest, littoral forest, peat swamp forest, riparian forest and heath forest (Fox, 1972).

Studies on family Acrididae does not gain much attention in the Bornean region, apart from being collected and documented occasionally when researchers took part in expeditions and conducting ecological study relating to insects in general. A handful of documented groundwork were published with regards to the family in general although there were none that focused exclusively on the systematics or phylogeny in Sabah and Sarawak

(Willemse, 1938; Chai, 2007; Mahmood et al., 2007, 2008; Chung & Majapun, 2013; Chung & Tangah, 2015; Chung et al., 2021). A total of 40 species under 27 genera from six subfamilies were documented in Malaysian Borneo based on the compilation of several literature records as listed in Table 2.2.

One of the first expeditions conducted in Sarawak was by the entomologists from Oxford University in 1932 (Willemse, 1938). They focused on collecting grasshoppers in different types of vegetation such as mixed forest, moss forest, heath forest and secondary forest around Mount Dulit, Miri, Sarawak, while some of the specimens were also collected in the white sand forest of Claudetown (Marudi). Specimens collected were then deposited to Oxford University Museum (OUMNH) and Sarawak Museum (SMSM), while some of the specimens were kept as the authors' own collection in the Stockholm Museum (NHRS). Results from their expedition recorded five subfamilies namely Acridinae, Catantopinae, Eumastacinae, Oedipodinae and Pyrgomorphinae, comprising of 25 species from 18 genera and the discovery of a new genus, *Coloracris* consisting of three new species, *C. azureus*, *C. coerulescens* and *C. viridis*, as well as two new species; *Phalaca sarawakensis* and *Pareuthymia obscura*. However, two subfamilies, Eumastacinae and Pyrgomorphinae recorded from the study has since been raised to family level in accordance to the current classification structure (Cigliano et al., 2021).

Therefore, Chai (2007) adhered to the classification system by omitting species raised to family level recorded by Willemse (1938) in her thesis on systematics and distribution of Acrididae exclusively in Sarawak and recorded a total of 20 species out of 864 specimens dating from 1891 to 2007, assessed from three major institutions in Sarawak, specifically SMSM, UNIMAS Insect Reference Collection (UIRC), and Sarawak Forest

Table 2.2: List of acridids species documented in Malaysian Borneo based on literature records.

Subfamily	Genus	Species	Reference(s)
Acridinae	*Acrida*	*Acrida* sp.	Chung et al. (2021)
	Phlaeoba	*Phlaeoba antennata*	C. Willemse (1938), L. Willemse (2001), Chai (2007), Farah Nabillah et al. (2020)
		Phlaeoba infumata	Willemse (2001), Mahmood et al. (2007), Farah Nabillah et al. (2020)
Catantopinae	*Althaemenes*	*Althaemenes maculalutea*	Chai (2007)
	Apalacris	*Apalacris varicornis*	Chai (2007), Mahmood et al. (2007), Farah Nabillah et al. (2020)
	Coloracris	*Coloracris azureus*	Willemse (1938)
		Coloracris coerulescens	Willemse (1938), Chai (2007), Farah Nabillah et al. (2020)
		Coloracris viridis	Willemse (1938)
		Coloracris sp.	Willemse (1938), Farah Nabillah et al. (2020)
	Craneopsis	*Craneopsis olivacea*	Farah Nabillah et al. (2020)
	Meltripata	*Meltripata picta*	Mahmood et al. (2007)
	Pareuthymia	*Pareuthymia brevifrons*	Chai (2007)
		Pareuthymia maculata	Mahmood et al. (2007)
		Pareuthymia obscura	Willemse (1938)
	Peitharchicus	*Peitharchicus fasciatus*	Chai (2007)
	Perakia	*Perakia borneensis*	Farah Nabillah et al. (2020)
	Phalaca	*Phalaca sarawakensis*	Willemse (1938)
		Phalaca waterstradti	Farah Nabillah et al. (2020)
	Stenocatantops	*Stenocatantops splendens*	C. Willemse (1938), L. Willemse (2001), Chai (2007), Mahmood et al. (2007), Farah Nabillah et al. (2020), Chung et al. (2021)
	Theomolpus	*Theomolpus* sp.	Chung et al. (2021)
	Traulia	*Traulia azureipennis*	C. Willemse (1938), L. Willemse (2001), Chai (2007), Mahmood et al. (2007), Farah Nabillah et al. (2020)
		Traulia flavoannulata	Chai (2007)

Table 2.2 continued.

Subfamily	Genus	Species	Reference
		Traulia hosei	Willemse (1938)
		Traulia sanguinipes sanguinipes	Farah Nabillah et al. (2020)
	Xenocatantops	*Xenocatantops humilis*	C. Willemse (1938), L. Willemse (2001), Chai (2007), Farah Nabillah et al. (2020)
Cyrtacanthacridinae	*Patanga*	*Patanga luteicornis*	C. Willemse (1938), L. Willemse (2001), Farah Nabillah et al. (2020)
		Patanga succincta	C. Willemse (1938), L. Willemse (2001), Chai (2007), Farah Nabillah et al. (2020)
	Valanga	*Valanga nigricornis*	Willemse (2001), Chai (2007), Mahmood et al. (2007), Chung & Majapun (2013), Chung & Tangah (2015), Farah Nabillah et al. (2020), Chung et al. (2021)
Oedipodinae	*Aiolopus*	*Aiolopus thalassinus tamulus*	C. Willemse (1938), L. Willemse (2001), Chai (2007), Mahmood et al. (2008), Farah Nabillah et al. (2020)
	Gastrimargus	*Gastrimargus marmoratus*	Willemse (2001), Chai (2007), Mahmood et al. (2008), Farah Nabillah et al. (2020)
	Heteropternis	*Heteropternis sarimahii*	Mahmood et al. (2008)
	Locusta	*Locusta migratoria manilensis*	Willemse (2001), Chai (2007), Mahmood et al. (2008), Farah Nabillah et al. (2020)
	Trilophidia	*Trilophidia annulata*	C. Willemse (1938), L. Willemse (2001), Chai (2007), Mahmood et al. (2008), Farah Nabillah et al. (2020)
Oxyinae	*Gesonia*	*Gesonia punctifrons*	Willemse (1938)
	Lucretilis	*Lucretilis splendens*	Mahmood et al. (2007)
	Oxya	*Oxya chinensis*	Willemse (1938)
		Oxya hyla intricata	Chai (2007), Mahmood et al. (2007), Farah Nabillah et al. (2020)
		Oxya japonica japonica	Willemse (2001), Chai (2007), Mahmood et al. (2007), Farah Nabillah et al. (2020)
	Pseudoxya	*Pseudoxya diminuta*	Mahmood et al. (2007), Farah Nabillah et al. (2020)
Spathosterninae	*Spathosternum*	*Spathosternum* sp.	Chung et al. (2021)
TOTAL	**27**	**40**	

Research Centre (FRC). Her study revealed the most abundant and well distributed species to be *Traulia azureipennis* (Catantopinae), whereas *Apalacris varicornis*, *Althaemenes maculalutea* and *C. coerulescens* were reported as the least abundant, represented by three individuals per species. Additionally, she made a comparison on species richness from the result of her study and the study conducted by Willemse (1938), revealing no record of eight species in current study at the time, namely *C. azureus*, *C. viridis*, *Gesonia punctifrons*, *Oxya chinensis*, *P. obscura*, *Ph. sarawakensis*, *Patanga luteicornis* and *T. hosei*. Apart from *T. hosei*, all seven species were represented by a singleton in the expedition conducted by Willemse (1938), and it was assumed that these specimens were brought back to Europe as voucher specimens in collectors' preferred institutions (Chai, 2007). On the other hand, *O. chinensis* was believed to be misidentified by previous collector as the species is geographically distributed in China and Asia-Temperate region, which includes Japan, Korea, Mongolia, Russia and Tibet (Khan et al., 2016; Cigliano et al., 2021).

Recent study by Farah Nabillah et al. (2020) on the composition of the family in Sarawak recorded 22 species from five subfamilies, based on assessments of 925 specimens deposited in UIRC and Research, Development and Innovation Division (RDID) of Forest Department Sarawak (FDS). Apart from slight increase in terms of species count, the study revealed an almost similar result to Chai (2007) in which *T. azureipennis* was found to be the most abundant with 146 individuals recorded, while *C. coerulescens* was the least abundant represented by a singleton alongside *Craneopsis olivacea*, *Perakia borneensis* and *Ph. waterstradti*. This study have also uncovered species not documented by Chai (2007) such as *Phlaeoba infumata* and *T. sanguinipes sanguinipes*, although some species from her research were not documented in this study, particularly from four genera namely *Althaemenes* (*A. maculalutea*), *Caryanda* (*Ca. diminuta*), *Pareuthymia* (*P. brevifrons*), and

Peitharchicus (*Pe. fasciatus*), as well as *T. flavoannulata*. However, the absence of these species in current study may be contributed by the fact that some of them were misidentified by previous researcher, in such case as *Ca. diminuta* where most authors recognised the species as *Pseudoxya diminuta* and the binomial *Ca. diminuta* itself was not registered in Orthoptera Species File (OSF) (Tan & Kamaruddin, 2014; Cigliano et al., 2021). A preliminary assessment in Sadong Jaya, Samarahan conducted by Wan Nurainie et al. (2020) on diversity of insects in mangrove forest and adjacent area revealed a total of five grasshopper species from two subfamilies, *Stenocatantops splendens* and *Xenocatantops humilis* from Catantopinae, *O. hyla intricata* and *Ps. diminuta* from Oxyinae and one unknown species, concluding the low diversity and composition of grasshoppers in the area. Table 2.3 showed the comparison between number of individuals for each species recorded by three authors throughout 1938 to 2020, where the number of species continues to grow.

Table 2.3: List of species recorded in Sarawak from 1938 – 2020 by different authors according to current classification system. Subfamilies in Willemse (1938) raised to family level were omitted from current record.

Subfamily	**Species**	**Willemse (1938)**	**Chai (2007)**	**Farah Nabillah et al. (2020)**
Acridinae	*Phlaeoba antennata* * *Phlaeobia antennata*	24	95	38
Catantopinae	*Phlaeoba infumata*	-	-	6
	Althaemenes maculalutea	-	3	-
	Apalacris varicornis	-	3	5
	Coloracris azureus	1	-	-
	Coloracris coerulescens	4	3	1
	Coloracris viridis	1	-	-
	Coloracris sp.	-	-	1
	Craneopsis olivacea	-	-	1
	Pareuthymia brevifrons	-	9	-
	Pareuthymia obscura	1	-	-
	Peitharchicus fasciatus	-	14	-
	Perakia borneensis	-	-	1
	Phalaca sarawakensis	4	-	-
	Phalaca waterstradti	-	-	1
	Stenocatantops splendens * *Catantops splendens*	16	37	61

Table2.3 continued.

Subfamily	Species	Willemse (1938)	Chai (2007)	Farah Nabillah et al. (2020)
	Traulia azureipennis	33	142	146
	Traulia flavoannulata	-	47	-
	Traulia hosei	4	-	-
	Traulia sanguinipes sanguinipes	-	-	13
	Xenocatantops humilis	22	91	113
Cyrtacanthacridinae	*Patanga luteicornis*	1	-	38
	Patanga succincta	1	51	10
	Valanga nigricornis	-	91	129
Oedipodinae	*Aiolopus thalassinus tamulus*	1	28	48
	Gastrimargus marmoratus	-	55	44
	Locusta migratoria manilensis	-	21	8
	Trilophidia annulata	18	61	34
Oxyinae	*Gesonula punctifrons* * *Gesonia punctifrons*	1	-	-
	Oxya chinensis	4	-	-
	Oxya hyla intricata	-	27	26
	Oxya japonica japonica	-	48	121
	Pseudoxya diminuta * *Caryanda diminuta*	-	36	80

Notes: (*) Name used by authors before synonymy of the species; (-) indicates not recorded.

Documented studies in Sabah were not centralised around the family as previously mentioned but focused on collecting data on the insects' composition in areas within Sabah. A study by Chung and Majapun (2013) conducted in Malua Forest Reserve discovered *S. splendens, X. humilis* and *Valanga nigricornis* to be common species within the forest compounds, while study in Sungai ISME, Sandakan revealed low insect diversity in total due to the type of vegetation; mangrove forest, which is generally known to have low species richness and abundance. The study showed only two species of acridids representing the population, namely *V. nigricornis* and one unknown species (Chung & Tangah, 2015). Recent documentation on crickets and grasshoppers by Chung et al. (2021) provided a graphic checklist of Orthoptera found in Sabah, which includes *Acrida* sp., *Saussurella* nr. *borneensis*, *Spathosternum* sp., *S. splendens*, *Theomolpus* sp., and *V. nigricornis*. Apart from that, Mahmood et al. (2007, 2008) had also presented the results of their study based on the

examination of voucher specimens deposited to Centre for Insect Systematics (CIS) of Universiti Kebangsaan Malaysia (UKM), where *P. maculata*, *Aiolopus thalassinus tamulus*, *Gastrimargus marmoratus*, *Locusta migratoria manilensis*, *Heteropternis sarimahii* and *Meltripata picta* were collected all around Sabah.

2.3 Comparative Morphology of Acrididae

Systematics descriptions of insects in general were constructed around the study of comparative morphology that build up the concepts of systematics, phylogeny and evolution in higher taxonomic levels (Bock, 1969). The basic tenets of comparative morphology study uses the technique of discriminating species using homologous characters which combines the principle of comparative study of the biology of morphological features and evolutionary theory (Bock, 1969). In general, comparative morphological studies were conducted in accordance with these two prospects, namely the homology of said organs and the functional aspects of the organs (Scudder, 1971; Krogmann & Song, 2013).

Studies of comparative morphology of Acrididae had been undertaken by few researchers focusing on subfamilies and species level, by inspecting the external morphological structures ranging from the shape of the head to the variation of external genitalia. Smith et al. (2004) discussed the overall morphological structures of 71 species of acridids known to occur in Florida with detailed illustrations describing the head, thoracic, wing and genitalic structures. Other than the colouration, markings and texture of the skin, they also focused on describing the formation and shapes of the morphological structures. The comparative study also focused on male genitalic characters as they believed that most species are only identifiable based on the male genitalic structures, while females are identified by associations with males during capture.

As such, one of the earliest study on male phallic structures was undertaken by Roberts (1941) on subfamilies of Acrididae, where he characterised two types of ejaculatory forms of phallus, namely chasmosacci and cryptosacci. Chasmosacci was described as phallus with open ejaculatory form and male diploid of 19 chromosomes, whereas cyrptosacci was the phallus with closed ejaculatory form and male diploid of 23 chromosomes. Based on his groupings, subfamilies Batrachotetriginae, Pamphaginae, Pyrgomorphinae and Thrincinae were classified as chasmosacci, while subfamilies Acrididae, Cyrtacanthacrididae, Oedipodinae, Ommexechinae, Paulinae and Romaleinae were classified as cryptosacci. He believed that the theory of comparative studies could help in uncovering the developmental history of structures of interest, and this was proven in his study as the Chasmosacci was indicated to be the more primitive form of ejaculatory sac as opposed to the Cryptosacci.

Other than that, most taxonomic research on the family would include comparative morphology on other common structures such as colouration and shape of head, thorax, abdomen, legs and wings as presented by Arya et al. (2015) in their study on taxonomy, distribution, ecology and behaviour of grasshoppers in Nanda Devi Biosphere Reserve, India. Although the taxonomic account was presented in a simplistic form, the use of comparative morphology method was able to discriminate between species by focusing on the details of their diagnostic features, and eventually distinguishing family Acrididae and Tettigoniidae.

Similarly, other recent study conducted by Memon and Panhwar (2021) on selected species of acridids in Sindh province of Pakistan focused on the taxonomy of six species of acridids represented by four subfamilies, namely Acridinae, Cyrtacanthacridinae,

Oedipodinae and Oxyinae. The comparative study on these species concentrated on the diagnostic features of each species by describing the shape of vertex and pronotum, colouration and patterns observed in tegmina and hind tibia, as well as the shape and curvature of male and female genitalic structures.

2.4 Phylogeny of Acrididae

The study on phylogeny of the Orthoptera had been an interesting topic of conversation among the orthopterists around the globe. Taxonomists and systematists such as Ronderos and Cigliano (1991), Cigliano et al. (1996), Flook and Rowell (1997, 1998), Rowell and Flook (1998), Song and Wenzel (2007), Liu et al. (2008), Li et al. (2011), Chapco (2013), Leavitt et al. (2013), Woller et al. (2014), García-Navas et al. (2017) and Song et al. (2017) were some of the researchers specialised in the study of phylogeny of acridids whether it was the study of higher level or lower level acridids using morphological and molecular data.

In the phylogeny analysis of Liu et al. (2008), 24 species of acridids were used to represent the family in the reconstruction of the phylogeny of higher level Acrididae based on the combined data of 12S rDNA and 16S rDNA, with *Prygomorpha conica* (Pyrgomorphidae) as the outgroup. Eight subfamilies were included in the analysis, namely Acridinae, Catantopinae, Cyrtacanthacridinae, Gomphocerinae, Melanoplinae, Oedipodinae, Oxyinae and Spathosterninae. The analysis resulted in the monophyly of Cyrtacanthacridinae, Oedipodinae and Oxyinae, while Acridinae and Catantopinae were deduced to be polyphyletic. They also concluded that the results from their study revealed Oedipodinae as a relatively primitive group within the family analysed due to its position at the base of the tree. Subsequently, Oxyinae was deduced to have diverged earlier than the

remaining subfamilies that were included in the analysis, as it was positioned above Oedipodinae in the phylogeny tree.

Aside from that, parsimony and Bayesian analysis conducted by Chapco (2013) on subfamily Catantopinae yielded comparable relationships of non-monophyletic grouping. Mitochondrial genes were used in the analysis, in addition to a few representatives of subfamilies Calliptaminae, Cyrtacanthacridinae, Eyprepocnemidinae, Melanoplinae and Oxyinae, with *P. conica* (Pyrgomorphidae) as the outgroup. The analysis resulted in non-monophyletic groupings of the catantopines, where they were positioned in five different clades on the tree. According to Chapco (2013), genus *Traulia* was revealed to be inconsistent in both analyses, as it showed robust association with *Calliptamus* in the parsimony tree but was positioned at the crown end of the Bayesian tree as part of a polytomy. Other than that, *Sphenophyma* was deduced as the first catantopine to diverge among other members of the subfamily, although taxonomically it belonged to tribe Pezotettigini that was positioned higher in the clade.

On the other hand, a study involving lower level category of genera *Scotussa* and *Leiotettix* were conducted to test the monophyly of the genera using morphological data with genus *Atrachelacris* as the outgroup (Cigliano et al., 1996). The study utilised 14 external morphological characters including eight male genitalic characters and seven female ovipositor characters of 16 species, where *Leiotettix* was represented by six species and *Scotussa* was represented by seven species. Three species of different genera were also included in the analysis, namely *Dichroplus bergi* and members of genus *Chlorus* and *Eurotettix*. Two cladistic analyses were conducted, where the first analysis omitted the female ovipositor characters, while the second analysis included all characters. The analyses

concluded consistent results of monophyletic groupings of both genera and proved that female ovipositor characters were informative at both lower and higher levels in the cladogram, as it resolved the polytomy of *S. brachyptera*, *S. delicatula* and *S. lemniscata*.

CHAPTER 3

SYSTEMATICS OF FAMILY ACRIDIDAE MACLEAY, 1821 (ORTHOPTERA: ACRIDIDAE) FROM MALAYSIAN BORNEO

3.1 Introduction

The family Acrididae comprises of the short-horned grasshoppers and locusts of the suborder Caelifera constitutes as one of the most diverse orthopteran lineages with more than 6,700 valid species described (Cigliano et al., 2021). Many orthopterists from all around the globe have been adamant in their work on various scopes of scientific research on the family, and the order Orthoptera in general. Tan (2012a) characterised the family as grasshoppers with vertical or slightly oblique heads laterally, with exceptions on the genus *Phlaeoba*, and lacking the median groove on fastigium and vertex dorsally. The family was also principally defined based on their short antennae, presence of tympanum on the side of the first segment of their abdomen, hind legs that are generally longer than its forelegs, hind femora wider towards the basal region, tarsi divided into three segments, stridulatory sound produced by rubbing the hind legs and tegmina together and female ovipositor composed of four short valves (Kirby, 1914; Lucas, 1920; Bei-Bienko & Mishchenko, 1963).

Physically, individuals of the family are known to cryptically blend with the natural surroundings. With the exceptions of a few species, the body of most grasshoppers are usually the colour of leaves or ground colours, making them very difficult to be seen. Lefroy (1909) gave the term ‘deceptive colouring’ to these insects principally based on their ability to deceive the predators by displaying a cryptic scheme of colouring pertaining to their wings, that concealed their body when at rest and revealed when they are in flight. The hindwings are often brightly coloured, such as a hue of blue, yellow, or red, whilst the

forewings possessed sombre colours that serve as camouflage from their enemies (Richards & Davies, 1977).

As acridids are known to be the oldest insects to survive the geological phenomenon (Lucas, 1920; Flook & Rowell, 1997; Song et al., 2018), many researchers took interest in the family and undertaken various studies, most notably regarding the taxonomic and systematics disciplines on the family. Walker (1870) was among the first to provide descriptions and keys on the subfamilies in Acrididae, which includes genera such as *Apalacris*, *Cyrtacanthacris* and *Oxya* from the British Museum (BMNH) collection. The collection includes specimens from all around the world such as Africa, America, Asia, Australasia and Madagascar, along with a few unknown countries. Stål's (1873) most prominent work, Recensio Orthopterorum: Revue Critique des Orthoptères, gave descriptions to family Acridiodea although his work focused solely on the acridids of America. Brunner (1878, 1893) gave vague keys and descriptions to the order Orthoptera of America, while his publication in 1898 focused on the Malay Archipelago, which included the Maluku Islands, North Sulawesi, Sunda Islands and North West of Borneo, where he concentrated on descriptions and keys to the group Dermaptera, Blattodea, Mantodea, Phasmodea, Acridiodea and Locustodea. Other notable authors whom provided extensive and fundamental taxonomic works on acridids, or the order Orthoptera in general, includes Bolivar (1898, 1902) with detailed keys and descriptions on orthopterans of South India, as well as the Austro- and Indo-Malayan region that was deposited in the Museo Civico di Storia Naturale di Genova (MCSN), and Kirby (1902, 1914) who sets his focus on the orthopterans of Africa and India. Lucas (1920) reviewed the British Orthoptera, encompassing suborders Acridiodea, Blattodea, Forficulodea, Gryllodea and Locustodea. Dirsh (1956) provided descriptions and keys to species, with addition of copious numbers of

new species in his work on South African acridids. Bei-Bienko and Mishchenko (1963, 1964) published their monographs on 433 species of locusts and grasshoppers in the Soviet Union and adjacent countries which constitutes of some countries in Europe and Asia, while Smith et al. (2004) provided a thorough dichotomous key on 71 species of adult acridids occurring in Florida.

One of the most comprehensive and significant work on acridids in Indo-Malayan region was published by Willemse (1930) as he made a compilation of translated descriptions and keys to family Acrididae based on the materials deposited in museums of Berlin-Dahlem, Genoa, Leiden, London, Stockholm, as well as his own collections. As most authors were from the European region, majority of the monographs published were of their native language, thus making it harder for other researchers to translate the contents in English, a language used globally. The translated monograph by Willemse (1930) made it easier for other researchers to study as reference. Willemse (1951, 1956, 1957) continued his studies in the Indo-Malayan and neighbouring regions as he provided exhaustive accounts on more than 200 genera on subfamilies Acridinae and Catantopinae of the family. His life career was a precursor to his legacy's successes, as both his child and grandchild followed in his footstep to venture into the science that is entomology. Fer Willemse developed the love for grasshoppers and came out with a monograph on the genera *Stenocatantops* and *Xenocatantops* in 1968 among other publications, although his works ultimately focused in the Southern Europe, mainly Greece. His grandchild, Luc Willemse published a handbook on the Orthoptera in the Indo-Malayan region aimed to assist experts and layman on pest species observed in the region by presenting a general taxonomic descriptions of the species reported (Willemse, 2001).

The family in general has not gain much traction in Malaysian Borneo, although the diverseness of this family ensured their wide distributions which leads to a specific niche of vegetations for different species. The consequences of having diversity in a community leads to taxonomic impediment, especially in Malaysian Borneo as acridids were not studied as much, thus hampering the effort to construct reliable taxonomic classification within the species in the areas of study. Undeniably, a few taxonomic works on the family in Malaysian Borneo were worth mentioning, although most of these studies were archaic and only addressing a small number of taxa comparing to the whole collection.

As such, this chapter aimed to undertake a comparative morphological study which would assist in firm establishment of acridids' collections, as well as building the taxonomic keys of the family, providing a revised description on the species within members of acridids, and documenting their distributions across Malaysian Borneo. An examination on the morphological characters, including the external genitalia on 1,216 specimens from the collections had been conducted to achieve the objectives of this chapter.

3.2 Methodology

3.2.1 Materials

The systematics analysis on family Acrididae was conducted principally based on the assessments on specimens from several repositories in Malaysian Borneo region, as well as new field collections. The collection of acridids in Malaysian Borneo was deposited in notable institutions namely Research, Development and Innovation Division (RDID) of Forest Department Sarawak, and Universiti Malaysia Sarawak Insect Reference Collection (UIRC) in Sarawak, as well as three reputable institutions in Sabah, specifically Sabah Museum (SM), Sabah Parks Natural History Museum (SPM) and Institute of Tropical

Biology and Conservation (ITBC) of Universiti Malaysia Sabah. Specimens examined from RDID were collected from expeditions since the year 1976 to 2016, while collections from UIRC were much recent from the year 1994 to 2019. Specimens deposited to the institutions in Sabah were also collected from expeditions conducted from year 1981 to 2019. Informational data such as date of collection, locality, collectors' name, sex, and host plant were recorded from each specimen to assist in data analysis.

Field samplings were also conducted at four sites in Sarawak as an effort to maximise the dataset, specifically: (i) Adis Buan Resort, Bau (1°32'32.3"N, 110°09'05.6"E) for seven days from 2nd to 9th March 2018; (ii) Libiki Bamboo Resort, Bau (1°19'57.9"N, 110°06'22.0"E) for five days from 25th to 30th March 2019; (iii) Sadong Jaya, Samarahan (1°24'47.6"N, 110°31'38.9"E) for five days from 17th to 22nd July 2019; and (iv) Kubah National Park, Kuching (1°36'46.0"N, 110°11'49.0"E) for four days from 4th to 8th December 2019. All samples collected from field samplings were deposited to UIRC, Sarawak.

3.2.2 Preservation and Curation of Samples

Samples collected from field samplings were killed in a jar containing 70% ethyl acetate and left for a few minutes to hours, depending on the size of the samples. They were removed from the jar immediately after death to avoid colour loss (Gullan & Cranston, 2010). The samples were then pinned using insect pins or continental pins with sizes ranging from 000 to 7 (thinnest to thickest), dependent upon the size of the samples. Continental pins are made of ordinary spring steel known as 'black' or stainless steel which are useful for long-term storage of specimens, and built with rounded heads, differing them from other

common and everyday use pins that are susceptible to rusting and corrosion (Upton & Mantle, 2010; Schauff, 2015; British Entomological & Natural History Society, 2020).

Mounting method used for the acridids was direct pinning, where the samples were pinned slightly to the right in the middle of thorax between the second and third legs (Rondon & Corp, 2012; Schauff, 2015). About 2/3 or 8 mm – 10 mm distance was left between the top of the sample's body and the top of the pin (Figure 3.1) to ensure that there was enough space to pick up the samples without causing any damage (Choate & Frank, 2008; Schauff, 2015). The samples were relaxed and positioned in their natural state, with all their legs spread and antennae positioned to the side of the body to ensure all parts were visible for further study and maximize the space efficiency in the insect box (Schauff, 2015).

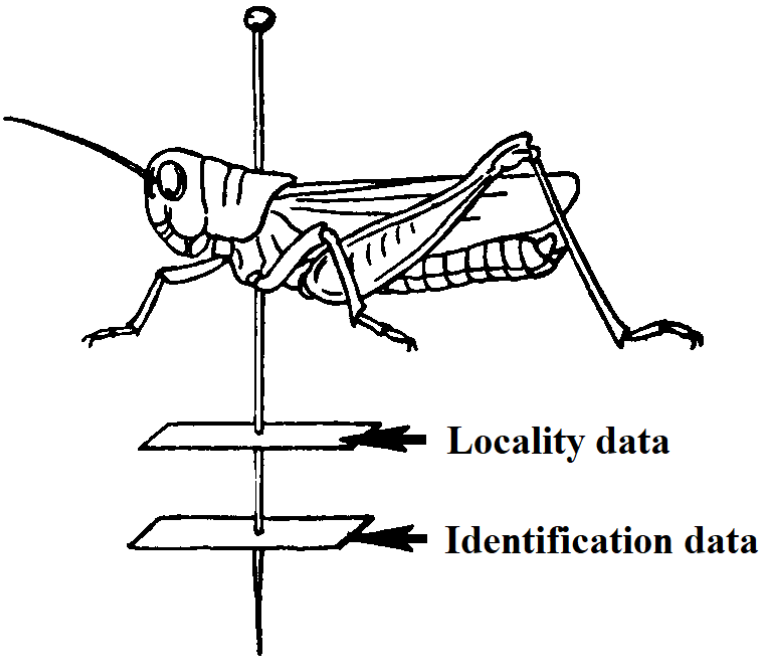


Figure 3.1: The correct height for the distance of sample's body to the top of the pin with the position of labelling data.

All samples were allowed to dry or set on the board for a couple of days to weeks varying on the type and size of the samples, as well as the ambient humidity of the room

(Upton & Mantle, 2010). Locality and identification data were labelled correctly on each samples as illustrated in Figure 3.1 before they were transferred to a permanent storage, which were the entomological cabinets (Figure 3.2) or entomological storeboxes (Figure 3.3) depending on the purpose of collections as shown in Figure 3.2 (Upton & Mantle, 2010; Schauff, 2015). Locality data includes location of the collected samples, date, and the collectors' names. Latitude and longitude of the location should be included whenever possible using Global Positioning System (GPS) to ensure the accuracy of the location stated. Day and year of collection should be written in full, in Arabic numerals, while the month written in Roman numerals to avoid confusion between the American and European date format (Schauff, 2015). Supplementary information such as collecting method or other information that is useful could be added to the locality data as added information (Upton & Mantle, 2010). Identification data should include species identification up to family level which is convenient for future research.



Figure 3.2: Entomological cabinet used to store insect specimens.



Figure 3.3: Entomological storebox used to store insect specimens.

3.2.3 Species Identification, Nomenclatural Data and Type Specimens

Species identification and diagnosis were based on the original descriptions of the species, taxonomic revisions, keys, and images from several entomologists and orthopterists, including Uvarov (1921, 1923a, 1923b), C. Willemse (1938, 1956, 1957), Rehn and Rehn (1940), Bei-Bienko and Mishchenko (1963, 1964), Hollis (1965, 1968, 1971, 1975), L. Willemse (2001), Mahmood et al. (2007, 2008), Tan (2010a, 2010b, 2012a), Tan and Kamaruddin (2014, 2016), Tan and Wahab (2018) and Cigliano et al. (2021). Other significant information regarding the taxonomic authority, dates, nomenclatural changes, and synonymies were compiled and recorded based on bibliographic compilation of the

original publications. Digital images of type specimens were used to revise and compare with the specimens assessed for species confirmation. Two repositories were solicited, namely: Natural History Museum (BMNH), London (https://data.nhm.ac.uk/dataset/collection-specimens) and Orthoptera Species File (OSF) (http://orthoptera.speciesfile.org/Common/editTaxon/SearchForTaxon.aspx).

3.2.4 Character Sampling

This study was based on comparative morphological methods that was used to distinguish among species (Bock, 1969). All specimens were examined and assessed using Nikon SMZ445 stereo microscope and further examination on genitalic characters were observed using Q-Scope Model QS.20200-P digital microscope.

Characters examined includes the colouration and structure of head, thorax, abdomen, and legs of the acridids that were useful in determining a species. Colouration and patterns displayed by each species on the vertex of head and face, segmental parts of the antennae, dorsum of pronotal disc, surface of legs and wing designs were valuable information for redescriptions in the taxonomic accounts as presented by Cigliano et al. (1996), Song and Wenzel (2007) and Li et al. (2011). Apart from that, structural composition of the species such as shape of head, inter-ocular distance between the compound eyes, length of antennae, integument and sculpting pattern on dorsum of prozona and metazona, convexity of median posterior margin of pronotum, distinctness of median carina on pronotum, shape of prosternal process, shape of mesosternal interspace, shape of genicular lobes, shape and curvature of male cerci, thickness of lateral ridge formed on the supra-anal plate, shape of posterior margin of female subgenital plate in ventral view and presence of lateral teeth on posterior margin of female subgenital plate in ventral view were also analysed

as part of the redescriptions of species following methods by Roberts (1941) and Song and Wenzel (2007).

3.2.5 Morphometric Measurements

Morphometric measurements were taken by using Mitutoyo CD-6”CSX digital calliper, calibrated to 0.01 mm and recorded to two decimal points. Data collected was computed in Excel software. The external morphological characters measured were: total body length (BL), length of front head (FHL), width of head (HW), length of pronotum (PL), length from fastigium to post-occiput (FPL), length from head to pronotum (PHL), width of pronotum (PW), length of antennae (AL), inter-ocular distance or width between eyes (WBE), size of eye (height) (ES (H)), size of eye (width) (ES (W)), length of tegmen (TL), width of tegmen at apex (TW (1)), maximum width of tegmen (TW (2)), width of tegmen basally (TW (3)), length of hind femora (HFL), length of hind tibia (HTL) and length of hind tarsi (HSL) following methods by Cisneiros et al. (2012) and Silva et al. (2014) with a few alterations and modifications to suit the specimens available, as illustrated in Figure 3.4. Missing characters were denoted by “-” (Appendix 1).

3.2.6 Imaging

Habitus images of dorsal and ventral view of the specimens from each species represented by one male and one female specimen were photographed with a size scale using Olympus Stylus TOUGH TG-3 digital camera with microscope function. GNU Image Manipulation Program (GIMP) 2.10.24 software was used for further corrections on the images. Focused images of minute body parts were taken using Q-Scope Model QS.20200-P digital microscope. Some species were only represented by a singleton, accounting for the lack of images representing said species.

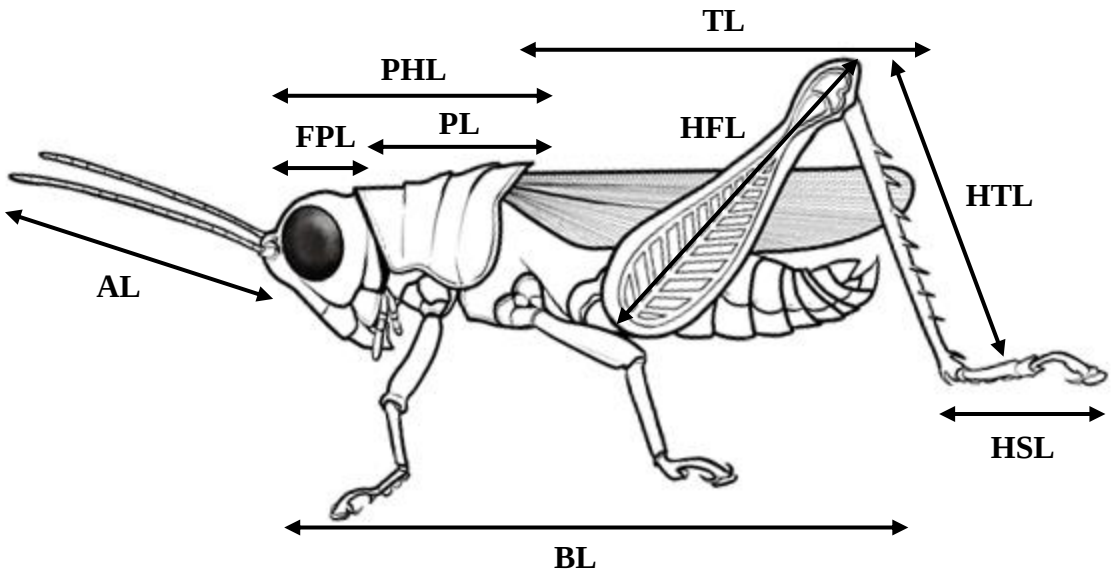


Figure 3.4: Lateral view of *Traulia azureipennis* focusing on some of the external morphological characters assessed in morphometrical measurements.

3.2.7 Distribution Maps

Locality for each specimen was obtained from the labelling data. Distribution maps for subfamilies and genera were then generated with Quantum Geographic Information System (QGIS) 3.10.9 (Figure 3.7, Figure 3.19, Figure 3.23, Figure 3.25, Figure 3.29, Figure 3.35, and Figure 3.39).

3.3 Results

3.3.1 Species Identification

General account and diagnosis on each species of the family have been thoroughly discussed. Available specimens of the following described species were examined: *Phlaeoba antennata* Brunner von Wattenwyl, 1893, *P. infumata* Brunner von Wattenwyl, 1895, *Apalacris varicornis* Walker, 1870, *Coloracris azureus* Willemse, 1938, *C. coerulescens* Willemse, 1938, *Coloracris* sp., *Craneopsis olivacea* Ramme, 1941, *Meltripata* sp. 1, *Meltripata* sp. 2, *Perakia borneensis* Willemse, 1936, *Phalaca waterstradti* Ramme, 1941,

Stenocatantops splendens (Thunberg, 1815), *Traulacris grandis* (Miller, 1932), *Traulia azureipennis* (Serville, 1839), *T. borneensis* (Willemse, 1921), *T. sanguinipes sanguinipes* Stål, 1878, *Xenocatantops humilis* (Serville, 1839), *Patanga luteicornis* (Serville, 1839), *P. succincta* (Linnaeus, 1763), *Valanga nigricornis* (Burmeister, 1838), *Aiolopus thalassinus tamulus* (Fabricius, 1798), *Gastrimargus marmoratus* (Thunberg, 1815), *Heteropternis obscurella* (Blanchard, 1853), *Locusta migratoria manilensis* (Meyen, 1835), *Trilophidia annulata* (Thunberg, 1815), *Oxya hyla intricata* (Stål, 1861), *O. japonica japonica* (Thunberg, 1824), and *Pseudoxya diminuta* (Walker, 1871).

3.3.2 Species Abundance and Composition

The study revealed a total of 1,216 specimens examined, comprising of five subfamilies, 20 genera and 28 species. A total of 928 specimens were examined from two institutions in Sarawak, while 288 of the specimens were assessed from three institutions in Sabah. The most abundant species was *Valanga nigricornis* with 180 individuals (14.80%), followed by *Traulia azureipennis* (12.17%), *Oxya japonica japonica* (11.02%), *Xenocatantops humilis* (10.69%), *Pseudoxya diminuta* (7.81%), *Aiolopus thalassinus tamulus* (6.91%), *Phlaeoba antennata* (6.17%), *Stenocatantops splendens* (6.09%), *Trilophidia annulata* (5.26%), *Gastrimargus marmoratus* (4.52%), *Patanga luteicornis* (3.70%), *O. hyla intricata* (2.55%), *P. succincta* (1.32%), *Locusta migratoria manilensis* (1.15%), *T. borneensis* (1.07%), *T. sanguinipes sanguinipes* (1.07%), *Ph. infumata* (0.99%), *Traulacris grandis* (0.82%), *Apalacris varicornis* (0.66%), *Heteropternis obscurella* (0.41%), and *Perakia borneensis* (0.25%). On the other hand, *Coloracris coerulescens*, *C. azureus*, *Coloracris* sp., *Craneopsis olivacea*, *Phalaca waterstradti*, *Meltripata* sp. 1 and *Meltripata* sp. 2 were each represented by 0.08% as shown in Table 3.1.

Table 3.1: List of species with the repositories, number of individuals and relative abundance of Acrididae examined from Malaysian Borneo. Abbreviations are as follows: UIRC: UNIMAS Insect Reference Collection, RDID: Research Development and Innovation Division of Forest Department Sarawak, SM: Sabah Museum, SPM: Sabah Parks Natural History Museum, and ITBC: Institute of Tropical Biology and Conservation of Universiti Malaysia Sabah.

Subfamily	Genus	Species	Repository	Number of individuals	Relative abundance (%)
Acridinae	*Phlaeoba*	*Phlaeoba antennata*	UIRC, RDID, SM, ITBC	75	6.17
		Phlaeoba infumata	UIRC, RDID, ITBC	12	0.99
Catantopinae	*Apalacris*	*Apalacris varicornis*	RDID, SPM	8	0.66
	Coloracris	*Coloracris azureus*	RDID	1	0.08
		Coloracris coerulescens	RDID	1	0.08
		Coloracris sp.	RDID	1	0.08
	Craneopsis	*Craneopsis olivacea*	RDID	1	0.08
	Meltripata	*Meltripata* sp. 1	UIRC	1	0.08
		Meltripata sp. 2	UIRC	1	0.08
	Perakia	*Perakia borneensis*	RDID, SPM, ITBC	3	0.25
	Phalaca	*Phalaca waterstradti*	RDID	1	0.08
	Stenocatantops	*Stenocatantops splendens*	UIRC, RDID, SM, SPM, ITBC	74	6.09
	Traulacris	*Traulacris grandis*	SPM, ITBC	10	0.82
	Traulia	*Traulia azureipennis*	UIRC, RDID, ITBC	148	12.17
		Traulia borneensis	SPM, ITBC	13	1.07
		Traulia sanguinipes sanguinipes	UIRC, RDID	13	1.07
	Xenocatantops	*Xenocatantops humilis*	UIRC, RDID, SPM, ITBC	130	10.69
Cyrtacanthacridinae	*Patanga*	*Patanga luteicornis*	UIRC, RDID, SM, SPM, ITBC	45	3.70
		Patanga succincta	UIRC, RDID, SM, SPM	16	1.32

Table 3.1 continued.

Subfamily	Genus	Species	Repository	Number of individuals	Relative abundance (%)
Oedipodinae	*Valanga*	*Valanga nigricornis*	UIRC, RDID, SM, SPM, ITBC	180	14.80
	Aiolopus	*Aiolopus thalassinus tamulus*	UIRC, RDID, SPM, ITBC	84	6.91
	Gastrimargus	*Gastrimargus marmoratus*	UIRC, RDID, SPM, ITBC	55	4.52
	Heteropternis	*Heteropternis obscurella*	ITBC	5	0.41
	Locusta	*Locusta migratoria manilensis*	RDID, SPM, ITBC	14	1.15
	Trilophidia	*Trilophidia annulata*	UIRC, RDID, SM, SPM, ITBC	64	5.26
Oxyinae	*Oxya*	*Oxya hyla intricata*	UIRC, RDID, SPM, ITBC	31	2.55
		Oxya japonica japonica	UIRC, RDID, SM, SPM, ITBC	134	11.02
	Pseudoxya	*Pseudoxya diminuta*	UIRC, RDID, SPM, ITBC	95	7.81
TOTAL	**20**	**28**		**1216**	**100**

3.3.3 Species Description

Systematics accounts for 28 species of Acrididae from five subfamilies, namely Acridinae, Catantopinae, Cyrtacanthacridinae, Oedipodinae and Oxyinae, including descriptions of the family and selected genera, as well as key to the subfamilies of Acrididae, distributional maps and habitus photographs of dorsal and ventral view of each species were presented.

Acrididae MacLeay, 1821

Diagnosis. Body length small to large in sizes with sexual size dimorphism; variable body colour; head lack furrow at the apex of fastigium, lacking median longitudinal sulcus, generally straight or slightly oblique in lateral view, slanting not more than 45 degrees; large compound eyes and small ocelli; antennae longer than fore femora but not longer than total body length; pronotum short with abdomen uncovered dorsally; prosternal process present except for subfamily Oedipodinae and Acridinae; tympana well-developed on first segment of abdominal tergites, covered by hindwings, stridulatory sound produced by rubbing the hind legs and tegmina together; forewings and hindwings covering part of dorsum of the abdomen when folded, forewings thick and not usually adapted for flight, hindwings thin, large and brightly coloured; hind legs longer than the forelegs, with hind femora wider towards the base; hind tibiae with double row of spines dorsally and two or more calcaria or spurs on the external end of apical region; tarsi three-segmented, first joint of tarsi longer than the second and third joint of tarsi and equipped with three pulvilli on the ventral surface, last joint terminates with two claws between the arolium; female ovipositors with four short valves projecting beyond supra-anal plate; male subgenital plate recurved and often almost pointed forming apex of the abdomen.

Keys to the subfamilies of Acrididae of Sarawak

1 Prosternal process present ……...……. 2

- Prosternal process absent …….……...…….. 4

2 Ventral genicular lobe of hind femora with spine-like apex ……..……...… Oxyinae

- Ventral genicular lobe of hind femora with apex obtuse or rounded ……..…… 3

3 Inner posterior corners of mesosternal lobe rectangular, with straight or sub-straight inner margins ……...…….. Cyrtacanthacridinae

- Inner posterior corners of mesosternal lobe not rectangular, with curved or angulated inner margins …….…….…….. Catantopinae

4 Head oblique laterally; fastigium and frons meet at an acute angle …..... Acridinae

- Head straight laterally; fastigium and frons meet at an obtuse angle ..... Oedipodinae

Subfamily Acridinae MacLeay, 1821

Genus *Phlaeoba* Stål, 1861

Diagnosis. Body size small to medium, more robust; head elongated and slightly slanted in profile, frontal ridge between antennae raised, fastigium of vertex extending slightly beyond compound eyes, surface of fastigium slightly concave, foveolae small and triangular; eyes prominent, inter-ocular distance marginally broader than fastigium of vertex; antennae widened and flattened basally; pronotum cylindrical and compressed in profile, prozona

longer than metazona, median carina straight and distinct, anterior margin truncated, posterior margin rounded; prosternal process absent; anterior border of mesosternum broadly projected in the middle forming triangular arch, mesosternal lobes broader than long, metasternal lobes separated; tegmina reaching as far as apex of abdomen, apex of tegmina rounded; genicular lobes of hind femora rounded; male supra-anal plate triangular with acute apex, cercus narrowing towards apex; female ovipositors slightly curved.

Phlaeoba antennata Brunner von Wattenwyl, 1893

Figure 3.5, Figure 3.7

Phlaeoba antennata Wattenwyl & Fea, 1893: 125; Kirby, 1914: 102; Willemse, 1930: 52

Phlaeoba angustidorsis Bolivar, 1902: 590

Materials examined. 75 specimens (♂: 42, ♀: 33). **BORNEO: EAST MALAYSIA: SARAWAK: Bintulu:** Jelalong, Sg. Mayop, 28.X.2000, caught by light trap, Ento Team, 2♀ (FN.00-1470, FN00-1552), 1♂ (FN.00-1471) (RDID). **Kuching:** Bau, Singai, Kg. Atas, 02.III.2018, Bernadine Sara Aras, 1♀ (UIRC). DBKU Garden, 30.IV.2016, Nur Asma, 1♂ (UIRC). Semenggoh, 01.II.1979, found on leaves of *Shorea macrophylla*, E.T. Yeo, 1♂ (FN.01260) (RDID). Semenggoh, Ulu Landeh, 09.II.1984, caught at agricultural plot, Ento Team, 1♂ (FN.84-0082) (RDID); 13.II.1984, caught at agricultural plot, Ento Team, 3♂ (FN.84-0135–FN.00-0137) (RDID). **Lundu:** Gunung Gading National Park, 12.V.1984, Haidir & Lippa, 1♀ (FN.84-0710) (RDID). Kg. Stuom Muda, 26.XI.1999, Jinal J., 1♀ (RDID). Samunsam Wildlife Sanctuary, 28.X.1979, C. Mercer & Suhaili, 1♀ (FN.79-0833) (RDID). **Miri:** Lambir Hills National Park, 13.VII.2015, caught in Malaise trap, Ento Team,

1♀ (RDID). Marudi, Loagan Bunut, 02.II.1995, Ento Team, 1♂ (RDID). Niah, 22.II.1979, A.A. Hamid, 1♂, E.T. Yeo, 1♂ (FN.01286) (RDID); 24.II.1979, A.A. Hamid, 1♀ (FN.01423) (RDID); 23.IX.1981, caught by Malaise trap, Ento Team, 1♂ (Y.81-242) (RDID); 29.III.1984, Ento Team, 2♂ (FN.84-0372, FN.84-0379) (RDID); 19.V.1987, A.A. Hamid, 1♀ (FN.87-0214) (RDID); 22.III.1997, Ento Team, 1♀ 2♂ (RDID). **Samarahan:** Kota Samarahan, 14.I.2003, Yenny, 1♂ (UIRC). UNIMAS, 12.III.1997, Rimons, 1♀ (UIRC); 24.I.2010, Sarina Mat Yasin, 1♂ (UIRC); 27.IV.2018, Salma Sulaiman, 1♀ (UIRC); 27.II.2019, Chin Cheong Wei, 1♂ (UIRC). UNIMAS, Basketball Court, 03.XII.2003, Sandra leg., 1♀ (UIRC). **Serian:** Balai Ringin P.I., 17.XI.1998, pest of *'engkabang jantong'* caught between 0700 – 0800, Ento Team, 2♀ (RDID). **Sibu:** Oya, 26.I.1988, A. Hamid & A. Rahman, 1♂ (FN.88-0012) (RDID). **Simunjan:** Sabal Forest Reserve, 19.V.1984, Isa Sait, 1♀ (FN.84-0918) (RDID); 08.I.1997, Ento Team, 1♂ (SFR01667) (RDID); 10.I.1997, Ento Team, 1♂ (SFR01806) (RDID); 15.IV.1997, Ento Team, 1♂ (SFR03839) (RDID). **SABAH: Kota Kinabalu:** Bukit UMS, 18.VIII.2012, Lam, 1♀ (UMS); 28.VIII.2012, Lam, 2♂ (UMS); 29.V.2014, caught by aerial net, Randall Lee, 1♀ 1♂ (UMS); 12.III.2017, caught by aerial net, Koid Qian Qun, 1♂ (UMS); 08.IV.2017, caught by sweep net, Nurul Amynina, 1♀ (UMS); 17.IV.2017, Wong Chee Leng, 1♂ (UMS); 22.IV.2017, caught by aerial net, Alya, 1♀ (UMS); 01.V.2017, caught on leaves by aerial net, Lia M., 2♀ (UMS); 13.V.2017, caught by sweep net, Clarice, 1♂ (UMS); 20.X.2017, caught in bushes by hand, Lau Zi Shan, 1♂ (UMS). Karamunsing, 10.VIII.1990, Salmin, 1♂ (ORT-1054) (UMS). Kingfisher, 02.III.2018, caught at grass field by hand, Celine, 1♀ (UMS). Muzium Kinarut, Panorama Rumah Besar, 09.IX.1997, Dennes Jonioh, 1♀ (ENT:4323) (SM). UMS, 17.VIII.2015, caught by aerial net, Kanami Noda, 1♀, caught by sweep net, Arata Ishikawa, 1♂ (UMS). UMS Peak, 08.IV.2017, caught by sweep net,

Norfarhain Jefri, 1♂ (UMS); 01.XII.2017, caught in forest by aerial net, Muhammad Adam, 1♂ (UMS). UMS, ITBC, 01.XI.2017, caught in forest by sweep net, Amiruddin, 1♀ (UMS). UMS, KSA, 11.III.2017, caught by aerial net, Clarice, 1♀ (UMS). UMS, T. Likas, 01.XI.1995, Entomology Unit, 1♂ (ORT-0930) (UMS); 16.XI.1995, Entomology Unit, 1♂ (ORT-0926) (UMS); 17.XI.1995, Entomology Unit, 1♂ (ORT-0927) (UMS); 18.XI.1995, Entomology Unit, 1♂ (ORT-0925) (UMS); 20.XI.1995, Entomology Unit, 1♂ (ORT-0924) (UMS); 21.XI.1995, Entomology Unit, 1♂ (ORT-0929) (UMS). **Kudat:** Kota Marudu, Kg. Batu 4, 23.III.1993, caught on paddy field, Jelius Gantor, 1♀ (ENT:1743) (SM). **Ranau:** Taman Kinabalu, Sub Stesen Monggis, 3-7.X.2009, Muzamil Mustaffa, Cornelius Peter & Hong Men Chin, 3♀ 1♂ (UMS). **Tawau:** Maliau Basin, Agathis Camp, 12-19.V.2001, caught in open grassland, Ito Gen & Azrie A., 1♀ (ORT-1278) (UMS). **Tenom:** Lagud Seberang, 20.VIII.1990, Ferdinand, 1♂ (ORT-0928) (UMS). **Tuaran:** Tuaran, 14.V.2017, caught by hand, Jabir & Mohd Rosyaidi, 1♀ 1♂ (UMS).

Diagnosis. *Phlaeoba antennata* is recognised by the following combination of characters: head slightly slanted with fastigium extending forward triangularly passing frons making elbow shape between antennae; tip of antennae white; dorsum with pale yellow longitudinal stripe from fastigium to apex of tegmina; prosternal process absent; apex of tegmina reaching hind knees or shorter.

Description. Male: Body size small, total length 17.88 mm – 21.66 mm. **Colouration:** Head: Generally unicolourous brown, dorsum with pale yellow longitudinal stripe from anterior of fastigium to post-occipital margin. *Antennae*: Dark brown with white tip. Thorax: Dorsum of pronotum pale yellow, lateral lobe brown. *Legs*: Hind femur dorsally yellowish brown, ventrally olivaceous green; hind tibia and tarsus brown. *Wings*: Uniformly brown

with pale yellow stripe dorsally; hind wings basally blue, apically hyaline throughout. **Structure:** Body small and robust. Head: Sub-pentagonal in frontal view, frons oblique, sub-triangularly to vertex of head with an angle of slightly over 40 degrees in profile; eyes sub-circular, vertical diameter longer than horizontal diameter of eye laterally, exceeding the outline of head dorsally, eyes as high as vertex of head in profile, inter-ocular distance distinctly wider than width of frontal ridge; foveolae long, sub-triangular; lateral carinae parallel with median carina, not cutting through fastigium ridge; distance from anterior margin of eyes to apex of fastigium equal or less than horizontal diameter of eye in profile, anterior apex of head sub-triangularly projecting forward away from eyes, transverse groove not interrupting lateral carinae of vertex, fastigium weakly excavated; frontal costa above frontal ocellus lightly punctured with thick frontal ridge extending towards clypeus; frontal costa between antennae obviously projected forward, forming slightly discernible arch above frontal ocellus in profile; frons with pebbled surface. *Antennae*: Longer than the combined length of pronotum and head; flattened and filiform-like shaped. Thorax: Lacking prosternal process; pronotum tectiform; wider than width of head; prozona significantly longer than metazona, sub-cylindrical dorsally and not constricted in the middle; median carina flat dorsally, straight and with no trace in profile, crossed by one sulcus, very shallow incision by principal sulcus, lateral carinae elevated; median posterior margin of metazona smoothly round and not concave; surface of pronotum thinly and irregularly carinulated; dorsum of prozona with irregular ridges, lateral lobe thinly and sparsely wrinkled; dorsum of metazona distinctly thickly ridged; posteroventral margin of lateral lobe angular with an angle of slightly more than 90 degrees; anterior border of mesosternum broadly projected in the middle, mesosternal lobe laterally wider than vertical length, mesosternal interspace wide with length of basal width as long as vertical length, anterior margin of interspace slightly

concave, inner posterior corners of lobe obtusely round; mesosternal lobe separated, anterior margin of interspace wider than basal width. *Legs*: Upper carina of hind femora prominently serrate, lower carinae smooth, basal lobe dorsally longer than ventral length, dorsal and ventral genicular lobe rounded distally, distal end of dorsal carina with acutely pointed spine; hind tibia without outer apical spine, number of spines on outer margin 10, distance between first and second spines on inner margin as long as any other inter-spine distance, distal half of hind tibia not obviously broadened towards apex. *Wings*: Tegmen macropterous, male wings developed in contact with each other above abdomen; distal margin round, cell of distal part sub-rectangular. Genitalia: Cerci narrowing towards apex, elongated conical, straight in profile, apex rounded; supra-anal plate long, scutatiform, apex not divided, lacking furcula and smooth without tubercles near lateral margins, thick lateral ridge basally extending to the middle field and forming deep groove; subgenital plate triangular ventrally with apex rounded and not divided, very short with basal width longer than vertical length, gradually tapering towards apex and lacking tubercle at end of apex.

Female: Slightly larger than male, total length 25.01 mm – 32.56 mm. Colouration, vestiture and texture as in male. **Structure**: Mostly resemble male specimens, body robust. Genitalia: Ovipositor long and curved apically in profile, dorsal and ventral valves with equal length; dorsal valves converging dorsally, with one apical tooth, weakly serrulated on the superior margin, non-bidentate and lacking notch on apex; ventral valves very narrow, external margins weakly serrated and faintly constricted laterally in the middle, external lateral teeth faintly projected outward; subgenital plate triangularly projected posteriorly in the middle, lacking lateral teeth on posterior margin of the plate.

Food plant. Bamboo grass, banana, cacao, durian, maize, rice, sugar cane and teak, particularly in India (Roffey, 1979; COPR, 1982; Willemse, 2001). The species has been

reported as pest of engkabang jantong (*Shorea macrophylla*) and collected in paddy fields.

Ecology. Abandoned cultivated land, bushes, secondary forest, moss forest, primary white sand forest, open grassland (Willemse, 1938; Roffey, 1979; COPR, 1982; Willemse, 2001; Tan & Kamaruddin, 2014, 2016).

Distribution. Bangladesh, Cambodia, China, India, Indonesia, Laos, Malaysia, Myanmar, Singapore, Thailand, Vietnam (Willemse, 1951; Roffey, 1979; COPR, 1982; Willemse, 2001; Mahmood et al., 2007; Tan, 2010a, 2010b, 2012; Tan & Kamaruddin, 2014, 2016; Cigliano et al., 2021).

Remarks. *Phlaeoba antennata* is similar to *P. infumata* by exhibiting clear and defined median and lateral carinae on pronotal disc, having somewhat short and obtuse vertex of fastigium that does not extend exceptionally beyond the compound eyes forming rounded arch with frons from lateral view, and possessing flattened and widened antennae, with the exception of the longitudinal yellow band running from the fastigium to the posterior end of the tegmina, white tip of the antennae, bluish hindwings and bluish hind tibias.

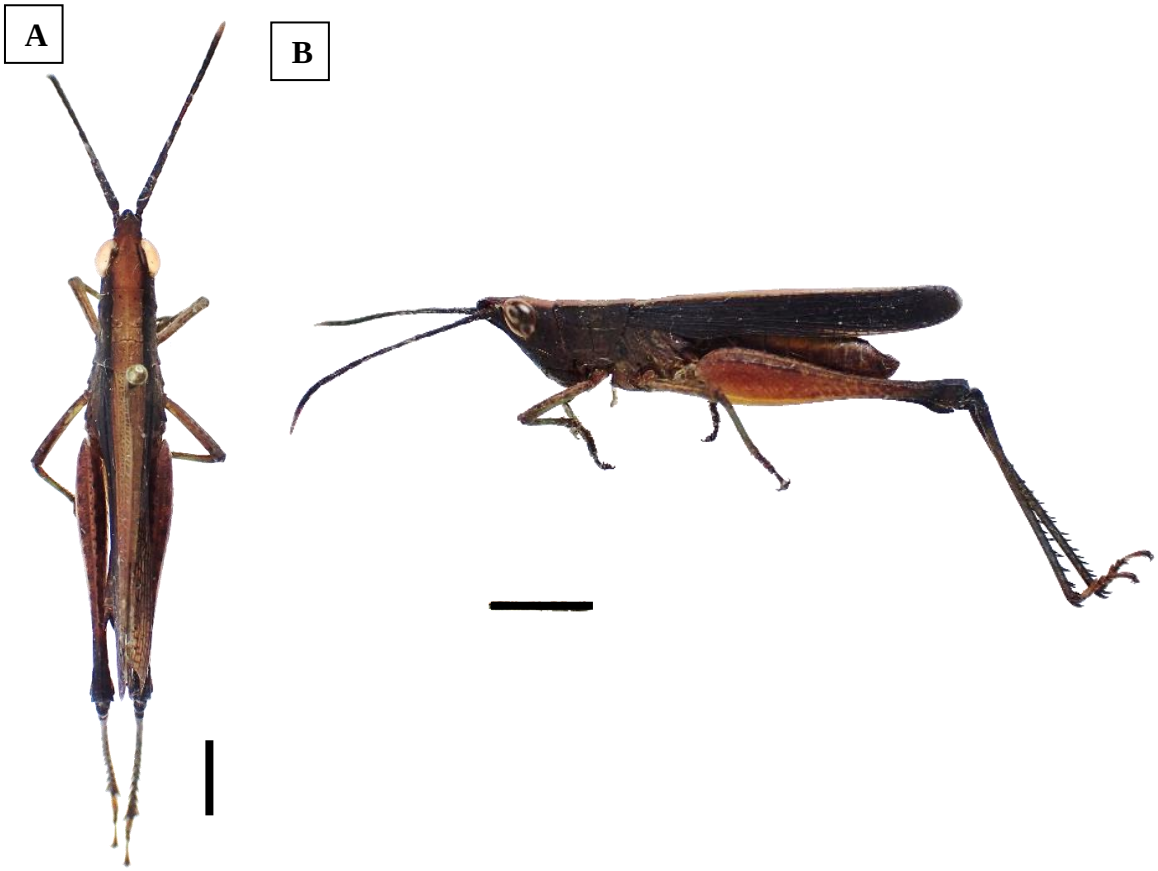


Figure 3.5: *Phlaeoba antennata*, ♂. **A.** Dorsal view of type; **B.** Lateral view of type. Scale = 5 mm.

Phlaeoba infumata Brunner von Wattenwyl, 1893

Figure 3.6, Figure 3.7

Phlaeoba infumata Wattenwyl & Fea, 1893: 124; Kirby, 1914: 103; Karny, 1915: 83

Phlaeoba angustipennis Bolivar, 1902: 592; Kirby, 1910: 138

Materials examined. 12 specimens (♂: 2, ♀: 10). **BORNEO: EAST MALAYSIA: SARAWAK: Bintulu:** Sungai Sibiyu, 10.I.1985, Lippa Akeng, 1♂ (FN.85-0009) (RDID). **Kuching:** Bau, 25.VII.2002, Monijane, 1♀ (UIRC). Bau, Gunung Singai, 24.IV.2017, Nurnatasha Amira, 1♀ (UIRC). Lundu, Gunung Gading National Park, 14.VII.1987, Ento

Team, 1♀ (FN.87-0319) (RDID). **Miri:** Niah, 22.II.1979, E. T. Yeo, 1♀ (FN.01285) (RDID); 16.I.1985, Manis Lintang, 1♀ (FN.85-0142) (RDID). **SABAH: Kota Kinabalu:** Bukit UMS, 08.IV.2017, caught by sweep net, Nurul Amynina, 1♀ (UMS). UMS Peak, 01.XII.2017, caught in forest by using aerial net, Muhammad Adam, 1♀ (UMS). **Ranau:** Kinabalu Park, Sub Stesen Monggis, 03-07.X.2009, Muzamil Mustaffa, Cornelius Peter & Hong Men Chin, 3♀ 1♂ (UMS).

Diagnosis. *Phlaeoba infumata* is recognised by the following combination of characters; head slightly slanted, fastigium extending forward roundly passing into frons, antennae widened and flattened basally, tip on antennae without white tinge, hindwings hyaline with apex slightly darkened.

Description. Male: Body size small, total length 18.27 mm – 19.35 mm. **Colouration:** Body uniformly rusty yellowish brown. Head: Generally brown with pale yellow longitudinal stripe from anterior of fastigium to post-occipital margin. *Antennae*: Pale to dark brown. Thorax: Pronotum dorsally pale yellow with brown lateral carinae, laterally rusty brown throughout; sternum generally rusty brown, sometimes pale yellow with dark brown markings. *Legs*: Hind femur generally rusty brown with black spots scattered along upper and lower carina getting darker apically; hind tibia dark brown throughout, nearly black; tarsus uniformly pale to dark brown. *Wings*: Tegmen pale yellow dorsally, laterally dark brown; hind wing hyaline with apex darkened bluish basally and darkened apically in some specimens. Abdomen: Uniformly rusty brown. **Structure:** Body short and robust. Head: Sub-rectangular in frontal view, frons sub-triangular to vertex of head in profile; eyes long oval, exceeding the outline of head, as high as vertex of head laterally, distance from anterior margin of eyes to apex of fastigium equal to the horizontal diameter of eye in profile, inter-

ocular distance wider than width of frontal ridge, lateral carinae and foveola present; anterior apex of head projecting forward away from eyes dorsally; apex of fastigium very weakly excavated with barely projected median carina on vertex; frontal ridge of head extending to clypeus; frontal costa between antennae obviously projected forward, moderately arched above median ocellus; frontal costa lightly punctured; frons weakly ridged. *Antennae*: As long as the combined length of head and pronotum; sword-shaped, widened and flattened basally. Thorax: Pronotum long, saddle-shaped; width as wide as head; lacking prosternal process; prozona longer than metazona; sub-cylindrical from dorsal view and longitudinal margins parallel with each other; transverse sulci shallowly impressed on pronotal disc, median carina crossed by one sulcus, straight and flat in profile, additional minor transverse sulci not cutting median carina, shallow incision on pronotum by principal sulcus; lateral carinae elevated, reaching the posterior margin of pronotum; median posterior margin of metazona smoothly round; pronotal disc coarsely carinulated; dorsum of prozona with irregularly wrinkled ridges, lateral lobe distinctly wrinkled; dorsum of metazona with distinctly small but thickened ridges; posteroventral margin of lateral lobe roundly angular and not concave; anterior border of mesosternum slightly arched; mesosternal lobe slightly wider laterally than its vertical length, mesosternal interspace wide with horizontal length equal to its vertical length, inner posterior corners of lobe obtusely round; metasternal lobe separated medially. *Legs*: Upper carinae of hind femur prominently serrate, lower carinae smooth, basal lobe dorsally longer than ventral length, dorsal and ventral genicular lobe roundly angular distally, distal end of dorsal carina spined, acutely pointed; hind tibia lacking outer apical spine, number of spines on outer margin 10, distance between first and second spines of inner margin as long as any other inter-spine distance, distal half not obviously broadened toward apex. *Wings*: Tegmen macropterous, fully winged, male wings developed

at least in contact with each other above abdomen, length reaching end of abdomen or hind knee of femora; distal margin round, cells of distal part irregular intermixed with rectangular. Genitalia: Cerci elongated conical, straight, narrowing toward apex, apex of cerci pointed; supra-anal plate scutatiform, lacking furcula and smooth without tubercles near lateral margins, middle field with deep groove from anterior margin to medial part of the plate, lacking tubercles and transverse ridge on middle field and sides of apical and middle field; subgenital plate with simple conical structure, apex not divided, very short with length equal to basal width, gradually tapering toward apex with blunted end dorsally, lacking tubercle at end of apex.

Female: Body size medium, larger than male, total length 26.23 mm – 32.25 mm. Colouration, vestiture and texture as in male. **Structure:** Mostly as in male, body robust. Genitalia: Ovipositor curved in profile, dorsal valves as long as ventral; dorsal valves convergent, with one apical tooth, very weakly serrulate on the superior margin, non-bidentate and lacking notch on apex of valves; ventral valves very narrow, external margins serrated and faintly constricted laterally in the middle field, external lateral teeth weakly projected outward; subgenital plate strongly projected triangularly posteriorly in the middle, lacking lateral teeth on posterior margin.

Food plant. Rice and sugar cane (Malaysia), sweet potato (Taiwan), maize (Thailand) (Roffey, 1979; COPR, 1982; Willemse, 2001).

Ecology. Abandoned cultivated land, edges and interior of forests, secondary forest, herby areas, grassy areas which includes areas with long grass and low vegetation along streams, and open grassland with well-drained soil (Roffey, 1979; COPR, 1982; Willemse, 2001; Tan & Kamaruddin, 2014, 2016).

Distribution. Bangladesh, Cambodia, China, India, Laos, Malaysia, Myanmar, Nepal, Singapore, Taiwan, Thailand, Vietnam (Roffey, 1979; Willemse, 2001; Mahmood et al., 2007; Tan, 2010a; Tan & Kamaruddin, 2014, 2016; Cigliano et al., 2021).

Remarks. Genus *Phlaeoba* holds great similarities with pyrgomorphids, with the obvious physical distinction of the body colour and projecting head vertex. Body colour of *Phlaeoba* is usually ground colour while pyrgomorphids are green and head vertex of pyrgomorphids are more projected forward forming distinct triangular shape, whereas *Phlaeoba* are less projected with fastigium of vertex are only extending slightly beyond the compound eyes.

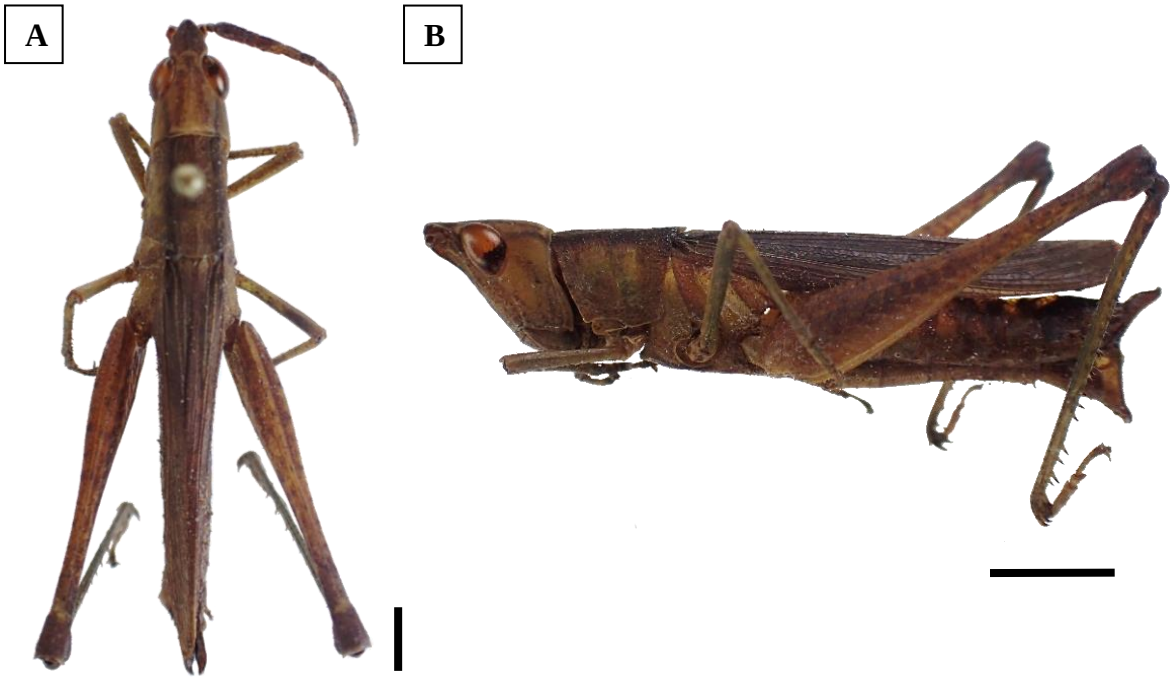


Figure 3.6: *Phlaeoba infumata*, ♀. **A.** Dorsal view of type; **B.** Lateral view of type. Scale = 5 mm.

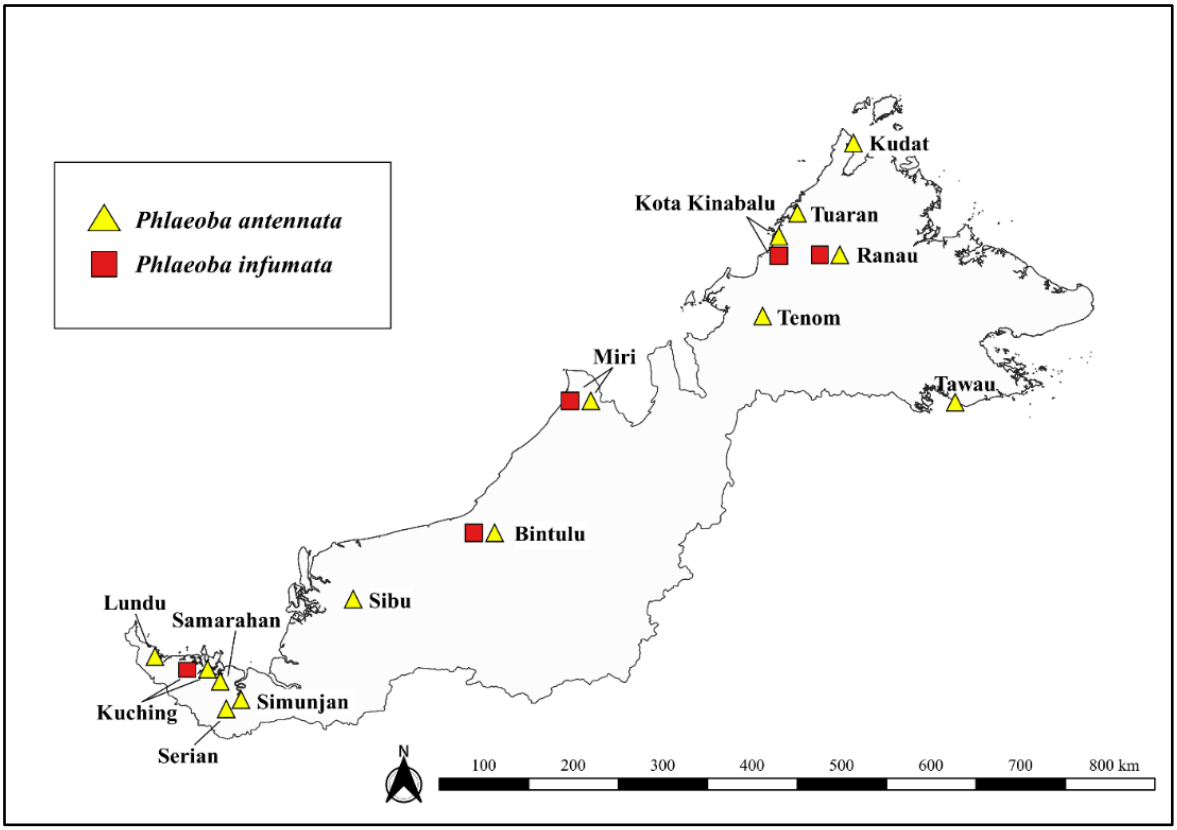


Figure 3.7: Distribution map of subfamily Acridinae in Malaysian Borneo.

Subfamily Catantopinae Brunner von Wattenwyl, 1893

Genus *Apalacris* Walker, 1870

Apalacris varicornis Walker, 1870

Figure 3.8, Figure 3.25

Apalacris varicornis Walker, 1870b: 642; Kirby, 1914: 238; Uvarov, 1921b: 502; Willemse, 1957: 453; Bei-Bienko & Mishchenko, 1963: 265 (eng ver.)

Catantops varicornis Kirby, 1910: 483

Materials examined. 8 specimens (♂: 3, ♀: 5). **BORNEO: EAST MALAYSIA: SARAWAK: Bintulu:** Labang Forest Reserve, 13.I.1985, Manis Lintang, 1♀ (FN.85-0127) (RDID). Jelalong, Sg. Mayop, 28.X.2000, Ento Team, 1♂ (FN.00-1522) (RDID). **Limbang:** Limbang, L. Trading, Camp A, 17.X.1985, Bunsu Buang, 1♀ (FN.85-1446) (RDID). **Miri:** Niah, 22.II.1979, A. A. Hamid, 1♂ (FN.01284) (RDID); 01.IV.1984, Lippa Akeng, 1♂ (FN.84-0518) (RDID). **SABAH: Kota Marudu:** Sub Stesen Serinsim, 22-27.IV.2019, 196 m elevation, 06º17'38.1"N 116º42'28.6"E, Yusilie K., 1♀ (SP/EOR/02050) (SPM). **Ranau:** Nalapak, Sub Stesen Utara, 14-16.XI.2016, Yusilie K., 1♀ (SP/EOR/01993) (SPM). Sub Stesen Monggis, 10.XII.2011, Alt: 360 m, Yusilie K., 1♀ (SP/EOR/01808) (SPM).

Diagnosis. *Apalacris varicornis* is recognised by having the combination of the following characters: a broad yellow spot along the posterior margin on the lateral lobe of pronotum, antennae with white tip, outer face of hind femora yellow with three black bands and inner face of hind femora orange-red.

Description. Male: Body is small to medium, total length 17.32 mm – 18.66 mm. **Colouration:** Body olivaceous green. *Antennae*: Pale to dark brown with white tip. Thorax: Pronotum olivaceous green with broad yellow spot along the posterior margin on lateral lobe of pronotum; sternum uniformly olivaceous green with a tinge of yellow. *Legs*: Outer face of hind femur yellow with three black bands, inner face reddish orange; hind tibia and tarsus dark brown or olivaceous green. *Wings*: Tegmen olivaceous green with yellowish green veins, getting darker brown apically. Abdomen: Uniformly olivaceous green with yellow tinge or rusty dark brown. **Structure:** Body small to medium long and robust. Head: Sub-rectangular in frontal view, frons sub-quadrangular to vertex of head in profile; eyes sub-circular, vertical diameter of eye greater than its horizontal diameter, exceeding the outline

of head, as high as vertex of head laterally, distance from anterior margin of eyes to apex of fastigium less than the horizontal diameter of eye in profile, inter-ocular distance narrower than width of frontal ridge, lateral carinae weakly projected, lacking foveolae; anterior apex of head linear and close to compound eyes, fastigium ridge formed horizontally into isosceles trapezoid with transverse groove cutting through lateral carinae of vertex; apex of fastigium prominently excavated with second depression on vertex of head adjacent to anterior apex of eyes dorsally; frontal ridge of head obliterated below median ocellus; frontal costa between antennae weakly projected forward, slightly arched above median ocellus; frontal costa above frontal ocellus with small and deep punctures, integument between pre-ocular ridge and frontal ridge with irregular punctures. *Antennae*: Longer than the combined length of pronotum and head; filiform-like shaped. Thorax: Prosternal process with simple conical structure, short and stout, apical part of tubercle straight; pronotum long, scutatiform; width of pronotum wider than head, continues to get broader on the metazonal area; prozona as long as metazona; expanding caudally from dorsal view and longitudinal margins parallel with median carina; median carina crossed by three sulci, transverse sulci shallowly impressed on pronotal disc, first and second transverse sulci cutting median carina on dorsum of prozona, median carina distinctly elevated medially forming low ridges, shallow incision on median carina by principal sulcus, lacking lateral carinae; median posterior margin of metazona convexly projected into acute angle; pronotal disc coarsely tuberculated irregularly; dorsum of prozona roughly tuberculated, lateral lobe of prozona distinctly punctured; dorsum of metazona with weakly formed thick ridges forming numerous small pits; posteroventral margin of lateral lobe roundly angular and slightly arched; anterior border of mesosternum straight, mesosternal lobe laterally wider than vertical length, mesosternal interspace elongate with longitudinal length broader than vertical length, inner

posterior corners of lobe roundly angular; metasternal lobe separated medially. *Legs*: Upper carinae of hind femur weakly serrated, lower carinae smooth, basal lobe dorsally longer than vertical length, dorsal and ventral genicular lobe roundly angular distally, distal end of dorsal carina spined, narrowly obtuse-angular; hind tibia lacking outer apical spine, number of spines on outer margin 9-10, distance between first and second spines on inner margin as long as any other inter-spine distance, distal half of hind tibia not obviously broadened towards apex. *Wings*: Tegmen macropterous, male wings developed in contact with each other above abdomen; distal margin round, cell of distal part rectangular. Genitalia: Cerci short triangular, straight, narrowing toward apex, apex of cerci pointed; supra-anal plate long and triangular, convexly projected anteriorly with transverse groove on middle field and deep lateral groove perpendicular to the transverse groove, lacking furcula and smooth without two digitiform tubercles near lateral margins; subgenital plate with simple conical structure, apex not divided, very short, length equal to basal width, gradually tapering toward apex with blunted end dorsally, lacking tubercle at end of apex.

Female: Larger than male, total length 24.04 mm – 30.24 mm. Vestiture and texture as in male. **Colouration:** Body uniformly brown, broad yellow spot along the posterior margin on lateral lobe of pronotum paler in female. *Wings*: Tegmen brownish with very pale and small yellow spots basally extending to the medial area. **Structure:** Mostly resemble male specimens, body robust. Genitalia: Ovipositor curved in profile, dorsal and ventral valves equal in length; dorsal valves convergent, with one apical tooth, lowly serrulate on the superior margin, non-bidentate and lacking notch on apex; ventral valves very narrow, external margins weakly serrated dorsally and weakly constricted laterally in the middle field, external lateral teeth very weakly projected outward; subgenital plate triangularly projected posteriorly in the middle, lacking lateral teeth on posterior margin.

Food plant. Has been reported as minor pest of cacao in Malaysia (Roffey, 1979; COPR, 1982; Willemse, 2001).

Ecology. This species has been reported to live in herby areas and tall grasses near trees in low altitude areas (Roffey, 1979; COPR, 1982; Willemse, 2001; Tan & Kamaruddin, 2016) with 196 m – 360 m elevation.

Distribution. Bangladesh, China, India, Indonesia, Japan, Malaysia, Myanmar, Singapore, Thailand, Vietnam (Roffey, 1979; COPR, 1982; Willemse, 2001; Mahmood et al., 2007; Tan, 2010a, 2010b, 2012; Tan & Kamaruddin, 2016; Cigliano et al., 2021).

Remarks. *Apalacris varicornis* is similar to *Xenocatantops humilis* from a distance by the brownish body colouration, transverse yellow and black hind femoral pattern, and reddish hind tibiae with the exceptions of the obvious yellow marking on the posteroventral lobes of the pronotum, white tips on the antennae, and the absence of the yellow longitudinal stripes from posterior margin of eye compounds to the posterolateral side of the metathoracic disc.

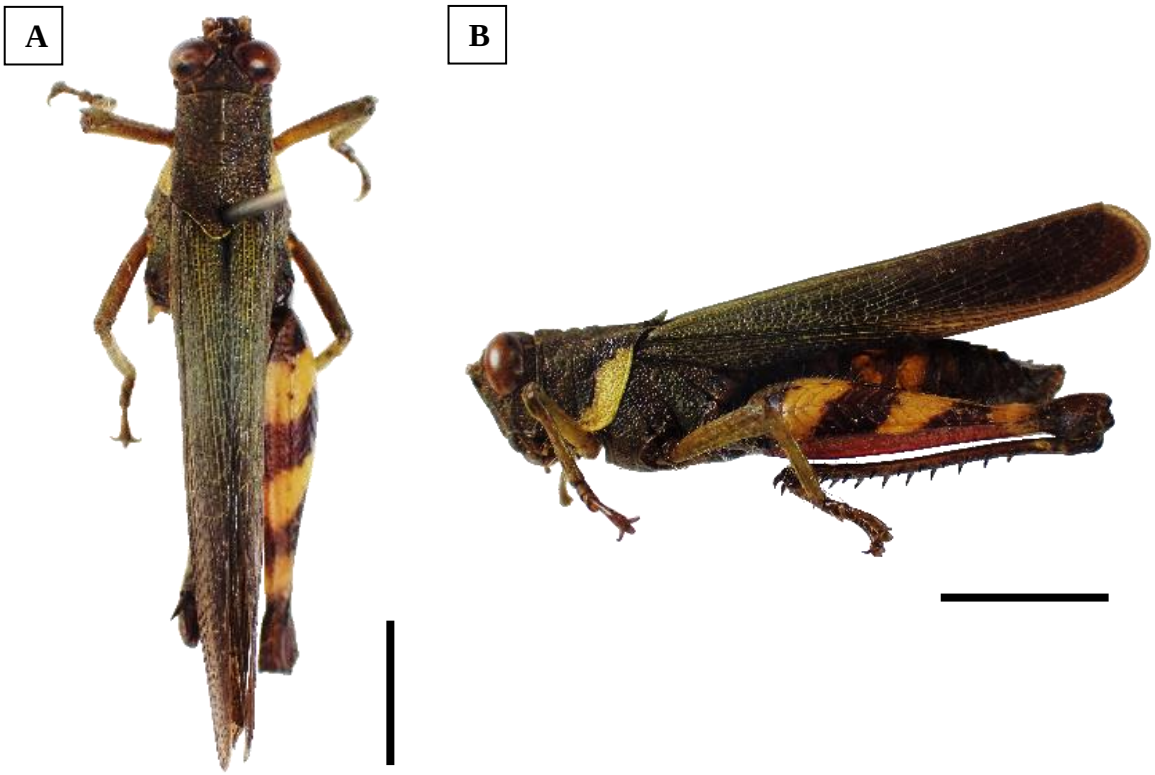


Figure 3.8: *Apalacris varicornis*, ♂. **A.** Dorsal view of type; **B.** Lateral view of type. Scale = 5 mm.

Genus *Coloracris* Willemse, 1938

Diagnosis. Body size medium, body robust; antennae filiform, extending slightly beyond posterior margin of pronotal disc; head slightly reclinate in profile, fastigium of vertex moderately slanted, forming rounded angle with frons; eyes prominent laterally, inter-ocular distance as broad as width of frontal ridge; anterior margin of pronotum slightly rounded, posterior margin of pronotum broadly rounded forming oblique arch, median and lateral carina absent; prosternal process short, straight and conical; anterior margin of mesosternum broadly projected in the middle, mesosternal lobe vertically longer than the lateral width, metasternal interspace almost contiguous in male but separated in female; tegmina reaching apex of abdomen with apex rounded; hind femora short and thick, hind tibiae with 6 to 8 spines on outer margins, without outer apical spine; male supra-anal plate scutate with apex

rounded, cerci curving upwards posteriorly and slightly bifurcated, subgenital plate short and obtuse, broadened toward apex; female supra-anal plate triangular with apex obtuse, ovipositor valves short with equal lengths, apex hooked.

Coloracris azureus Willemse, 1938

Figure 3.9, Figure 3.19

Coloracris azureus Willemse, 1938: 229 (sp. nov.); Willemse, 1957: 415

Materials examined. 1 specimen (♂: 1). **BORNEO: EAST MALAYSIA: SARAWAK: Kuching:** Dulit Range, 22.X.1983, Lippa Akeng, 1♂ (FN.83-1194) (RDID).

Diagnosis. *Coloracris azureus* is recognised by having the following combination of characters: head thick, slightly reclinate backwards; forelegs olivaceous-green; hind tibia cobalt blue, brownish apically; tegmina reaching end of abdomen, bluish with dark brown veins and yellow longitudinal stripes; hindwings bluish.

Description. Female: Unknown. Male: Body small, total length 21.53 mm. **Colouration:** Generally reddish brown. Head: Olivaceous-green; dorsum of head with yellow longitudinal stripes from apex of fastigium to post-occipital margin; yellow transverse stripes from antennal base runs along the margin of compound eyes extending to post-gena. *Antennae*: Green basally, gradually turning to dark brown apically with pale yellow tip on the first three of the flagellums. Thorax: Reddish brown; dorsum of pronotum with two yellow longitudinal stripes, lateral lobe with yellow stripe on each side from anterior margin to posterior margin of pleuron; sternum yellowish brown with reddish brown borders. *Legs*: Forelegs olivaceous-green; coxae yellowish brown; hind femur reddish brown with yellow mark on

pre-genicular lobe; hind tibia brown on basal joint with pale yellow ring, bluish basally, brownish apically; tarsi brown. *Wings*: Tegmen blue with dark brown veins and yellow longitudinal stripes; hindwing cobalt blue. **Structure:** Body small and robust. Head: Slightly reclinate backwards; sub-rectangular in frontal view; frons slightly oblique, sub-triangularly to vertex of head with an angle of over 40 degrees in profile; eyes sub-ovate, vertical diameter equal to horizontal diameter of eye laterally; exceeding the outline of head dorsally; eyes as high as vertex of head in profile; inter-ocular distance same as width of frontal ridge; lacking lateral carinae and foveolae; distance from anterior margin of eyes to apex of fastigium shorter than horizontal diameter of eye in profile; anterior apex of head projecting forward away from eyes; lacking transverse groove at base of fastigium; fastigium not excavated; integument above frontal ocellus lightly punctured; frontal ridge obliterated below median ocellus; frontal costa between antennae slightly projected forward but not forming discernible arch above median ocellus in profile; frons with distinctly thickened ridges. *Antennae*: Extending much beyond pronotum; filiform-like shaped. Thorax: Prosternal process conical, short and small, straight, apex pointed apically; pronotum saddle-shaped, sub-quadrate; width as wide as head, with the exception of the mandible that is slightly broadened dorsally; prozona significantly longer than metazona; expanding caudally and not constricted in the middle; lacking median and lateral carinae; dorsum of pronotum crossed by three sulci with deep incisions by principal and two minor transverse sulci; median posterior margin of metazona smoothly rounded; surface of pronotum irregularly and coarsely carinulated; dorsum of prozona with irregularly wrinkled and thickened ridges, lateral lobe distinctly wrinkled; dorsum of metazona with thickened ridges forming numerous irregular and slightly deep pits; posteroventral margin of lateral lobe broadly rounded with an angle of over 90 degrees, and slightly arched; sternum long; mesosternum

slightly shorter than metasternum; anterior border of mesosternum broadly projected in the middle, mesosternal lobe vertically longer than basal width, mesosternal interspace elongate laterally with basal width broader than vertical length, anterior margin of interspace deeply concave, inner posterior corners of lobe obtusely round; metasternal interspace cordiform, completely contiguous. *Legs*: Upper carinae of hind femur weakly serrated with blunted spines, lower carinae smooth; basal lobe dorsally longer than ventral lobe, dorsal genicular lobe rounded distally, ventral genicular lobe roundly angular apically, distal end of dorsal carina with acutely pointed spine; hind tibia lacking outer apical spine, number of spines on outer margin 7, distance between first and second spines on inner margin as long as any other inter-spine distance, distal half of hind tibia not obviously broadened towards apex without obvious edges running through the spines. *Wings*: Tegmen macropterous; wings developed in contact with each other basally above abdomen; apex rounded; cell of distal part sub-rectangular. Genitalia: cerci thick, simple rod-like shape, curving upwards posteriorly, apex bifurcated; supra-anal plate scutatiform, apex not divided with small tubercle, furcula large, long and slightly curving upwards, smooth and lacking tubercles near lateral margin; subgenital plate apex not divided, very short with vertical length significantly shorter than basal width ventrally, not tapering towards apex with blunted end and lacking tubercle at end of apex; last sternite with two small, pointed tubercles on posterior margins of each sides.

Food plant. Unknown.

Ecology. Primary forest with 762 m altitude (Willemse, 1938, 1957).

Distribution. Malaysia (Borneo) (Willemse, 1938, 1957; Cigliano et al., 2021).

Remarks. Only one male specimen available to be assessed from Sarawak. *Coloracris azureus* shares the same characteristics as *C. coerulescens* by the presence of two yellow spots on the mandible with thick head and face slightly reclinate in profile, with the exceptions on the colouration of fore- and hindwings that are bluish with a yellow longitudinal stripe from the apex to basal vein that extended to the apex of hind femora, and the absence of black insertions with yellow spots.



Figure 3.9: *Coloracris azureus*, ♂. **A.** Dorsal view of type; **B.** Lateral view of type. Scale = 5 mm.

Coloracris coerulescens Willemse, 1938

Figure 3.10, Figure 3.19

Coloracris coerulescens Willemse, 1938: 228; Willemse, 1957: 413

Material examined. 1 specimen (♀: 1). **BORNEO: EAST MALAYSIA: SARAWAK: Miri:** Niah, 20.I.1985, Lippa Akeng, 1♀ (FN.85-0181) (RDID).

Diagnosis. *Coloracris coerulescens* is recognised by the following characters: head thick, slightly reclinate; mandible slightly reclinate towards prosternal process; forelegs dark olivaceous green; hind femora with reddish-orange pre-genicular ring, apical spine of tarsi long; forewings with yellow transverse band not reaching end of tegmina, hindwings bluish.

Description. Male: Unknown. Female: Body moderately long, total length 27.31 mm. **Colouration:** Body uniformly black. Head: Dorsum of head with two yellow longitudinal stripes from lateral ocellus to post-occipital margin; yellow thin stripes transversely run from antennal base along the lower margin of eyes extending to post-gena on both sides, not reaching frontal costa anteriorly; frontal ridge under median ocellus with a yellow spot; yellow spots on each side near clypeal margin; labrum with a yellow spot on each side; mandibles with yellow spots on anterior and posterior margins on each side. *Antennae*: Yellowish brown on outer side, brownish black on inner sides of scapus. Thorax: Dorsum of pronotum with two thin longitudinal yellow stripes from anterior to posterior margins; sides of lateral lobe with thin yellow longitudinal stripes not reaching posteroventral margin of lobes. *Legs:* Coxae black with yellow spot; femora and tibiae of forelegs olivaceous green, tarsi brown; outer face of hind femur seaweed green, lower marginal area cobalt blue, inner face reddish brown, hind knees dark brown to black with reddish-orange pre-genicular ring;

hind tibia and tarsi brownish black. *Wings*: Tegmen brownish black with yellow longitudinal stripes not reaching apex of tegmina; hindwing bluish. **Structure:** Body moderately long and robust. Head: Slightly reclinate towards pronotum; sub-rectangular in frontal view, broader apically on the mandibular area, frons not oblique, slightly right angular to vertex of head in profile; eyes sub-circular, vertical diameter longer than horizontal diameter of eye in profile, not exceeding outline of widest width of head dorsally, eyes as high as vertex of head laterally, inter-ocular distance same as width of frontal ridge, lacking lateral carinae and foveolae, distance from anterior margin of eyes to apex of fastigium much shorter than horizontal diameter of eye in profile, anterior apex of head projecting forward away from eyes, lacking transverse groove at base of fastigium, fastigium not excavated; integument above frontal ocellus lightly punctured, frontal ridge obliterate above median ocellus; frontal costa between antennae projected forward forming discernible arch above median ocellus in profile; frons with distinctly thickened ridges forming irregular pits. Thorax: Prosternal process conical, compressed laterally, short and straight; pronotum saddle-shaped; head slightly wider than pronotum dorsally, prozona longer than metazona; sub-cylindrical dorsally and lightly constricted in the middle; lacking median and lateral carinae, dorsum of pronotum crossed by three sulci with shallow impression by principal and minor transverse sulci; median posterior margin of metazona smoothly rounded, anterior margin slightly arched; surface of pronotum coarsely and irregularly carinulated and punctured; dorsum of prozona and metazona with irregular and thickened ridges forming shallow pits, lateral lobe distinctly wrinkled; posteroventral margin of lateral lobe broadly round and slightly arched; sternum metasternum lightly broader than mesosternum; anterior border of mesosternum broadly projected in the middle, mesosternal lobe laterally wider than vertical length; mesosternal interspace trapeziform, wide with basal width as long as vertical length, anterior

margin of interspace lightly concave, inner posterior corner of lobe angularly round; metasternal interspace lobiform, almost reduced and contiguous. *Legs*: Upper carinae of hind femur prominently serrated with weakly pointed spine, lower carinae smooth; basal lobe with equal length of dorsal and ventral lobes, dorsal and ventral genicular lobe roundly angular distally, distal end of dorsal carina with obtuse-angular spine; hind tibia without outer apical spine, number of spines on outer margin 6, distance between first and second spines on inner margin as long as any other inter-spine distance, distal half of hind tibia not obviously broadened towards apex without obvious edges running through the spines. *Wings*: Tegmen macropterous, apex of tegmina reaching tip of abdomen; wings developed in contact with each other basally above abdomen; apex rounded; cell of distal part sub-rectangular. Genitalia: Ovipositor short and thick, strongly curved posteriorly in profile, dorsal valves slightly longer than ventral valves laterally; dorsal valves converging dorsally, with one apical tooth, very faintly serrated to almost smooth on the superior margin, non-bidentate and lacking notch on apex; ventral valves narrow, very weakly serrated on posterior margin, external apical tooth widely pointed, constricted laterally in the middle field; subgenital plate triangularly projected posteriorly in the middle, lacking lateral teeth on posterior margin of the plate.

Food plant. Unknown.

Ecology. Primary forest with 762 m elevation and along the river (Willemse, 1938, 1957).

Distribution. Malaysia (Borneo) (Willemse, 1938, 1957; Cigliano et al., 2021).

Remarks. Only one female specimen available. *Coloracris coerulescens* bears the same resemblance to *C. azureus* by the cylindrical pronotal disc that is marginally longer than the length of the head, with slightly rounded anterior margin and broadly rounded posterior

margin. *Coloracris coerulescens* can be distinguished from *C. azureus* by the presence of the black insertion with yellow spots on coxae of forelegs and brownish black hind tibia and hind tarsi. This specimen does not agree with the description on the type specimen described by Willemse (1938, 1957) on the account of the colouration of the hind femora. Willemse (1938, 1957) described the hind femora to be "coral red, area infero interna dirty yellow, knee black with an indication of a lighter, reddish coloured, praegenicular ring" as opposed to the "outer face seaweed green, lower marginal area cobalt blue, inner face reddish brown, hind knees dark brown with reddish-orange pre-genicular ring" defined from the current specimen.



Figure 3.10: *Coloracris coerulescens*, ♀. **A.** Dorsal view of type; **B.** Lateral view of type. Scale = 5 mm.

Coloracris sp.

Figure 3.11, Figure 3.19

Material examined. 1 specimen (♂: 1). **BORNEO: EAST MALAYSIA: SARAWAK: Miri:** Pulong Tau National Park, 22.V.2012, ATL, Ento Team, 1♂ (PTNP0176) (RDID).

Diagnosis. *Coloracris* sp. is recognised by the following combination of characters: antennae reaching apex of abdomen, tip of antennae white; head thick, slightly reclinate in profile; forelegs olivaceous-green; hind femora olivaceous green with inner face yellowish green medially, hind knees black with yellowish pre-genicular ring; forewings with yellow transverse band reaching end of tegmina, hindwings carmine-red.

Description. Female: Unknown. Male: Body small, total length 21.32 mm. **Colouration:** Body uniformly black. Head: Dorsum of head with two yellow longitudinal stripes runs from apex of fastigium along the margin of eyes to post-occipital margin; yellow thin transverse stripes runs from antennal base along the lower margin of eyes extending to post-gena on both sides, not reaching frontal costa anteriorly, with a yellow spot under median ocellus and yellow spots on each sides near clypeal margin; labrum with yellow spots on each side and two spots on anterior and posterior margin of the mandible respectively; palpi yellow. *Antennae*: Scapus dark brown, outer margin with yellow stripe; pedicel dark green to brownish; flagellum black with pale white tip. Thorax: Dorsum of pronotum with two thin longitudinal yellow stripes from anterior to posterior margins; sides of lateral lobe with thin yellow longitudinal stripes not reaching posteroventral margin of lobes, episternum yellow, pleuron with yellow stripes. *Legs*: Coxae black with yellow spot; femora and tibiae of forelegs olivaceous green, yellowish brown; hind femur olivaceous green, inner median face bright yellowish green, hind knees black with yellowish pre-genicular ring; hind tibia and

tarsi dark brown. *Wings*: Tegmen brownish black basally, brown apically with yellow longitudinal lines from basal to apex of tegmina; hind wing carmine-red. **Structure:** Body small and robust. Head: Slightly reclinate towards pronotum; long, sub-rectangular in frontal view, frons oblique, sub-triangularly to vertex of head with an angle of over 40 degrees in profile; eyes long oval, vertical diameter greater than horizontal diameter of eye in profile, slightly exceeding the outline of head dorsally, eyes as high as vertex of head in profile, inter-ocular distance same as width of frontal ridge, lacking lateral carinae and foveolae, distance from anterior margin of eyes to apex of fastigium much shorter than horizontal diameter of eye in profile, anterior apex of head projecting forward away from eyes, lacking transverse groove at base of fastigium, fastigium not excavated; integument above frontal ocellus with wide and deep punctures, frontal ridge obliterated below median ocellus; frontal costa between antennae projected forward forming discernible arch above median ocellus in profile; frons with thickened ridges forming deep pits. *Antennae*: Extending beyond pronotum, almost reaching tip of abdomen; filiform-like shaped. Thorax: Prosternal process conical; compressed laterally; moderately long, apex almost reaching palpi when folded; straight; apex rounded; pronotum saddle-shaped; mandible very slightly broader than width of pronotum dorsally; prozona significantly longer than metazona; sub-cylindrical dorsally and not constricted in the middle; lacking median and lateral carinae, dorsum of pronotum crossed by three sulci with shallow incision by principal and minor transverse sulci; median posterior margin of metazona smoothly rounded, anterior margin slightly arched; surface of pronotum coarsely and irregularly carinulated and punctured; dorsum of prozona and metazona with irregular and thickened ridges forming deep pits, lateral lobe distinctly wrinkled; posteroventral margin of lateral lobe roundly angular with an angle of over 90 degrees and slightly arched; sternum long; anterior border of mesosternum broadly projected

in the middle; mesosternal lobe vertically longer than basal width; mesosternal interspace trapeziform, wide with basal width as long as vertical length, anterior margin of interspace strongly concave, inner posterior corner of lobe angularly round; metasternal interspace triangular and contiguous. *Legs*: Upper carinae of hind femur weakly serrated, lower carinae smooth; basal lobe dorsally longer than ventral length, dorsal and ventral genicular lobe roundly angular distally, distal end of dorsal carina narrowly obtuse-angular; hind tibia without outer apical spine, number of spines on outer margin 6, distance between first and second spines on inner margin as long as any other inter-spine distance, distal half of hind tibia not obviously broadened towards apex without obvious edges running through the spines. *Wings*: Tegmen macropterous, apex of tegmina reaching tip of abdomen; wings developed in contact with each other basally above abdomen; apex rounded; cell of distal part sub-rectangular. Genitalia: Cerci narrowing towards apex, elongated conical, straight in profile, apex rounded with one small tooth on the inner side; supra-anal plate scutatiform, apex not divided with moderately long tubercle, furcula large, long and slightly curving upwards, lacking tubercles near lateral margin; subgenital plate apex not divided, very short with vertical length significantly shorter than basal width ventrally, not tapering towards apex with blunted end, lacking tubercle at end of apex; last sternite with two small, pointed tubercles on posterior margins of each sides.

Food plant. Unknown.

Ecology. Unknown.

Distribution. Malaysia (Borneo) (Willemse, 1938, 1957; Cigliano et al., 2021).

Remarks. Only one male specimen available for redescription. *Coloracris* sp. shared the same characteristics as *C. azureus* and *C. coerulescens* by the presence of bright yellow

transverse bands from anterior margin of head to the posterior margin of pronotal disc and from the antennal base running on the lower margin of compound eyes to the postero-lateral margins of pronotal disc. This species can be distinguished by the colour and pattern on the hind femora and the colour of its hindwings. The light olivaceous green hind femora with yellow pre-genicular rings accompanied with black hind knees, as well as bright carmine-red hindwings uniquely defined this species.

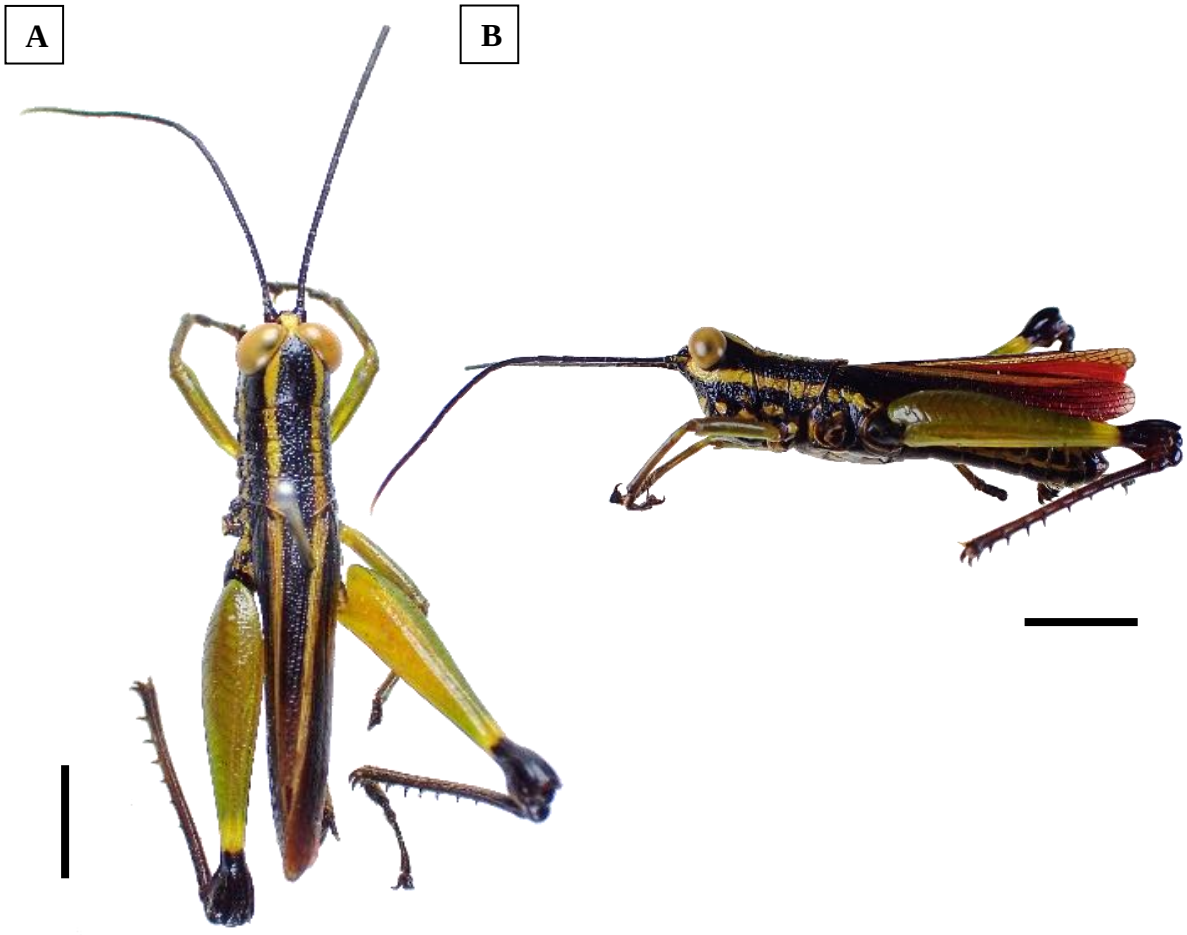


Figure 3.11: *Coloracris* sp., ♂. **A.** Dorsal view of type; **B.** Lateral view of type. Scale = 5 mm.

Genus *Craneopsis* Willemse, 1933

Craneopsis olivacea Ramme, 1941

Figure 3.12, Figure 3.19

Craneopsis olivacea Ramme, 1941: 86; Willemse, 1956: 112

Material examined. 1 specimen (♂: 1). **BORNEO: EAST MALAYSIA: SARAWAK: Miri:** Niah, 23.VIII.1986, Manis Lintang, 1♂ (FN.86-0196) (RDID).

Diagnosis. *Craneopsis olivacea* is recognised by the following combination of characters: body stout; head and pronotum with equal width from dorsal view, head with two yellow longitudinal bands from vertex of head to posterior margin of pronotal disc; first pair of fore femora with acute spine on the ventral margin basally; tegmina not reaching the end of the abdomen, without yellow longitudinal bands but unicolourous green; fore femora shorter and thicker than fore tibiae.

Description. Female: Unknown. Male: Body moderately long, total length 27.67 mm. **Colouration:** Body greenish brown. Head: Dorsum of head with two yellow lateral stripes from the anterior margin of eyes to post-occipital margin; thick yellow stripes transversely run from antennal base along the lower margin of eyes extending to post-gena on both sides, not reaching frons and frontal costa anteriorly; mandible jade green. *Antennae*: Scapus and pedicel dark green basally, gradually darken to brown or black apically. Thorax: Dorsum of pronotum with two yellow lateral bands from anterior margin, not reaching posterior margin of pronotal disc; lateral lobe with yellow bands from anterior margin of lobe to posterior margin of pleuron. *Legs*: Hind femur yellowish green, upper and lower carina dark green, hind knees dark blue to almost black; hind tibia very pale blue to almost hyaline, dark cobalt

blue basally with very thin, pale-yellow ring; tarsi pale brown. *Wings*: Tegmen pale yellowish green, margins hyaline. **Structure:** Body moderately long and robust. Head: Sub-hexagonal in frontal view, frons right angular to vertex of head in profile; eyes oval, vertical diameter as long as horizontal diameter of eye laterally, not exceeding the outline of head dorsally, eyes slightly lower than vertex of head in profile, inter-ocular distance wider than width of frontal ridge, lacking foveolae and lateral carinae, distance from anterior margin of eyes to apex of fastigium much shorter than horizontal diameter of eye in profile, anterior apex of head slightly projecting forward away from eyes, lacking transverse groove at base of fastigium, fastigium not excavated; integument above frontal ocellus lightly punctured, frontal ridge obliterate below median ocellus; frontal costa between antennae not obviously projected forward forming slightly discernible arch below median ocellus in profile; frons thickly ridged and very lightly punctured. *Antennae*: Longer than the combined length of head and pronotum, filiform-like shaped. Thorax: Prosternal process cylindrical, short and straight, compressed anteriorly, slightly tapering basally, flat apically; pronotum saddle-shaped; thick, longer than head but width as wide as head dorsally, prozona significantly longer than metazona, expanding caudally from dorsal view and not constricted in the middle; median carina barely discernible and not elevated dorsally, straight and present as low ridges in profile, dorsum of pronotum crossed by three sulci with deep impression by principal and minor transverse sulci, lacking lateral carinae; median posterior margin of metazona broadly angular; surface of pronotum punctured and irregularly carinulated; dorsum of prozona and lateral lobe distinctly punctured; dorsum of metazona with distinctly thickened ridges; posteroventral margin of lateral lobe roundly angular with an angle with slightly more than 90 degrees and slightly arched; anterior margin of pronotal disc thickened forming slightly deep groove before the first transverse sulcus, lateral and posterior margin

of pronotal disc slightly thickened but not forming transverse grooves; anterior border of mesosternum slightly arched in the middle, mesosternal lobe with vertical length significantly longer than lateral width, mesosternal interspace elongate with vertical length longer than basal width, resembling hour-glass shape, anterior margin of interspace deeply concave and slightly pushed inside, inner posterior corners of lobe obtusely round; metasternal lobe completely contiguous. *Legs*: Hind femur thick and short, constricted on hind knee; upper carinae prominently serrated, lower carinae very weakly serrated; basal lobe slightly longer dorsally than its ventral lobe, dorsal genicular lobe rounded apically, ventral genicular lobe acutely spined distally, distal end of dorsal carina rounded; hind tibia with outer apical spine, number of spines on outer margin 9, distance between first and second spines on inner margin as long as any other inter-spine distance, distal half of hind tibia slightly broadened towards apex without obvious edges running through the spines. *Wings*: Tegmen brachypterous, apex of wing not reaching tip of abdomen and not covering cerci dorsally, male wings developed in contact with each other basally above abdomen; surface of tegmen with irregular sub-quadrangular punctures; apex rounded; cell of distal part sub-quadrangular. Genitalia: Cerci narrowing towards apex, elongated conical, compressed laterally, straight in profile, apex resembling a right angle dorsally, acutely pointed apically; supra-anal plate scutatiform, apex not divided with moderately long tubercle, with two digitiform tubercles near lateral margin, lacking furcula; subgenital plate simple conical structure in ventral view, apex not divided, very short with vertical length less than the length of basal width, not tapering and slightly broadened towards apex with end truncated, lacking tubercle at end of apex.

Food plant. The species was found feeding on leaves of lemon tree (*Citrus limon*) (Tan & Wahab, 2018).

Ecology. Primary forest (Willemse, 1957; Tan & Wahab, 2018).

Distribution. Brunei, Malaysia (Willemse, 1957; Tan & Wahab, 2018; Cigliano et al., 2021).

Remarks. Only one male specimen available for redescription. This is the only known species from the collections examined that possessed posterior spines on the basal margin of coxae located on the fore femora. *Craneopsis olivacea* can also be distinguished based on its body size which is noticeably stouter and shorter with tegmina barely reaching the end of the abdomen. The femora are visibly thicker in comparison with species of the same subfamily examined from the collections. *C. olivacea* was noted to be endemic to Borneo.

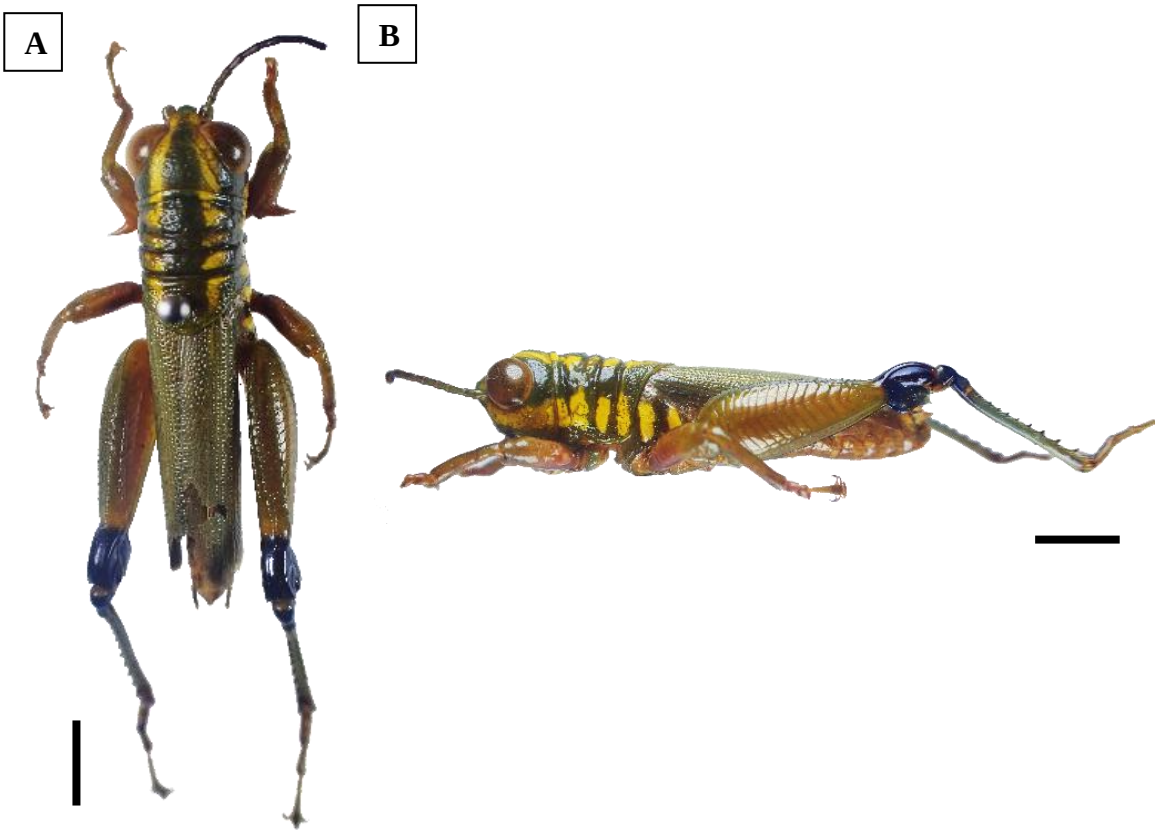


Figure 3.12: *Craneopsis olivacea*, ♂. **A.** Dorsal view of type; **B.** Lateral view of type. Scale = 5 mm.

Genus *Meltripata* Bolivar, 1923

Meltripata sp. 1

Figure 3.13, Figure 3.19

Materials examined. 1 specimen (♂: 1). **BORNEO: EAST MALAYSIA: SARAWAK: Samarahan:** Kg. Sebayor, 12.III.2016, Lim Lee Lian, 1♂ (RDID).

Diagnosis. *Meltripata* sp. 1 is recognised by having the following combination of characters: eyes very prominent; wings brachypterous reaching the anterior margin of supra-anal plate; distance of the last spine on outer area of hind tibia farther any other outer-spine distance; male cerci thick and longer than supra-anal plate.

Description. Female: Unknown. Male: Body small, total length 24.79 mm. **Colouration:** Body green and brownish yellow. Head: Green; dorsum of head with two yellow longitudinal stripes runs from the apex of fastigium, covering the area on lateral ocellus, along the upper margin of eyes to post-occipital margin; yellow transverse stripes running from antennal base along the lower margin of eyes extending to post-gena on both sides, not reaching frontal costa anteriorly, with a small pale yellow spot under median ocellus; two pale yellow spots on anterior margin of clypeus medially; black spots on each sides of anterior margin of mandible and clypeal margin; labrum pale yellow; palpi mint green. *Antennae*: Green basally; black apically. Thorax: Dorsum of pronotum with two yellow longitudinal stripes from anterior to posterior margins; sides of lateral lobe with yellow longitudinal stripes; pleuron with faded yellow stripes; prosternal process mint green apically; sternum green with a tinge of yellow. *Legs*: Forelegs green; hind femur uniformly green; hind knee orange-red, black mark on dorsal genicular lobe, with a tinge of yellow ring

on pre-genicular lobe; hind tibia olivaceous green, outer face reddish orange basally; tarsi green with brownish tinge. *Wings*: Tegmen dark brown to almost black, veins yellow. **Structure:** Body small and robust. Head: Sub-rectangular in frontal view; frons oblique, sub-triangularly to vertex of head with an angle of over 40 degrees in profile; eyes sub-ovate, vertical diameter equal to horizontal diameter of eye in profile, significantly prominent, exceeding the outline of head dorsally, eyes as high as vertex of head laterally, inter-ocular distance wider than width of frontal ridge, lacking lateral carinae and foveolae; distance from anterior margin of eyes to apex of fastigium much shorter than horizontal diameter of eye in profile, anterior apex of head projecting forward away from eyes, lacking transverse groove at base of fastigium, fastigium not excavated; integument above frontal ocellus with wide punctured resembling the surface of a golf ball and deep lateral groove formed by thick frontal ridge, frontal ridge obliterated below ocellus; frontal costa between antennae slightly projected forward, not forming discernible arch above median ocellus in profile; frons with thickened ridges forming deep pits. *Antennae*: Extending beyond pronotum; filiform-like shaped. Thorax: Prosternal process cylindrical, short and straight, compressed laterally, flat apically; pronotum saddle-shaped, wide and short; as wide as width of head dorsally; prozona significantly longer than metazona; sub-cylindrical dorsally and not constricted in the middle; lacking median and lateral carinae; dorsum of pronotum crossed by three sulci with shallow incision by principal and minor transverse sulci; median posterior margin of metazona smoothly rounded; surface of pronotum irregularly carinulated and punctured; dorsum of prozona and metazona with irregular and thickened ridges forming numerous pits, lateral lobe distinctly wrinkled; posteroventral margin of lateral lobe roundly angular with an angle of 90 degrees; sternum long, length of mesosternum slightly shorter than metasternum; anterior border of mesosternum slightly arched in the middle; mesosternal lobe

vertically longer than basal width; mesosternal interspace trapeziform, wide with basal width as long as vertical length, anterior margin of interspace slightly concave, inner posterior corners of lobe obtusely round; metasternal interspace completely contiguous. *Legs*: Upper carinae of hind femur prominently serrated, lower carinae smooth; basal lobe dorsally longer than ventral length, dorsal genicular lobe round distally, ventral genicular lobe roundly angular distally, distal end of dorsal carina rounded apically; hind tibia with outer apical spine, number of spines on outer margin 6, distance of the last spine on outer area of hind tibia farther any other outer-spine distance, distance between first and second spines on inner margin as long as any other inter-spine distance, distal half of hind tibia not obviously broadened towards apex without obvious edges running through the spines. *Wings*: Tegmen brachypterous, apex of tegmina reaching anterior margin of supra-anal plate; wings developed in contact with each other basally above abdomen; apex rounded; cell of distal part sub-rectangular. Genitalia: Cerci thick, narrowing towards apex, elongated conical, straight in profile, apex acutely pointed; supra-anal plate triangular, apex not divided, lateral margin with two small tubercles, lacking furcula, sub-triangular groove basally, transverse groove on sides of middle field, tubercles on both sides of lateral margins on the middle field; subgenital plate simple conical structure, apex not divided, very short with basal width as long as vertical length ventrally, gradually tapering towards apex and slightly pointed, tubercles at end of apex short.

Food plant. Unknown.

Ecology. Unknown.

Distribution. Malaysia (Borneo) (Cigliano et al., 2021).

Remarks. Only one male specimen available for redescription. *Meltripata* sp. 1 is a colourful species and one of seven species examined possessing brachypterous wings. The eye is truly prominent as it is wider than the width of head and pronotum from dorsal view and it is the only species with clear venation of wings. Due to the truncated wings, male cerci and subgenital plate can be seen from dorsal view. This species does not hold any similarity with other species examined.

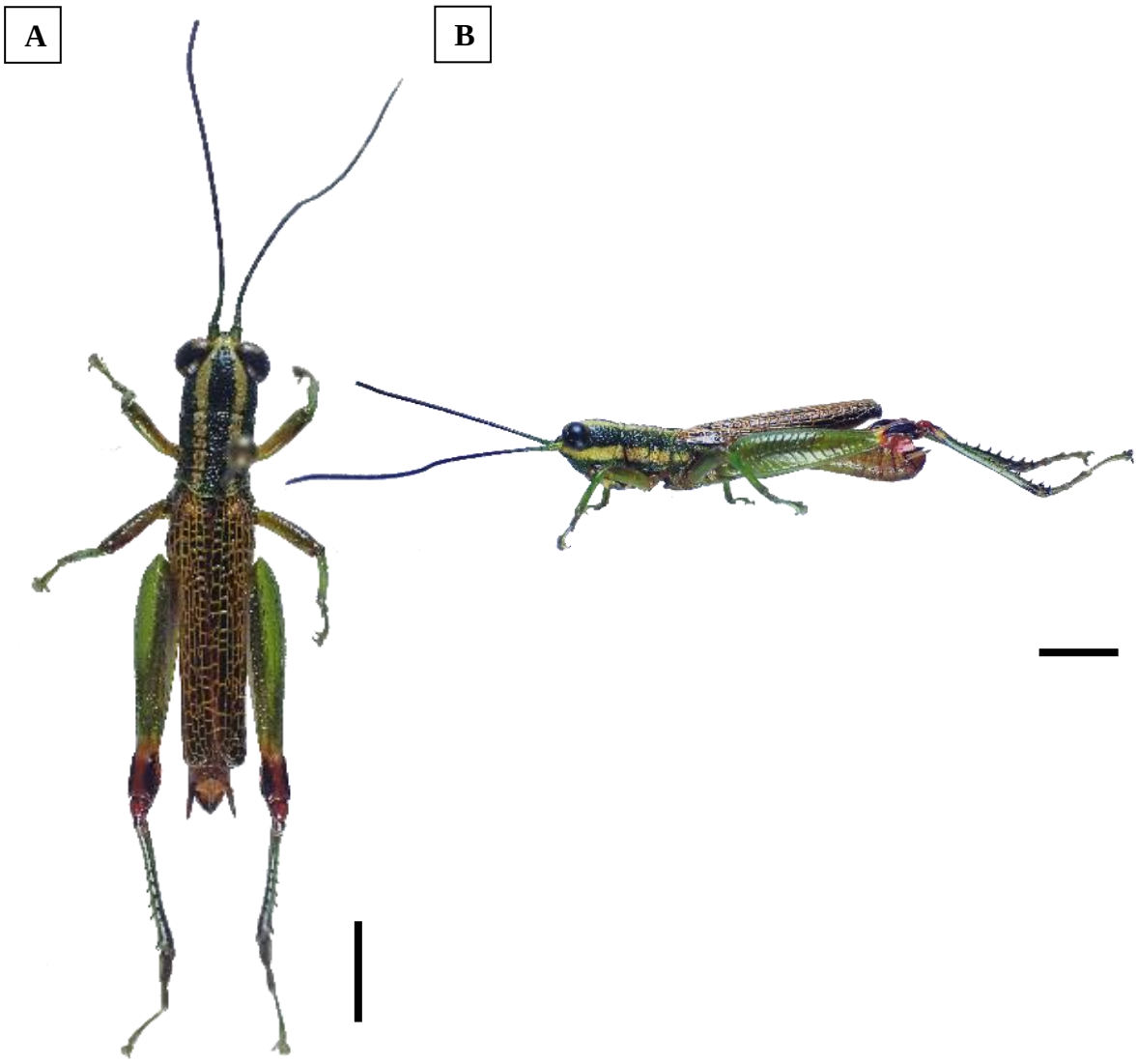


Figure 3.13: *Meltripata* sp. 1, ♂. **A.** Dorsal view of type; **B.** Lateral view of type. Scale = 5 mm.

Meltripata sp. 2

Figure 3.14, Figure 3.19

Materials examined. 1 specimen (♀: 1). **BORNEO: EAST MALAYSIA: SARAWAK: Limbang:** Gunung Murud, 05.V.2003, F. Abang & C.J. Laman, 1♀ (UIRC).

Diagnosis. *Meltripata* sp. 2 is recognised by having the following combination of characters: head thick and slightly recline backwards; dorsum of pronotum crossed with deep impression by four transverse sulci; wings brachypterous not reaching anterior margin of supra-anal plate, uniformly navy blue with yellow longitudinal stripes dorsally, red apically; fore femora red; hind tibia navy blue.

Description. Male: Unknown. Female: Body small, total length 19.43 mm. **Colouration:** Uniformly deep yellow, almost mustardy-yellow, with black marks on grooves of body. Head: Dorsum of head black with black stripes along the margin of compound eyes, yellow longitudinal stripes from apex of fastigium runs along the anterior margin of eye and not reaching post-occipital margin; frontal view of head burnt orange with black markings on grooves of frontal costa, frons, clypeal, mandibular, and labial margins. *Antennae*: Scapus and pedicel yellowish green; flagellum seaweed green basally, gradually turning black apically with pale yellow tip. Thorax: Pronotum mustard yellow with black marking on grooves of transverse sulci; sternum mesosternal lobe and interspace black; metasternal groove and interspace black. *Legs*: Fore femur red, genicular lobe green; fore tibia brown; hind femur greenish yellow with green ring on pre-genicular lobe and pale brown dorsal genicular lobe; hind tibia navy blue; tarsi pale cobalt blue with pale brown claws. *Wings*: Tegmen uniformly dark blue with yellow longitudinal stripes dorsally, red apically. **Structure:** Body small and robust. Head: Slightly reclinate backwards; sub-rectangular in

frontal view; frons slightly right-angular to vertex of head with an angle of almost 90 degrees in profile; eyes sub-circular, vertical diameter slightly greater than horizontal diameter of eye in profile; barely prominent, not exceeding the outline of head dorsally; eyes as high as vertex of head laterally; inter-ocular distance same as width of frontal ridge; lacking lateral carinae and foveolae; distance from anterior margin of eyes to apex of fastigium shorter than horizontal diameter of eye in profile; anterior apex of head projecting forward away from eyes; lacking transverse groove at base of fastigium; fastigium not excavated; integument above frontal ocellus lightly and sparsely punctured with one deep, slightly longitudinal pit above frontal ocellus, deep longitudinal groove below frontal ocellus not reaching clypeal margin; frontal ridge obliterated below median ocellus; frontal costa between antennae slightly projected forward, not forming discernible arch above median ocellus in profile; frons smooth with only wide sub-longitudinal groove not reaching clypeal margin. *Antennae*: Extending much beyond pronotum; filiform-like shaped. Thorax: Prosternal process conical, short and straight, compressed laterally, apex pointed apically; pronotum saddle-shaped, sub-squared, short with length as long as head vertically; width as wide as head dorsally; prozona longer than metazona; slightly expanding caudally and faintly constricted in metazonal area; lacking median and lateral carinae; dorsum of pronotum crossed by four sulci with deep incision by principal and three minor transverse sulci; median posterior margin of metazona smoothly rounded; dorsum of prozona and lateral lobe smooth with no pattern; dorsum of metazona with thickened ridges forming numerous small pits; posteroventral margin of lateral lobe roundly angular with an angle of slightly more than 90 degrees; sternum anterior border of mesosternum broadly projected in the middle, mesosternal lobe vertically longer than basal width, mesosternal interspace resembling wide hour-glass shape, with basal width as long as vertical length, anterior margin of interspace

deeply concave, inner posterior corners of lobe angularly round; metasternal interspace sub-triangular, completely contiguous. *Legs*: Coxae of first pair of legs with anterior margin projected into acutely pointed spine curving downwards; upper carinae of hind femur prominently but weakly serrated with blunted spines, lower carinae smooth; basal lobe dorsally longer than ventral length, dorsal and ventral genicular lobe rounded distally, distal end of dorsal carina with acutely pointed spine apically; hind tibia lacking outer apical spine, number of spines on outer margin 6, distance between first and second spines on inner margin slightly longer than any other inter-spine distance, distal half of hind tibia not obviously broadened towards apex without obvious edges running through the spines. *Wings*: Tegmen brachypterous, apex of tegmina not reaching anterior margin of supra-anal plate; wings developed in contact with each other basally above abdomen; apex rounded; cell of distal part sub-rectangular. Genitalia: Ovipositor short and thick, curved posteriorly in profile, dorsal valves as long as ventral valves laterally; dorsal valves converging dorsally, with one apical tooth, very weakly serrated on the superior margin, non-bidentate and lacking notch on apex; ventral valves wide, weakly serrulate on posterior margin, external apical tooth pointed obtuse-angularly pointed, slightly constricted laterally in the middle field; subgenital plate triangularly projected broadly in the middle, lacking lateral teeth on posterior margin of the plate.

Food plant. Unknown.

Ecology. Unknown.

Distribution. Malaysia (Borneo) (Cigliano et al., 2021).

Remarks. Only one female specimen available. Pronotum is immensely sculpted, transverse sulci cutting across the pronotal disc is very pronounced causing deep impression from

lateral view. Wings truncated with ovipositor valves and subgenital plate clear from dorsal view, similar to *Meltripata* sp. 1. Fore and mid femora with bright red colour, apical region of tegmina with reddish hue. Both *Meltripata* sp. 1 and *Meltripata* sp. 2 do not hold any similarity with other species from the collections.

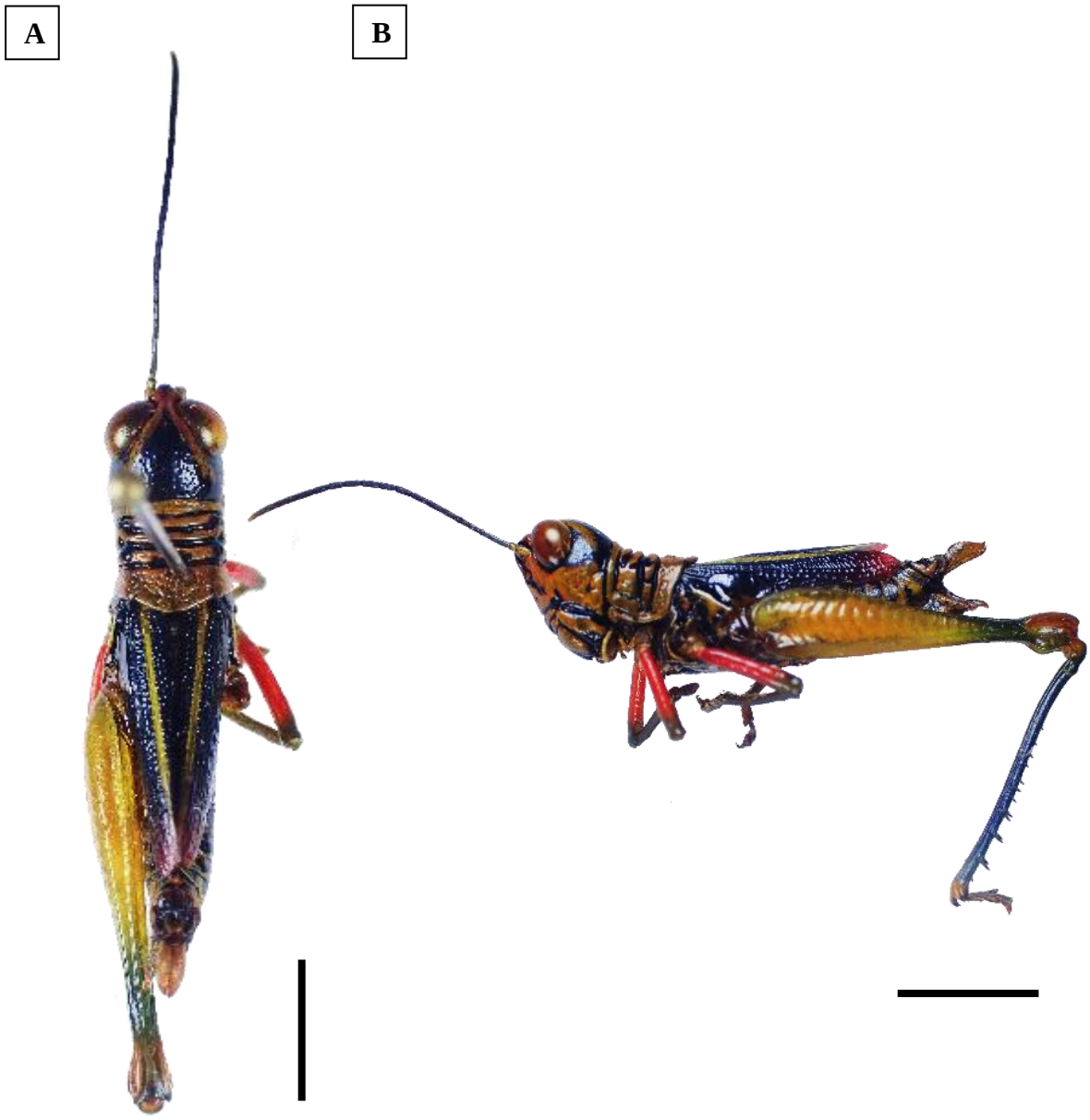


Figure 3.14: *Meltripata* sp. 2, ♀. **A.** Dorsal view of type; **B.** Lateral view of type. Scale = 5 mm.

Genus *Perakia* Ramme, 1929

Perakia borneensis Willemse, 1936

Figure 3.15, Figure 3.19

Perakia borneensis Willemse, 1936: 15; Rehn, 1944: 84; Willemse, 1956: 66

Materials examined. 2 specimens (♂: 2). **BORNEO: EAST MALAYSIA: SARAWAK: Miri:** Niah, 18.I.1985, Lippa Akeng, 1♂ (FN.85-0224) (RDID). **SABAH: Tawau:** Kuamut, Gunung Rara Forest Reserve, 5-14.XII.1996, caught by light trap, Entomology Unit, 1♂ (ORT-2733) (UMS). Tawau Hill Park, 24.XI.2000, Suati S., 1♀ (OR/00/00633) (SPM).

Diagnosis. *Perakia borneensis* can be recognised by the following combination of characters: frontal ridge narrowed down the antennal base and dissolved into the sculpturation after median ocelli; prozona twice the length of metazona, median and lateral carinae of pronotal disc indistinct; mesosternal lobes with X-shaped interspace and distinct median sulcus; abbreviated wings, reaching a little bit to the middle of abdomen, overlapping in the middle; hind femora not reaching tip of abdomen.

Description. Female: Unknown. Male: Body moderately long, total length 32.66 mm – 33.21 mm. **Colouration:** Body yellowish brown with irregular dark spots distributed unevenly throughout body. *Antennae*: Pale to dark brown. *Legs*: Hind femur yellowish brown with very faint transverse bands, hind knee olivaceous green to dark brown; hind tibia brown basally, gradually turn to dark red apically, spines with black tips; tarsi yellowish brown. *Wings*: Tegmen olivaceous green to dark brown, hyaline apically; tegminal veins bright yellow. **Structure:** Body moderately long and robust. Head: Trapeziform in frontal view; frons right angular to vertex of head in profile; eyes long oval, vertical diameter longer

than horizontal diameter of eye laterally, slightly exceeding the outline of head dorsally, eyes as high as vertex in profile, inter-ocular distance slightly narrower than width of anterior margin of frontal ridge, lacking foveolae and lateral carinae, distance from anterior margin of eyes to apex of fastigium much shorter than horizontal diameter of eye in profile, anterior apex of head linear and close to compound eyes forming horizontally elongated isosceles trapezoid, lacking transverse groove at base of fastigium, fastigium not excavated; integument above frontal ocellus with wide and deep punctures, frontal ridge obliterated bellow median ocellus; frontal costa between antennae not obviously projected forward forming slightly discernible arch below frontal ocellus in profile; frons with distinct wrinkles and thickened ridges. *Antennae*: Longer than the combined length of head and pronotum, filiform-like shaped. Thorax: Prosternal process cylindrical, very short and straight, compressed laterally, flat apically; pronotum saddle-shaped; much longer than head but width as wide as head dorsally, prozona significantly longer than metazona, sub-cylindrical from dorsal view and not constricted in the middle; lacking median carina, dorsum of pronotum crossed by three sulci with deep impression by principal and minor transverse sulci, lacking lateral carinae; median posterior margin of metazona smoothly round; surface of pronotum irregularly carinulated; dorsum of prozona and lateral lobe with irregularly wrinkled ridges; dorsum of metazona with distinctly thickened ridges; posteroventral margin of lateral lobe broadly round and slightly arched; pronotal margin distinctly thickened; sternum long, anterior border of mesosternum broadly projected in the middle, mesosternal lobe vertically longer than lateral width, mesosternal interspace elongate, resembling hour-glass shape, with lateral margins partly contiguous, anterior margin of interspace straight, inner posterior corners of lobe obtusely round; metasternal lobe completely contiguous. *Legs*: Hind femur slender and long, slightly constricted on hind knee; upper and lower

carinae smooth; basal lobe dorsally longer than ventral lobe, dorsal genicular lobe rounded apically, ventral genicular lobe roundly angular apically, distal end of dorsal carina rounded; hind tibia with outer apical spine, number of spines on outer margin 9, distance between first and second spines on inner margin as long as any other inter-spine distance, distal half of hind tibia broadened towards apex without outer and inner edges running through the spines. *Wings*: Tegmen brachypterous, not reaching middle of hind femora, male wings developed in contact with each other basally above abdomen; apex rounded; cell of distal part sub-quadrangular. Genitalia: Cerci narrowing towards apex, elongated conical, straight in profile, apex pointed; supra-anal plate long, scutatiform, apex truncated and not divided, lacking furcula and smooth without tubercles near lateral margins, transverse ridge on middle field of plate with two lateral ridges on middle field not reaching posterior margin of the plate; subgenital plate with simple conical structure, apex not divided, very long with vertical length almost twice the length of basal width, strongly tapering towards apex with acutely pointed end, lacking tubercle at end of apex.

Food plant. Unknown.

Ecology. Dipterocarp forest (Tan & Wahab, 2018).

Distribution. Indonesia, Malaysia (Borneo) (Willemse, 1957; Tan & Wahab, 2018; Cigliano et al., 2021).

Remarks. Only male specimen available for redescription. *Perakia borneensis* is presumed to be a canopy species (Tan & Wahab, 2018). This species has long body with very truncated wings, hind femora does not reach the end of the abdomen. Length of head very short in comparison with the pronotum length, forming rectangular shape from dorsal view.

Pronotum with deeply impressed sulci and surface of pronotum deeply rugose. *Perakia borneensis* does not hold any similarity with other species of the family.

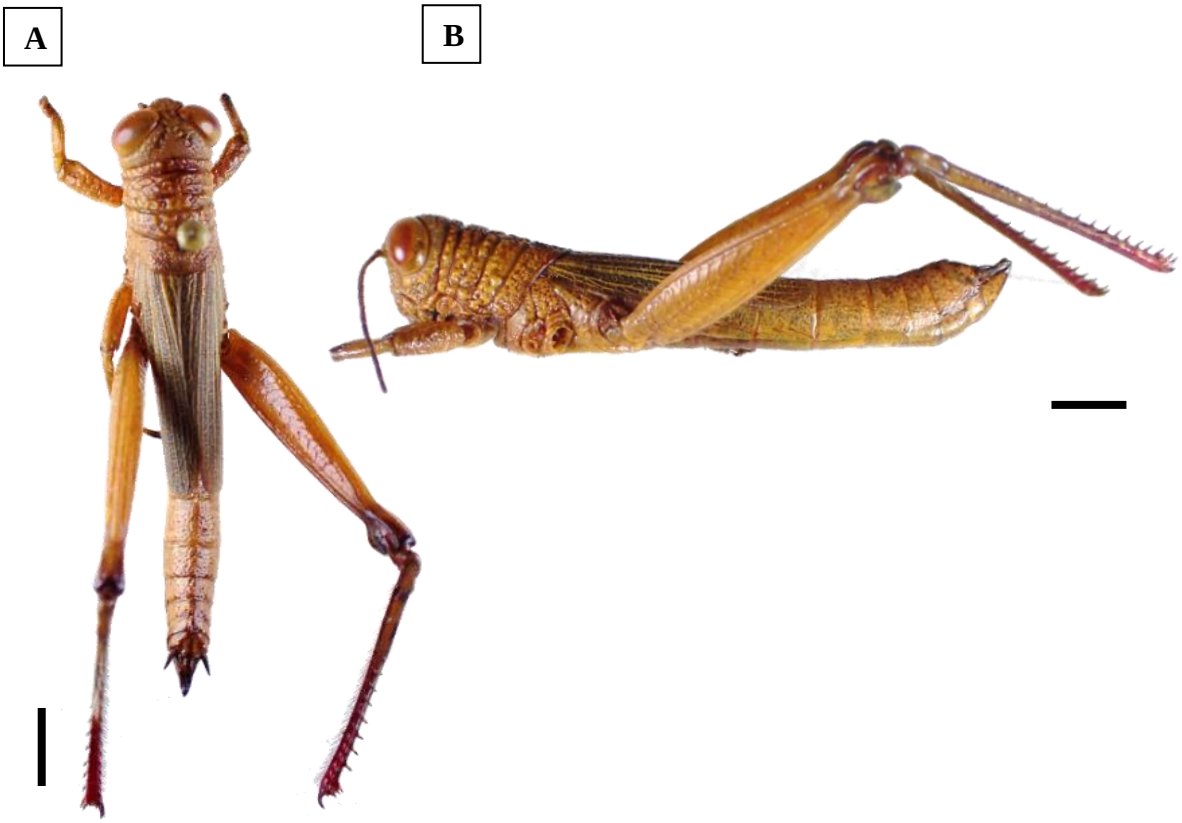


Figure 3.15: *Perakia borneensis*, ♂. **A.** Dorsal view of type; **B.** Lateral view of type. Scale = 5 mm.

Genus *Phalaca* Bolivar, 1906

Phalaca waterstradti Ramme, 1941

Figure 3.16, Figure 3.19

Phalaca waterstradti Ramme, 1941: 84; Willemse, 1956: 135

Material examined. 1 specimen (♂: 1). **BORNEO: EAST MALAYSIA: SARAWAK: Miri:** Niah, 17.V.1987, Mahmud Merdek, 1♂ (FN.87-0192) (RDID).

Diagnosis. *Phalaca waterstradti* is recognised by having the following characters: antennae extending beyond pronotum, not reaching tip of abdomen; pronotum very defined with clearly sculpted posterior and anterior pronotal margin, integument finely dotted; forewings light brown with translucent apical region, hindwings hyaline; hind femora short and thick, constricted on hind knees.

Description. Female: Unknown. Male: Body small, total length 22.66 mm. **Colouration:** Body olivaceous green and pale brown. Head: Olivaceous green with two yellow longitudinal stripes from apex of fastigium to post-occipital margin; thick yellow band transversely on front face not reaching clypeus runs from antennal base along the lower margin of eyes extending to post-gena. *Antennae*: Black, olivaceous green basally. Thorax: Dorsum of pronotum with yellow lateral stripes from anterior to posterior margin contiguous from post-occipital margin; lateral lobe with yellow bands contiguous from post-gena to posterior margin of pleura. *Legs*: Forelegs olivaceous green; hind femur yellowish green; hind tibia and tarsi yellowish brown. *Wings*: Tegmen brownish with very faint green stripes laterally, hyaline apically. **Structure:** Body robust and small. Head: Sub-triangular in antero-ventral view; frons oblique, sub-triangularly to vertex of head with an angle of over 40 degrees in profile; eyes oval, vertical diameter as long as horizontal diameter of eye laterally, exceeding the outline of head dorsally, eyes as high as vertex in profile, inter-ocular distance same as the width of frontal ridge, lacking foveolae and lateral carinae, distance from anterior margin of eyes to apex of fastigium much shorter than horizontal diameter of eye in profile, anterior apex of head obliquely, sub-triangularly projecting forward away from compound eyes, lacking transverse groove at base of fastigium, fastigium not excavated; integument above frontal ocellus smooth without any pattern with thick frontal ridge forming deep lateral groove below frontal ocellus reaching about midpoint of frontal

costa; frontal costa between antennae not obviously projected forward, not forming discernible arch above frontal ocellus in profile; frons lightly punctured and thinly ridged. *Antennae*: Extending much beyond pronotum but not reaching tip of abdomen; filiform-like shaped. Thorax: Prosternal process cylindrical, slightly compressed laterally, short and straight, apex flat and blunt; pronotum saddle-shaped; pronotum longer than head, width as wide as head, prozona significantly longer than metazona, expanding caudally from dorsal view and very faintly constricted in the metazona; median carina barely discernible and not elevated dorsally, straight and present as low ridges in profile, crossed by three sulci, deep impression by principal and minor transverse sulci, lacking lateral carinae; median posterior margin of metazona broadly angular and not concave; surface of pronotum irregularly carinulated; dorsum of prozona with irregularly wrinkled thick ridges, lateral lobe distinctly wrinkled; dorsum of metazona with distinctly thickened but flat ridges; posteroventral margin of lateral lobe roundly angular with an angle of slightly more than 90 degrees and slightly arched; pronotal margin distinctly thickened; anterior border of mesosternum slightly arched in the middle, mesosternal lobe laterally wider than vertical width, mesosternal interspace elongate with vertical length longer than basal width, anterior margin of interspace widely concave, inner posterior corners of lobe obtusely round; metasternal lobe contiguous. *Legs*: Hind femur short and thick, long oval, constricted on the hind knee; upper carinae prominently serrulated, lower carinae weakly serrate, basal lobe dorsally longer than ventral lobe, dorsal genicular lobe rounded distally, ventral genicular lobe with acutely pointed spine, distal end of dorsal carina rounded; hind tibia with outer apical spine, number of spines on outer margin 8, distance between first and second spines on inner margin as long as any other inter-spine distance, distal half of hind tibia broadened towards apex with slightly projected outer and inner edges running through the spines. *Wings*:

Tegmen macropterous, male wings developed in contact with each other above abdomen; surface of tegmen punctured basally; distal margin round, cell of distal part sub-rectangular. Genitalia: Cerci narrowing towards apex, elongated conical, slightly compressed laterally, straight in profile, apex pointed; supra-anal plate short, scutatiform, apex not divided, furcula small and obtuse-angularly pointed, lacking tubercles near lateral margins, tubercle on apex of plate roundly angular, lateral ridge basally forming slightly deep groove; subgenital plate with apex blunted and not divided, very short with basal width longer than vertical length, slightly tapering and lacking tubercle at end of apex.

Food plant. Unknown.

Ecology. Unknown.

Distribution. Malaysia (Borneo) (Willemse, 1957; Cigliano et al., 2021).

Remarks. Only one male specimen available for redescription. *Phalaca waterstradti* is distinctly similar to *Craneopsis olivacea* in terms of the structure of hind femora. Hind femur of both species is prominently thicker and shorter in comparison with the slender and long hind femur of other members of acridids in the collections examined. Additionally, the finely dotted pronotal disc is evident through the naked eyes whilst most of the other species possessed subtle spots that could be observed with the help of optical instruments.

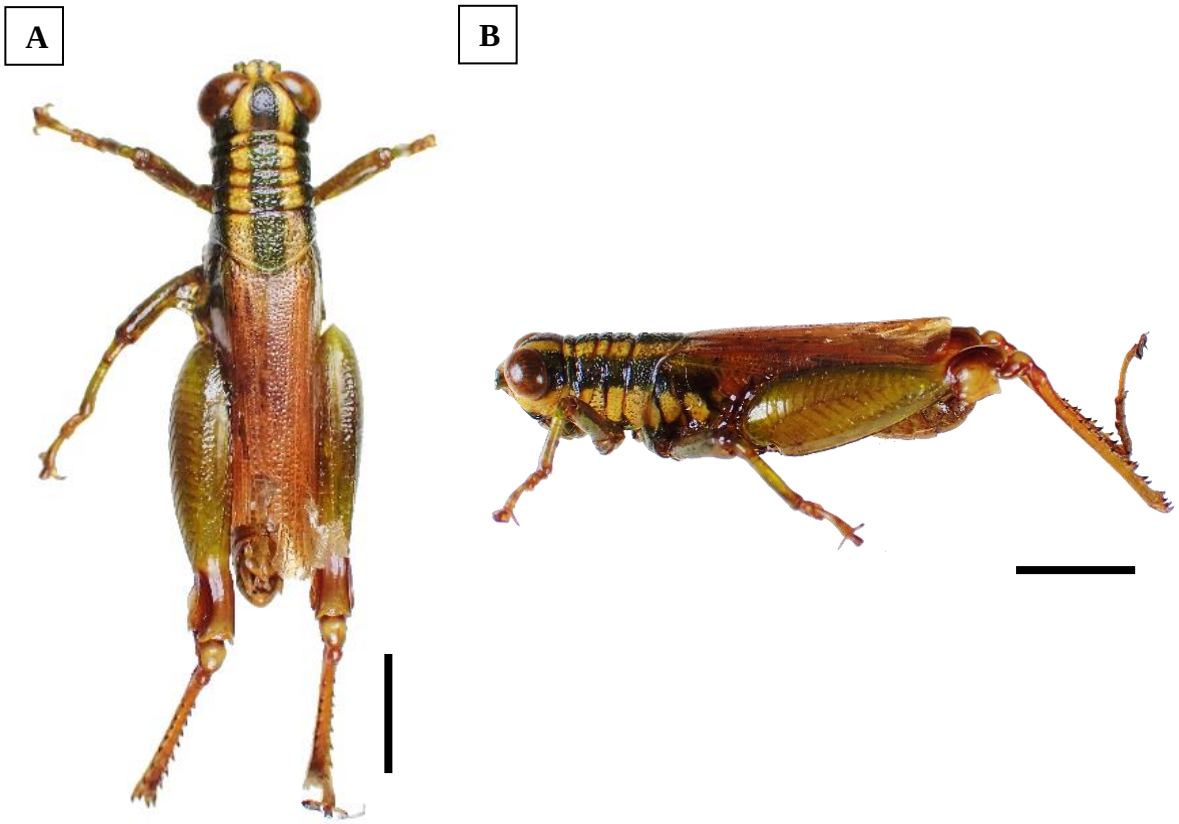


Figure 3.16: *Phalaca waterstradti*, ♂. **A.** Dorsal view of type; **B.** Lateral view of type. Scale = 5 mm.

Genus *Stenocatantops* Dirsh, 1953

Stenocatantops splendens (Thunberg, 1815)

Figure 3.17, Figure 3.25

Gryllus splendens Thunberg, 1815: 236

Catantops splendens Stål, 1873: 71; Kirby, 1914: 250; Bruner, 1915: 255 (61); Karny, 1915: 88; Bolivar, 1918: 406; Willemse, 1930: 193; Willemse, 1953: 2; Bei-Bienko & Mishchenko, 1963: 265, 266 (eng ver.)

Catantops infuscatus Bruner, 1915: 255 (61)

Catantops luteolus Bruner, 1915: 255 (61)

Stenocatantops splendens Dirsh & Uvarov, 1953: 237

Catantops (Stenocatantops) splendens Willemse, 1957: 469

Materials examined. 74 specimens (♂: 28, ♀: 46). **BORNEO: EAST MALAYSIA: SARAWAK: Betong:** Skuyat Baru, 16.III.2019, Felycia Rinta, 1♀ (UIRC). **Bintulu:** Jelalong, Sg. Mayop, 28.X.2000, 2♀ (FN.00-1462, FN.00-1463), caught by light trap, 2♂ (FN.00-1464, FN.00-1546) (RDID). Labang Forest Reserve, 12.I.1985, Manis Lintang, 1♂ (FN.85-0109) (RDID). Similajau National Park, 22.VII.1999, Ento Team, 1♀ (RDID); 12.IX.2000, Ento Team, 1♀ (FN.00-1103) (RDID). Sg. Sibiyu Nursery, 21.III.1997, Ento Team, 2♂ (RDID). **Kuching:** Bau, Adis Buan, 03.IV.2018, Sarah & Zhi Han, 1♀ (UIRC). Lanjak Entimau Wildlife Sanctuary, 19.VIII.1998, Nafri & Mat, 1♂ (FN.98-1043) (RDID). Padawan, 13.VII.2002, Dorina, 1♀ (UIRC). Padawan, Borneo Highlands, Kg. Benuk, 11.X.2015, Anisa Grace Robert, 1♂ (UIRC). Padawan, Gunung Regu, 19.VIII.2009, Insect Group, 2♀ 2♂ (UIRC). Petra Jaya, 31.I.2000, Shalihin Anuar, 1♀ (UIRC). **Lundu:** Samunsam Wildlife Sanctuary, 24.IX.1988, A. Rahman Osman, 1♂ (FN.88-0614) (RDID). Sebandi, 18-28.I.2003, Group 3, SLUSE 02/03, 1♀ (UIRC). Sematan Beach Forest, 19.V.1984, Ento Team, 1♀ (RDID). Sematan, Gunung Pueh, 14.X.2015, Ento Team, 2♀ (GC6553, GC6554), 1♂ (GC6551) (RDID). **Miri:** Lambir Hills National Park, 03.VII.1989, Mahmud Merdek, 1♂ (FN.89-0586) (RDID); 05.VII.1989, Mahmud Merdek, 1♂ (FN.89-0613) (RDID); 08.IX.1994, caught by UV light, Ento Team, 1♀ (C0597) (RDID); 09.IX.1994, caught by UV light, Ento Team, 1♂ (C0598) (RDID); 24.X.1998, caught by UV light, Ento Team, 1♂ (G0118) (RDID); 10.VIII.2001, caught by light trap, Ento Team, 1♀ (CR00162) (RDID); 21.VIII.2003, LUBL Project, Kishimoto-Yamada & Itioka, 1♀

(ZB4A-011) (RDID); 29.VIII.2003, LUBL Project, Kishimoto-Yamada & Itioka, 1♀ (ZB3B-012) (RDID). Niah, 27.I.1977, A. A. Hamid, 1♂ (FN.00130) (RDID); 01.IV.1984, Manis Lintang, 1♂ (FN.84-0535) (RDID); 22.VIII.1985, caught while mating, Lippa Akeng, 1♀ (FN.85-0803), 1♂ (FN.85-0804) (RDID); 15.II.1987, Lippa Akeng, 1♀ (FN.87-0089) (RDID); 09.III.1989, Mahmud Merdek, 3♀ (FN.89-0041 – FN.89-0043) (RDID). **Samarahan:** Samarahan, 05.VIII.2002, Nazahiyah A. R., 1♂ (UIRC); 16.III.2016, Siti Zulaikha, 1♀ (UIRC). Sadong Jaya, 18.VII.2019, Ento Team, 1♀ (UIRC). UNIMAS, 12.II.1997, Rimons, 1♀ (UIRC); 12.III.1997, Rimons, 1♂ (UIRC); 15.II.2000, Felicia, 1♂ (UIRC); 26.I.2003, Apoi, 1♀ (UIRC); 19.IV.2016, Radin Azreena, 1♀ (UIRC); 19.II.2019, Ketty Loh Siew Lan, 1♀ (UIRC). UNIMAS, Arboretum, 17.III.2017, Yap Wen Ling, 1♀ (UIRC). **Serian:** Serian, 02.IV.2016, Faridah & Hazwani, 1♀ 1♂ (UIRC). Balai Ringin P. I., 19.XI.1998, caught between 1900 – 2000, Ento Team, 1♀ (RDID). Ranchan Recreation Park, 18.XI.2003, Wahap M., 1♀ (UIRC). **Sibu:** Oya, 15.XII.1982, Ento Team, 1♀ (FN.82-0761) (RDID); 18.XII.1982, Ento Team, 1♂ (FN.82-0786) (RDID). **Simunjan:** Sabal Forest Reserve, 19.V.1984, Ento Team, 1♀ (FN.84-0927) (RDID). **Sri Aman:** Lingga, Bukit Lesung, 01.III.1991, Sarkawi & Wan Khata, 1♂ (FN.91-0112) (RDID); 21.III.1991, Sarkawi & Wan Khata, 1♀ (FN.91-0052) (RDID). Sg. Lingga, 05.IV.1991, Sarkawi & Wan Khata, 1♂ (FN.91-0129) (RDID). **SABAH: Keningau:** Taman Banjaran Crocker, 10.IV.1997, Alt: 1,080 m, Jelius Gantor, 1♀ (ENT:3108) (SM); 1-14.XI.2018, Eksplorasi Mantailang, 458 m elevation, 05º10'18.1"N 115º55'55.7"E, Johny L., 1♂ (SP/EOR/02018) (SPM). **Kota Kinabalu:** Muzium Sabah, 27.VIII.1983, Dail Sintia, 1♀ (ENT:4212) (SM). UMS Hill, 28.VIII.2012, Lam, 1♀ (UMS); 19.IV.2014, caught by sweep net, Muhamad Amirul Ashraf, 1♀ (UMS). UMS Peak, 08.IV.2017, caught by sweep net, Norfarhain Jefri, 1♀ (UMS). UMS, ITBC, 20.V.2017, found on grasses, caught by hand, Azila N., 1♀ (UMS);

03.III.2018, found in forest, caught by sweep net, Muhammad Ridzuan, 1♀ (UMS). **Kudat:** Pulau Malawali, 03.V.2017, Johny L., 2♂ (SPM). **Lahad Datu:** Jeroco Kertam, 24.III.1988, Jelius Gantor, 1♀ (ENT:3964) (SM). **Sipitang:** Ulu Mendulong, 10.II.1996, Jelius Gantor, 1♀ (ENT:2388) (SM). **Tawau:** Maliau Basin, Agathis Camp, 12-19.V.2001, found in open grassland, Ito Gen & Azrie A., 1♀ (ORT-1268) (UMS).

Diagnosis. *Stenocatantops splendens* can be distinguished by other species in the subfamily Catantopinae on the basis of a slender body; pronotal disc not constricted in the middle; outer face of hind femora with dark longitudinal band, inner face of hind femora black on the upper margin and red on lower margin, hind tibia orange-red; male cerci simple and not dilated on the apical region.

Description. Male: Body size medium to long, total length 29.43 mm – 38.58 mm. **Colouration:** Body uniformly brownish, sometimes pale yellow. *Antennae*: Pale to dark brown. Thorax: Side of thorax with oblique pale band; sternum generally brownish or pale yellow with tinge of brownish orange on anterior margin of mesosternum. *Legs:* Outer face of hind femur pale yellow with dark longitudinal stripe in the middle, inner face black on the upper margin, red on lower margin; hind tibia and tarsus pale reddish orange. *Wings*: Tegmen uniformly pale brown dorsally, darker brown laterally. **Structure:** Body robust and medium long. Head: Long, sub-rectangular in frontal view, frons sub-triangular to vertex of head and slightly slanted of over 40 degree in profile; eyes long oval, exceeding the outline of the head, as high as vertex of head laterally, distance from the anterior margin of eyes to apex of fastigium equal to the horizontal diameter of eye in profile, inter-ocular distance narrower than width of frontal ridge, lateral carinae weakly projected with thick ridges, lacking foveola; anterior apex of head linear and close to compound eyes dorsally, fastigium ridge

weakly formed vertically elongated isosceles trapezoid and not interrupting lateral carinae of vertex; apex of fastigium not excavated with lateral carinae almost merging; frontal ridge of head extending to clypeus; frontal costa between antennae faintly projected forward, very weakly arched to sometimes barely discernible above the median ocellus; frontal costa with small and deep punctures, frons very weakly ridged. *Antennae*: As long as the combined length of head and pronotum; filiform-like shaped. Thorax: Prosternal process cylindrical, slightly bent posteriorly nearly reaching anterior margin of mesosternum; pronotum long, saddle-shaped; width as wide as head; prozona slightly longer than metazona; slightly expanding caudally and longitudinal margins parallel with each other; transverse sulci shallowly impressed on pronotal disc, median carina crossed by three sulci, straight and flat laterally, first and second transverse sulci cutting median carina, shallow incision on pronotal disc by principal sulcus; lacking lateral carinae with median carina projected as low and blunt ridge; median posterior margin of pronotum projected into an obtuse angle; pronotal disc irregularly carinulated; dorsum of prozona with lightly and weakly punctured, lateral lobe irregularly wrinkled; dorsum of metazona lightly ridged forming numerous honeycomb shape; posteroventral margin of lateral lobe roundly angular and not concave; sternum long; anterior border of mesosternum slightly arched, nearly straight; mesosternal lobe vertically longer than lateral width, mesosternal interspace very reduced and long with the lateral margins almost contiguous forming hourglass shape, anterior margin of the interspace broadly concave, inner posterior corners of lobe obtusely round; metasternal lobe contiguous. *Legs*: Upper carinae of hind femur prominently serrate, lower carinae smooth, basal lobe dorsally longer than its ventral length, dorsal and ventral genicular lobe rounded distally, distal end of dorsal carina slightly broadly angular; hind tibia lacking outer apical spine, number of spines on outer margin 9 to 10, distance between first and second spines

on inner margin as long as any other inter-spine distance, distal half slightly broadened towards apex. *Wings*: Tegmen macropterous, fully winged, male wings developed at least in contact with each other above abdomen, distal margin round, cells of distal part rectangular. Genitalia: Cerci highly elongated, curved inwards posteriorly, narrowing toward apex, apex pointed; supra-anal plate scutatiform, lacking furcula, smooth without tubercles near lateral margins, middle field with deep groove from anterior margin to medial part of plate; subgenital plate overall simple conical structure, apex not divided, long, with length greater than basal width, strongly tapering toward apex with rounded end dorsally, lacking tubercle at apex.

Female: Body size medium, larger than male, total length 31.21 mm – 43.68 mm. Colouration, vestiture and texture as in male. **Structure:** Mostly as in male, body robust. Genitalia: Ovipositor curved in profile; dorsal valves as long as ventral; dorsal valves convergent, with one apical tooth, very weakly serrulate on the superior margin, non-bidentate, lacking notch on apex of valves; ventral valves very narrow, external margins weakly serrated, constricted laterally in the middle field, external lateral teeth prominently projected outward; subgenital plate strongly projected triangularly posteromedially, lacking lateral teeth on posterior margin.

Food plant. Cacao, coconut, finger millet, kapok, maize, mulberry, oil palm, rice, rubber, sugar cane, tea, teak and tobacco (Dammerman, 1929; Willemse, 1968; Roffey, 1979; COPR, 1982; Willemse, 2001).

Ecology. Open grassland, forests, previously cultivated land, urban areas, along roadsides (Dammerman, 1929; C. Willemse, 1938; Roffey, 1979; COPR, 1982; L. Willemse, 2001) and montaneous forest with 458 m – 1,080 m elevation.

Distribution. Andaman Islands, China, India, Indonesia, Malaysia, Myanmar, Nepal, Nicobar Islands, the Philippines, Singapore, Sri Lanka, Taiwan, Thailand, Vietnam (C. Willemse, 1938; F. Willemse, 1968; L. Willemse, 2001; Mahmood et al., 2007; Tan, 2010b, 2012; Tan & Kamaruddin, 2014; Cigliano et al., 2021).

Remarks. *Stenocatantops splendens* shares certain similarity with *Xenocatantops humilis* in terms of the colouration and structure of body. Face of both species are reclinate with frontal ridge not projecting between the antennae, eyes moderately prominent sideways and upwards, and inter-ocular distance narrower than width of frontal ridge. However, the body of *S. splendens* are slender and longer than *X. humilis*, in addition to the absence of dark transverse bands on the outer face of hind femora.

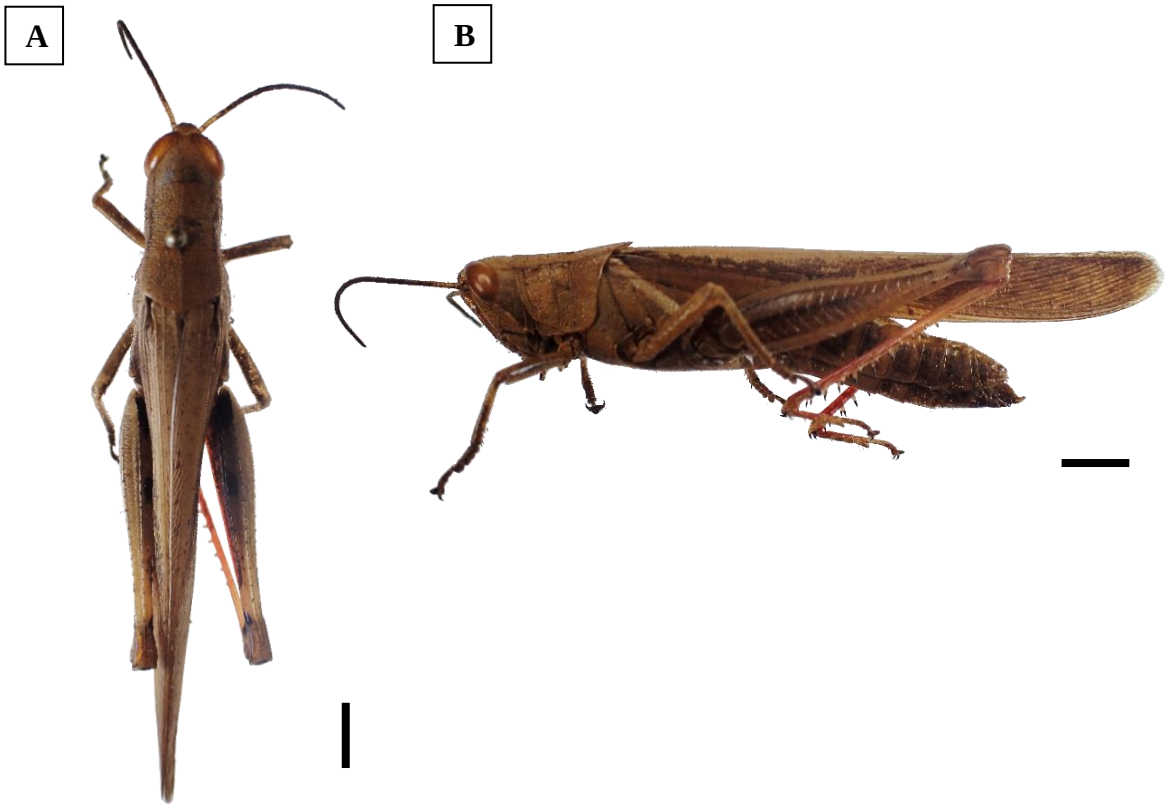


Figure 3.17: *Stenocatantops splendens*, ♂. **A.** Dorsal view of type; **B.** Lateral view of type. Scale = 5 mm.

Genus *Traulacris* Willemse, 1933

Traulacris grandis (Miller, 1932)

Figure 3.18, Figure 3.19

Traulidea grandia Miller, 1932: 204

Malayacris grandis Ramme, 1941: 100

Traulacris grandis Willemse, 1957: 422

Materials examined. 10 specimens (♂: 7, ♀: 3). **BORNEO: EAST MALAYSIA: SABAH: Keningau:** Mount Trus Madi, 31.X.2001, Ekspedisi Trus Madi, Ito Gen, 2♀ (OR/01/00693, OR/01/00695), 1♂ (OR/01/00694) (SPM); 23.X.-07.XI.2001, trail to summit, Azrie Alliamat, 2♂ (ORT-2847, ORT-2848) (UMS). **Ranau:** Kinabalu Park HQ, 10.III.2000, Ito Gen, 1♀ (ORT-2500) (UMS), 3♂ (OR/01/00653) (SPM) (ORT-2499, ORT-2501) (UMS). Mesilau Park, 01.I.1996, Johny L., 1♂ (OR/96/00193) (SPM).

Diagnosis. *Traulacris grandis* is recognised by having the following combination of characters: antennae elongated much beyond pronotum; surface of head and pronotal disc distinctly rugosely punctate; tegmina abbreviated, reaching half the length of hind femur; hind femur red with olivaceous green pre-genicular ring and brownish yellow hind knee.

Description. Male: Body small to medium, total length 18.64 mm – 20.78 mm. **Colouration:** Generally olivaceous green or brownish black. Head: Dorsum of head with yellow stripes from anterior margin of compound eyes to post-occipital margin, yellow transverse stripes running along the antennal base to post-gena. *Antennae*: Scapus and pedicel yellowish green; flagellum black. Thorax: Dorsum of pronotum with two yellow

longitudinal stripes; lateral lobe with yellow stripes on both sides reaching posterior margin of pleuron. *Legs*: Hind femur red with olivaceous green pre-genicular ring and brownish yellow hind knee; hind tibia olivaceous green. *Wings*: Tegmen yellowish brown with yellow longitudinal stripes dorsally. **Structure:** Body small to moderately long and robust. Head: Sub-rectangular in frontal view; frons oblique, sub-triangular to vertex of head with an angle of over 40 degrees in profile; eyes sub-ovate, vertical diameter equal to its horizontal width of eye in profile; exceeding the outline of head; eyes as high as vertex of head from lateral view; distance from anterior margin of eyes to apex of fastigium less than horizontal diameter of eye in profile; inter-ocular distance slightly wider than width of frontal ridge; lacking lateral carinae and foveolae; anterior apex of head distinctly projecting forward away from eyes; lacking transverse groove at base of fastigium; apex of fastigium not excavated; frontal ridge obliterated below median ocellus; frontal costa between antennae projected forward forming obvious arch above median ocellus in profile; frontal costa above median ocellus with wide punctures proportionally; frons widely punctured with deep pits. *Antennae*: Long, extending much beyond pronotum; filiform-like shaped. Thorax: Prosternal process simple conical structure; straight; pronotum short, total length almost equal to length of head dorsally; saddle-shaped; pronotum as wide as head dorsally; prozona much longer than metazona; sub-cylindrical from dorsal view; median carina barely discernible to almost absent; flat dorsally; straight to almost no trace in profile; crossed by three sulci with slightly deep impression by principal sulcus and minor transverse sulci; lacking lateral carinae; median posterior margin of pronotum smoothly round; dorsum of pronotum coarsely punctured, formed by distinctly thickened ridges; lateral lobe distinctly wrinkled; posteroventral margin of lateral lobe roundly angular with an angle of over 90 degrees; anterior border of mesosternum broadly projected in the middle; mesosternal lobe slightly

longer vertically than its horizontal width; mesosternal interspace wide, with vertical length as long as basal width; anterior margin of interspace distinctly concave; inner posterior corner of lobe obtusely round; metasternal interspace distinctly contiguous. *Legs*: Upper carinae of hind femur serrated, lower carinae smooth, basal lobe with equal length of dorsal and ventral lobe, dorsal and ventral genicular lobe roundly angular distally, distal end of dorsal carina obtuse-angularly pointed; hind tibia with outer apical spine, number of spines on outer margin 7, distance between first and second spines on inner margin as long as any other inter-spine distance, distal half of hind tibia not obviously broadened towards apex without obvious edges running through the spines. *Wings*: Tegmen brachypterous, wings developed in contact with each other above abdomen, distal margin round, cell of distal part rectangular. Genitalia: Cerci narrowing towards apex, short triangular, slightly compressed laterally, straight in profile, apex round; supra-anal plate scutatiform, constricted medially, furcula short and obtusely angular, lacking tubercles near lateral margin; subgenital plate apex not divided and blunt, very short, vertical length less than basal width, not tapering towards apex, lacking tubercle at end of apex.

Female: Larger than male, total length 23.82 mm – 25.57 mm. Colouration, vestiture and texture as in male. **Structure:** Mostly resemble male specimens, body robust. Genitalia: Ovipositor curved posteriorly in profile; dorsal and ventral valves with equal length laterally; dorsal valves convergent posteriorly, with one apical tooth, lowly serrulated to almost smooth on the superior margin, apex non-bidentate, lacking notch apically; ventral valves very narrow, external margins weakly serrated on the posterior margin, constricted laterally in the middle, external lateral teeth not prominently projected outward; subgenital plate acutely pointed posteromedially forming widely concaved projection ventrally, lacking lateral teeth on posterior margin in ventral view.

Food plant. Unknown.

Ecology. Primary dipterocarp forest and montane forest with 1,005 m – 1,219 m elevation (Willemse, 1957; Tan & Wahab, 2018).

Distribution. Brunei, Malaysia (Willemse, 1957; Tan & Wahab, 2018; Cigliano et al., 2021).

Remarks. Genus *Traulacris* was found to be endemic to Borneo with only two species described and recognised, *T. erecta* and *T. grandis* (Tan & Wahab, 2018). Body structure of the species resembles genus *Meltripata*, however head of *T. grandis* is distinctly elevated above the pronotum from lateral view with barely projecting frontal ridge. Additionally, tegmina of *T. grandis* is noticeably shorter, only reaching 2/3 of the length of abdomen in comparison with genus *Meltripata* with tegmina almost reaching the subgenital plate of tergites. Nonetheless, the specimen does not match the description by Willemse (1957) on the colouration of hind femora where almost half of the posterior region were red, followed by dirty green which almost reaching the knee, while the pre-genicular ring were yellowish brown in colour, whereas the description defined the hind femora as castaneous with greenish sub-genicular.



Figure 3.18: *Traulacris grandis*, ♀. **A.** Dorsal view of type; **B.** Lateral view of type. Scale = 5 mm.

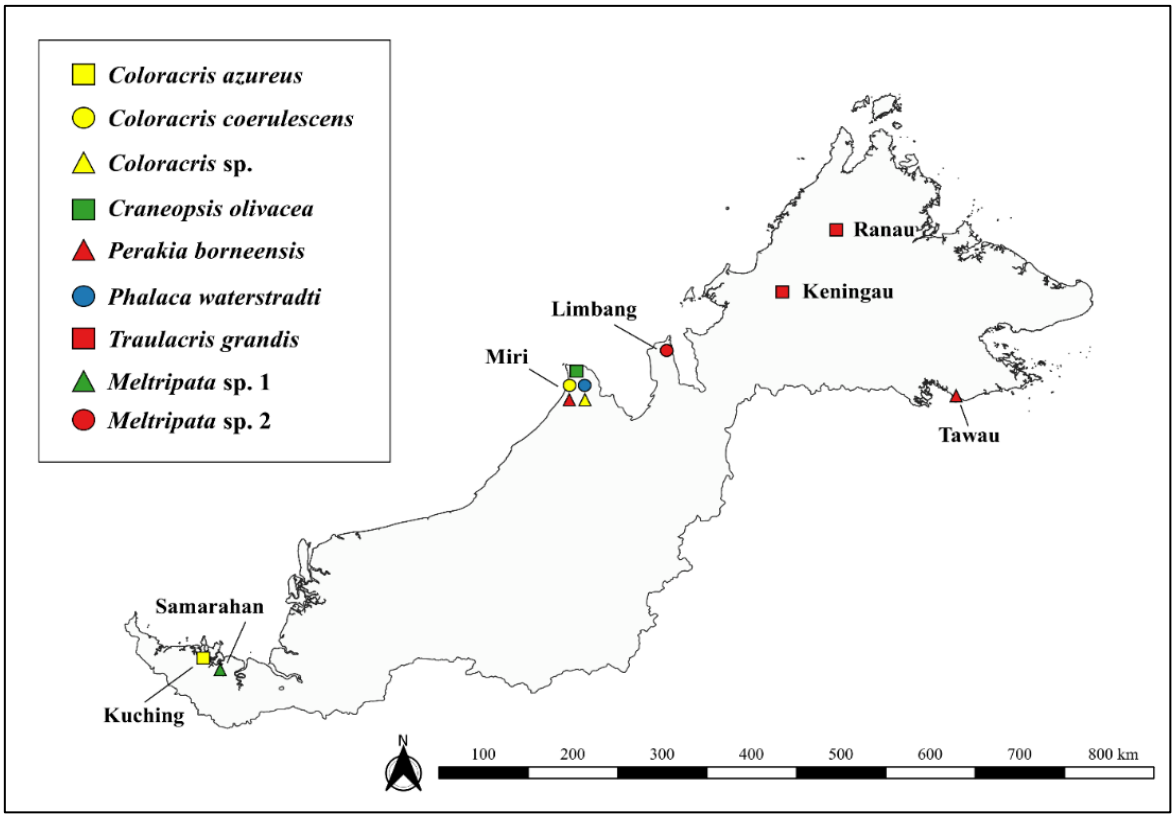


Figure 3.19: Distribution map of genera *Coloracris* and *Meltripata*, including *Craneopsis olivacea*, *Perakia borneensis*, *Phalaca waterstradti* and *Traulacris grandis* from subfamily Catantopinae in Malaysian Borneo.

Genus *Traulia* Stål, 1873

Diagnosis. Body size medium, body robust or at times slender; antennae filiform, longer than the combined length of head and pronotum; head slightly reclinate in profile, frontal ridge distinctly projecting between the antennae; eye prominent sideways from dorsal view, inter-ocular distance wider than the width of frontal ridge; pronotum cylindrical, missing lateral carinae, median carinae lightly present, anterior margin of pronotum slightly rounded, posterior margin of pronotum obtusely angulate; mesosternal lobes horizontally wider than its vertical length, metasternal lobe distinctly separated; tegmina reaching the tip of abdomen; tibiae with 7 to 8 outer spines, lacking outer apical spine; male supra-anal plate scutatiform, apex with or without tubercle distinctly projected; female supra-anal plate

subquadrangular with apex slightly rounded, ovipositor valves straight with apex hooked, subgenital plate with posterior margin triangularly projected in the middle.

Traulia azureipennis (Serville, 1838)

Figure 3.20, Figure 3.23

Xiphicera azureipennis Serville, 1838: 616

Xiphocera azureipennis Walker, 1870a: 525

Traulia azureipennis Stål, 1878: 72; Kirby, 1910: 475; Bolivar, 1917: 614; Willemse, 1921: 30; Willemse, 1930: 176; Willemse, 1935: 140; Willemse, 1938: 226; Ramme, 1941 [1940]: 184, 185; Willemse, 1957: 378

Traulia dimidiata Wattenwyl & Fea, 1893: 160, 161; Brunner, 1898: 247, 248; Kirby, 1910: 475; Kirby, 1914: 245

Acridium (Oxya) dimidiatum Willemse, 1928: 10

Materials examined. 148 specimens (♂: 65, ♀: 83). **BORNEO: EAST MALAYSIA: SARAWAK: Bintulu:** Labang Forest Reserve, 12.I.1985, Manis Lintang, 2♀ (FN.85-0110, FN.85-0111) (RDID); 13.I.1985, Lippa Akeng, 1♀ (FN.85-0123), 1♂ (FN.85-0119) (RDID); 14.I.1985, Manis Lintang, 1♀, Lippa Akeng, 2♂ (RDID). Jelalong, Sg. Mayop, 28.X.2000, caught by light trap, Ento Team, 5♀ (FN.00-1456, FN.00-1497, FN.00-1524, FN.00-1536, FN.00-1537), 2♂ (FN.00-1460, FN.00-1467) (RDID). Similajau National Park, 13.IX.2000, Ento Team, 1♀ (FN.00-1105), 1♂ (FN.00-1104) (RDID). **Kuching:** Agriculture Research Centre, 20.I.1983, Jamal M., 1♀ (RDID). Bau, Adis Buan, 03.IV.2018,

Ilina, 1♀ (UIRC). Bau, Gunung Singai, 29.IV.2017, Dasi Ong, 1♀ (UIRC). Bau, Libiki Bamboo Resort, 21.IV.2019, Nur Ilmi, 1♀ (UIRC). Bau, Skibang, 29.IV.2017, Damianne Joem, 1♀ (UIRC). Lanjak Entimau Wildlife Sanctuary, 19.VIII.1998, Nafri & Mat, 1♀ (FN.98-1042) (RDID); 25.VIII.1998, Nafri & Mat, 1♀ (FN.98-0616) (RDID). Matang, 08.II.1985, Manis Lintang, 1♀ (FN.85-0340) (RDID). Padawan, 21.VII.2002, Dorina, 1♀ (UIRC). Padawan, Borneo Highland Resort, 17.IV.2017, Sim Pey Nee, 1♀ (UIRC). Padawan, Borneo Highlands, 15.V.2016, Aina & Syafinaz, 1♂ (UIRC); 03.III.2018, Marcellinus Isaac Stia, 1♂ (UIRC). Padawan, Gunung Regu, 19.VIII.2009, Insect Group, 1♀ 2♂ (UIRC). Petra Jaya, 04.II.2000, Dayang Sa'emah, 1♀ (UIRC). Santubong National Park, 17.III.2016, Zakirah Jasni, 1♂ (UIRC). **Lawas:** Machimu, 09.X.1985, Lippa Akeng, 1♀ (FN.85-0851) (RDID). **Lundu:** Gunung Gading National Park, 13.VII.1987, Ento Team, 1♀ (FN.87-0335), 2♂ (FN.87-0333, FN.87-0334) (RDID). Jangkar Waterfall, 07.IV.2017, Atiqah Azizi, 1♀ (UIRC). Kg. Stuom Muda, 26.XI.1999, Jinal J., 1♀ (UIRC). Sampadi Forest Reserve, 09.IX.2013, Ento Team, 1♀ (GC2962) (RDID). Sematan, Gunung Pueh, 10.IV.2015, Ento Team, 1♀ (GPH0152), 1♂ (GPH0026) (RDID). **Miri:** Bario, Kelabit Highlands, 12.IV.1995, found at quarry, day trail, S.H., F.A., Lim, W.M., 1♀ (O1179) (UIRC). Bario, Pulong Tau National Park, 22.V.2012, Ento Team, 1♀ (PTNP0512) (RDID). Bario, Sungai Mada, 16.III.1988, Abdul Rahman Osman, 1♀ (FN.88-0100) (RDID). Lambir Hills National Park, 03.VII.1989, Mahmud Merdek, 1♀ (FN.89-0585) (RDID); 05.VII.1989, Mahmud Merdek, 1♂ (FN.89-0612) (RDID); 07.II.2002, caught by light trap, Ento Team, 1♂ (LTY00935-1) (RDID); 28.II.2014, Ento Team, 1♀ (GC3337) (RDID). Niah, 24.II.1979, A. A. Hamid, 2♂ (FN.01408, FN.01423A) (RDID); 29.III.1984, Ento Team, 2♀ (FN.84-0376, FN.84-0377), 1♂ (FN.84-0375) (RDID); 16.I.1985, Manis Lintang, 2♀ (FN.85-0140, FN.85-0141), 1♂ (FN.85-0138) (RDID); 17.V.1987, A. A. Hamid, 1♀ (FN.87-0194)

(RDID); 19.V.1987, Mahmud Merdek, 1♀ (FN.87-0216), 1♂ (FN.87-0217) (RDID). **Mukah:** Mukah, 22.II.2004, Lizawati R., 1♂ (UIRC). **Samarahan:** Kota Samarahan, 20.III.2016, Hazwani, 1♀ (UIRC). Kota Samarahan, Taman Desa Ilmu, 04.V.2017, Syifa, 1♂ (UIRC). UNIMAS, 04.III.1997, Anita Bruin, 1♀ (UIRC); 19-28.II.2007, Hadayu, Hazwani & Normukarimah, 1♀ (UIRC); 25.III.2009, Muhammad Faadzil bin Amram, 1♂ (UIRC); 14.I.2010, Jennifer Ubung Nawan, 1♂ (UIRC); 07.III.2010, Sarina Mat Yasin, 1♂ (UIRC); 23.IV.2017, A. Abdullah, B. Teepol & F. Fizy, 1♀ 1♂ (UIRC); 05.III.2018, Aufa Ahmad, 1♂ (UIRC); 21.III.2018, Ahmad Faiz Zulkipli, 1♀ (UIRC). UNIMAS, Arboretum, 16.III.2017, Shirly Olvy Sumil, 1♀ (UIRC); 17.III.2017, Yap Wen Ling, 1♂ (UIRC); 03.V.2017, Kathleen M. I., 1♀ (UIRC); 01.III.2018, Syafiqah Aqilah, 1♀ (UIRC). UNIMAS, DETAR PUTRA, 23.IV.2017, Naim Che Kamaruddin, 1♀ (UIRC). UNIMAS, East Campus, 15.III.2016, Noor Najilah Anifah, 1♂ (UIRC); 09.IV.2016, Maisharah, 1♂ (UIRC); 10.IV.2016, Norazmina, 1♂ (UIRC); 09.IV.2017, Naim Che Kamaruddin, 1♂ (UIRC); 01.IV.2019, Reincce Rhyl, 1♂ (UIRC). UNIMAS, External Laboratory, 09.III.2016, Rahmawati S. & Fatimah, 1♂ (UIRC); 17.V.2016, Ummu Safiyyah, 1♂ (UIRC); 29.III.2017, Athirah, 1♂ (UIRC); 30.IV.2017, Berlyna, 1♀ (UIRC). UNIMAS, Herbarium, 02.IV.2016, Siti Nur Zulaikha Halimi, 1♂ (UIRC). UNIMAS, Kolej Allamanda, 15.IV.2019, Zalifah Husna, 1♂ (UIRC). UNIMAS, Kolej Tun Ahmad Zaidi, 22.III.2016, Clementine M. & Nickitta D., 1♂ (UIRC). UNIMAS, Tapak Ceria, 13.III.2017, Noraini Ahmad Latif, 1♂ (UIRC). **Serian:** Annah Rais, 02.I.2004, Lily Sir, 1♂ (UIRC). Balai Ringin P. I., 17.XI.1998, pest of *'engkabang jantong'*, caught between 2200 – 2300, Ento Team, 1♂ (RDID); 11.III.2000, caught by hand, Ento Team, 3♀ (FN.00-0130 – FN.00-0132) (RDID). Kg. Segenam, 15.V.2016, Veronica Martin, 1♂ (UIRC). Ranchan Recreation Park, 27.II.2011, Nor Syakina Nor Rahim, 1♀ (UIRC); 14.IV.2018, Lim Zhi Han & Amanda

Wilson, 2♂ (UIRC); 16.III.2019, Jelina Hilo, 1♀ (UIRC); 27.IV.2019, Bell & Faezah, 2♀ (UIRC); 01.V.2019, Nur Emylia, 1♀ (UIRC). Semenggoh, 25.VII.1978, A. A. Hamid, 1♂ (FN.00944) (RDID). Semenggoh, Ulu Landeh, 09.II.1984, caught at agricultural plot, Ento Team, 1♀ (FN.84-0100) (RDID). Siburan, 14.V.2016, Delianistie Jackeria, 1♀ (UIRC). Tebakang, 02.VII.1983, trapped in Malaise trap, set up at hilltop at logged over area, Ento Team, 1♂ (FN.83-0667) (RDID). **Sibu:** Kestrel Sdn. Bhd., 10.VIII.1984, caught at flight, Lippa Akeng, 3♀ (FN.84-1215, FN.84-1217, FN.84-1218), 1♂ (FN.84-1216) (RDID). Oya, 18.XII.1982, Ento Team, 3♀ (FN.82-0784, FN.82-0787, FN.82-0788), Lippa Akeng, 1♂ (FN.82-0887) (RDID); 20.XII.1982, Lippa Akeng, 1♂ (FN.82-0888) (RDID); 12.II.1987, Lippa Akeng, 3♀ (FN.87-0068 – FN.87-0070) (RDID); 28.I.1988, A. Hamid & A. Rahman, 3♀ (FN.88-0018, FN.88-0019, FN.88-0021), 2♂ (FN.88-0020, FN.88-0023) (RDID). Panasu Camp, 31.X.1997, Ento Team, 1♂ (FN.97-0295) (RDID); 04.XI.1997, Ento Team, 1♂ (FN.97-0567) (RDID). Sg. Rasau, Batang Igan, 05.XII.1976, caught at campsite, *'midin'* available, A. A. Hamid, 2♀ (FN.00268, FN.00269), 1♂ (FN.00270) (RDID). **Simunjan:** Sabal Forest Reserve, 17.V.1984, Manis Lintang, 1♀ (FN.84-0919) (RDID); 18.V.1984, Ento Team, 1♀ (FN.84-0931), 1♂ (FN.84-0922) (RDID); 19.V.1984, Ento Team, 1♀ 1♂ (RDID); 20.V.1984, Manis Lintang, 2♀ (FN.84-0920), 1♂ (FN.84-0921) (RDID); 07.VIII.1985, Ento Team, 1♂ (RDID); 02.II.1989, Mahmud Merdek, 1♂ (RDID); 29.X.1996, Ento Team, 1♀ (SFR00340) (RDID); 12.XII.1996, Ento Team, 1♂ (SFR00670) (RDID); 08.I.1997, Ento Team, 1♂ (SFR01664) (RDID); 15.I.1997, Ento Team, 1♂ (SFR02325) (RDID); 31.III.2014, Ento Team, 1♀ (GC3563) (RDID); 03.III.2015, Ento Team, 1♀ (GC5590) (RDID). **Sri Aman:** Batang Engkari, Sungai Balat, 31.X.1989, attracted to lights, Ento Team, 1♀ (FN.89-0662) (RDID). **SABAH: Beaufort:** Membakut,

Binouluk, 23.VIII.1987, Shau Hwai, 1♀ (ORT-2767) (UMS). **Kota Kinabalu:** UMS, ITBC, 25.II.2017, caught by sweep net, Harris, 1♂ (UMS).

Diagnosis. *Traulia azureipennis* is recognised by having the following characters; usually found in two forms – dark brown and velvety black form; head and thorax with two sets of yellow bands forming from above the clypeus to lateral sides of thorax, and from above the frontal ocellus to almost reaching the apex of wings; antennae with white or pale tip; hind femur with a yellow band basally, a yellow dot on the lower margin medially and thick yellow ring near hind knee; hind tibia with yellow ring basally and red ring covering at least three inter-spine distances apically nearing tarsi.

Description. Male: Body small to medium, total length 18.91 mm – 24.03 mm. **Colouration:** Body in black form with very bright and clear yellow bands, spots and rings; body in dark brown form less shiny. Head: Front of face with yellow band resembling half a square, from below frontal ocellus not reaching the anterior margin of clypeus, extending laterally on frons of both sides reaching the anterior margin of clypeus and further extend to post-gena; vertex with two yellow lateral bands from the frontal ridge above frontal ocellus reaching the post-occipital line; palpi pale yellow. *Antennae*: Dark brown to black with pale or white tip. Thorax: Dorsum of pronotal disc with two lateral yellow bands continuing from the post-occiput to the end of metazona; lateral lobe on both sides with yellow band from anterior to posterior margin; sternum black or dark brown with three yellow spots above the mesosternal and metasternal interspace, and below the metasternal interspace reaching posterior margin of metasternum respectively. *Legs*: Outer face of hind femur with yellow band basally, yellow spot on the lower marginal area on the middle field and yellow ring before hind knee, inner face yellow spot basally in between the outer carina and lower

carinula; hind tibia with yellow ring basally and red ring apically covering at least three inter-spine distances near tarsi. *Wings*: Tegmen black with two yellow bands dorsally almost reaching apex of wings; hindwing bluish basally. *Abdomen*: Upper portion of tergum covered with wings yellow, lateral sides black; two lateral yellow bands from sternite III and almost faded reaching the last sternite. **Structure:** Body small to moderately long and robust. Head: Sub-cylindrical in frontal view, frons sub-triangular to vertex of head with obtuse angle of over 40 degree in profile; eyes sub-circular, vertical diameter greater than horizontal diameter of eye, exceeding the outline of head, eyes slightly higher than vertex of head laterally, distance from anterior margin of eyes to apex of fastigium less than the horizontal diameter of eye in profile, inter-ocular distance slightly wider than width of frontal ridge, lateral carinae and foveolae weakly projected; anterior apex of head slightly projecting forward away from eyes, transverse groove at base of fastigium not interrupting lateral carinae of vertex, apex of fastigium excavated with median carina very faintly extending to the post-occipital margin; frontal ridge of head extended to clypeus but sunken midway below frontal ocellus almost cut by transverse groove on frons; frontal costa between antennae obviously projected forward forming an arch above median ocellus in profile; integument above median ocellus and frons are with small and deep punctures. *Antennae*: Longer than the combined length of pronotum and head, filiform-like shaped. Thorax: Prosternal process simple conical structure, short and straight, apical part of tubercle pointed; pronotum short and wide, not selliform, as wide as width of head but slightly broader on the lateral lobe of metazonal area, prozona much longer than metazoan, expanding caudally from dorsal view and slightly constricted in the middle, median carina crossed by three sulci, pronotal disc with slightly impressed incision by transverse sulci, first and second transverse sulci cutting median carina on dorsum of prozona, slightly deep incision on median carina

by principal sulcus, median carina distinctly elevated forming rounded thick ridges laterally, lacking lateral carinae, median posterior margin of metazona broadly angular, pronotal disc strongly carinulated irregularly, dorsum of prozona with irregularly wrinkled ridges, lateral lobe of prozona distinctly wrinkled and ridged resembling the honeycomb shape, dorsum of metazona with distinctly thickened ridges, posteroventral margin of lateral lobe roundly angular and slightly arched; anterior border of mesosternum very slightly arched to almost straight, mesosternal lobe laterally wider than vertical length, mesosternal interspace elongate with horizontal length broader than vertical length, inner posterior corners of lobe obtusely round, metasternal lobe separated medially and metasternal interspace appear narrower than its basal width. *Legs*: Upper carinae of hind femur prominently serrated, lower carinae smooth, basal lobe of hind femur with dorsal lobe as long as ventral lobe, dorsal and ventral genicular lobe roundly angular distally, distal end of dorsal carina acutely pointed; hind tibia lacking outer apical spine, number of spines on outer margin 7, distance between first and second spines on inner margin as long as any other inter-spine distance, distal half of hind tibia slightly broadened towards apex. *Wings*: Tegmen macropterous, male wings developed in contact with each other above abdomen; distal margin round, cell of distal part long rectangular. Genitalia: Cerci expanding and round, compressed laterally, broad, curving inwards and downwards posteriorly, apex round; supra-anal plate scutatiform, furcula short, small and distinctly separated, basal field with two tubercles near lateral margin, lateral groove from anterior to posterior margin of the epiproct, transverse ridge weakly projected on the middle field, lacking transverse groove on middle and apical field, lacking tubercles on sides of middle and apical field, tubercle distinctly projected on the apical field; apex of subgenital plate not divided and blunt, almost straight, very short, length slightly shorter than

basal width, tapering faintly towards apex and slightly broaden with end truncated, lacking tubercle at end of apex.

Female: Larger than male, total length 27.44 mm – 38.96 mm. Colouration, vestiture and texture as in male. **Structure:** Mostly resemble male specimens, body robust. Genitalia: Ovipositor curved in profile; dorsal and ventral valves equal in length; dorsal valves faintly convergent, with one apical tooth, weakly serrulate on the superior margin, non-bidentate, lacking notch on apex; ventral valves wide, external margins lowly serrated dorsally, weakly constricted laterally in the middle field, external lateral teeth weakly projected outward; subgenital plate slightly triangularly projected posteriorly in the middle, lacking lateral teeth on posterior margin.

Food plant. Coffee shrubs and ferns (Willemse, 2001). This species has been reported as minor pest of midin (*Stenochlaena palustris*) and engkabang jantong (*Shorea macrophylla*).

Ecology. Abandoned cultivated land, agricultural plot, forests, forest edge, forest clearings, reed beds and rubber plantations, jelutong plantation (*Dyera costulata*) (C. Willemse, 1938; Roffey, 1979; COPR, 1982; L. Willemse, 2001; Tan & Wahab, 2018).

Distribution. Brunei, Indonesia, Malaysia, Myanmar, Singapore, Thailand (C. Willemse, 1938; Roffey, 1979; COPR, 1982; L. Willemse, 2001; Mahmood et al., 2007; Tan, 2010a, 2012; Tan & Wahab, 2018; Cigliano et al., 2021).

Remarks. *Traulia azureipennis* shares the similarity with *T. borneensis* and *T. sanguinipes sanguinipes* with the exception on the length of tegmina, that is almost reaching the apex of hind femora; the patterns on hind femora, with the distinct yellow transverse bands on the outer face of the legs; and the patterns on hind tibiae, where the basal region had complete

yellow rings, while the apical region were defined with bright red-coloured rings covering at least three outer spines. Genus *Traulia* was known to have similar body colouration, brownish or ground colour, sometimes black, with yellow transverse bands on top of the head and across the face, reaching the metanotum.

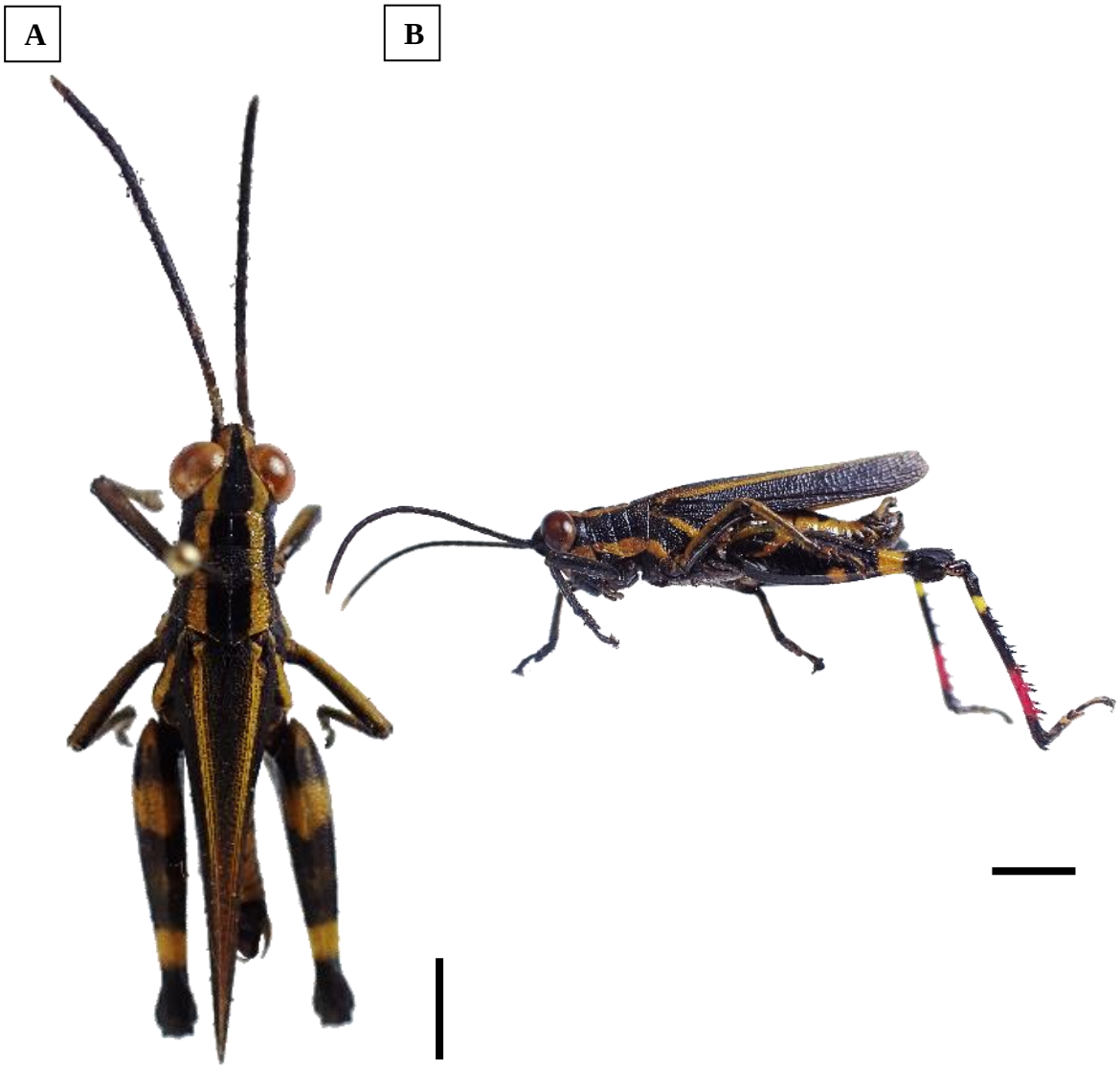


Figure 3.20: *Traulia azureipennis*, ♂. **A.** Dorsal view of type; **B.** Lateral view of type. Scale = 5 mm.

Traulia borneensis Willemse, 1921

Figure 3.21, Figure 3.23

Traulia borneensis Willemse, 1921: 31; Willemse, 1935: 141; Ramme, 1941 [1940]: 184, 193; Willemse, 1957: 392

Materials examined. 13 specimens (♂: 8, ♀: 5). **BORNEO: EAST MALAYSIA: SABAH: Keningau:** Mount Trus Madi, 30.X.-07.XI.2001, Alt: 1,500 m – 1700 m, Ito Gen, 1♂ (ORT-2492) (UMS). **Kota Kinabalu:** UMS Peak, 20.III.2017, caught by aerial net, Lee Jing Wen, 1♂ (UMS). **Penampang:** Inobong Sub Station, 30.XI.2002, Alt: 450 m, Yusilie K., 1♀ (OR/02/00761) (SPM). **Ranau:** Kg. Singgaron Baru, 22-29.IV.2016, Eksplorasi Hutan Simpan Komuniti, Johny L., 1♂ (SP/EOR/01978) (SPM). Kinabalu Park HQ, 07.IV.2003, Alt: 1,450 m, Norhayani, 1♀ (SP/EOR/00857) (SPM). Kinabalu Park, Sub Stesen Monggis, 05-10.XII.2011, Alt: 360 m, Yusilie K., 1♀ (SP/EOR/01804), Johny L., 1♂ (SP/EOR/01805) (SPM). **Sipitang:** Long Pasia, 22-27.I.2003, Ekspedisi Ulu Padas, Alt: 1,125 m, Johny L., 1♂ (SP/EOR/00853) (SPM). **Tambunan:** Crocker Range National Park, Pos Kawalan Melunggung, 07-12.XI.2011, Alt: 819 m, Johny L., 1♂ (SP/EOR/01795) (SPM). **Tawau:** Balung, 14.V.2006, Yusilie K., 1♀ (SP/EOR/01199) (SPM). Maliau Basin, Agathis Camp, 12-19.V.2001, found on forest floor, Ito Gen & Azrie A., 1♂ (ORT-1265) (UMS). Tawau Hill Park, 24.XI.2000, Yusilie K., 1♂ (OR/01/00654) (SPM); 20-29.VI.2002, Alt: 300 m, Yusilie K., 1♀ (OR/02/00766) (SPM).

Diagnosis. *Traulia borneensis* is recognised by having the following combination of characters: antennae with white tip; tegmina slightly brachypterous, mostly only reaching anterior margin of supra-anal plate; male cerci with apex quadrated; hind femur red medially,

upper marginal area olivaceous green with yellow pre-genicular ring and black hind knee; hind tibia bright red with yellow ring basally, reaching the first outer spine.

Description. Male: Body small to medium, total length 19.66 mm – 22.65 mm. **Colouration:** Generally olivaceous green or brownish black. Head: Front of face with yellow transverse stripes from antennal base, extending laterally to post-gena; dorsum of head with yellow stripes from apex of fastigium to post-occipital margin; palpi yellow. *Antennae*: Dark brown or reddish brown with white tips. Thorax: Dorsum of pronotum with two very thin yellow longitudinal stripes; lateral lobe with yellow stripes on both sides reaching posterior margin of pleuron. *Legs*: Hind femur red medially, upper marginal area olivaceous green with yellow pre-genicular ring and black hind knee; hind tibia bright red with yellow ring basally, reaching the first outer spine. *Wings*: Tegmen black or olivaceous green with two yellow longitudinal stripes dorsally. **Structure:** Body small to moderately long and robust. Head: Sub-rectangular in frontal view; frons oblique, sub-triangular to vertex of head with an angle of over 40 degrees in profile; eyes sub-circular, vertical diameter greater than horizontal width of eye; exceeding the outline of head; eyes slightly higher than vertex of head laterally; distance from anterior margin of eyes to apex of fastigium less than horizontal diameter of eye in profile; inter-ocular distance slightly wider than width of frontal ridge; lateral carinae weakly projected; anterior apex of head slightly projecting forward away from eyes; lacking transverse groove at base of fastigium; apex of fastigium weakly excavated; frontal ridge elongated below median ocellus; frontal costa between antennae obviously projected forward forming an arch above median ocellus in profile; integument above median ocellus and frons are with small and deep punctures. *Antennae*: Longer than the combined length of pronotum and head; filiform-like shaped. Thorax: Prosternal process with simple conical structure, short and straight, apical part of tubercle

rounded; pronotum short and wide, not selliform, pronotum as wide as head dorsally; prozona much longer than metazona; expanding caudally from dorsal view; median carina barely discernible; flat dorsally; straight to almost no trace in profile; crossed by three sulci with shallow impression by principal sulcus and minor transverse sulci; lacking lateral carinae; median posterior margin of pronotum broadly angular; dorsum of pronotum lightly ridged forming numerous small pits, lateral lobe of prozona distinctly punctured; posteroventral margin of lateral lobe angularly projected with an angle of over 90 degrees; anterior border of mesosternum slightly arched, mesosternal lobe laterally wider than vertical length, mesosternal interspace wide, with vertical length as long as basal width, anterior margin of interspace faintly concave to almost straight, inner posterior corner of lobe obtusely round, metasternal interspace short, basal width separated. *Legs*: Upper carinae of hind femur serrated, lower carinae smooth, basal lobe dorsally longer than ventral length, dorsal and ventral genicular lobe roundly angular distally, distal end of dorsal carina acutely pointed; hind tibia lacking outer apical spine, number of spines on outer margin 7, distance between first and second spines on inner margin as long as any other inter-spine distance, distal half of hind tibia not obviously broadened towards apex without obvious edges running through the spines. *Wings*: Tegmen brachypterous, male wings developed in contact with each other above abdomen, distal margin round, cell of distal part long rectangular. Genitalia: Cerci narrowing midway and expanding quadrately at the apex, compressed laterally, curving inwards and upward posteriorly, apex truncated; supra-anal plate scutatiform, furcula very short, small and distinctly separated, basal width with two tubercles near lateral margin; apex of subgenital plate not divided and blunt, very short, vertical length significantly shorter than basal width, not tapering towards apex, lacking tubercle at end of apex.

Female: Larger than male, total length 26.64 mm – 30.93 mm. Colouration, vestiture and texture as in male. **Structure:** Mostly resemble male specimens, body robust. Genitalia: Ovipositor curved in profile; dorsal and ventral valves with equal length laterally; dorsal valves convergent, with one apical tooth, lowly serrulate on the superior margin, apex non-bidentate, lacking notch apically; ventral valves wide, external margins lowly serrated dorsally, weakly constricted in the middle, external lateral teeth not prominently projected outward; subgenital plate slightly triangularly projected in the middle, lacking lateral teeth on posterior margin in ventral view.

Food plant. Unknown.

Ecology. Forest edge (Tan & Wahab, 2018), forest floor and montane forest with 300 m – 1,700 m elevation.

Distribution. Brunei, Malaysia (Sabah) (Willemse, 1957; Tan & Wahab, 2018; Cigliano et al., 2021).

Remarks. *Traulia borneensis* resembles members of the genus with the exceptions of the body colouration and patterns of the hind femora and hind tibiae. Hind femora of this species appeared to be dirty olive on the basal portion, whereas the pre-genicular rings were covered with yellow rings and hind knee were complete black. Hind tibiae were red with yellow ring completely covering the apical region, with black rings on the apex jointed with the knee of hind femora. Plus, tarsi of *T. borneensis* was also red in colour in comparison with *T. azureipennis* and *T. sanguinipes sanguinipes*.

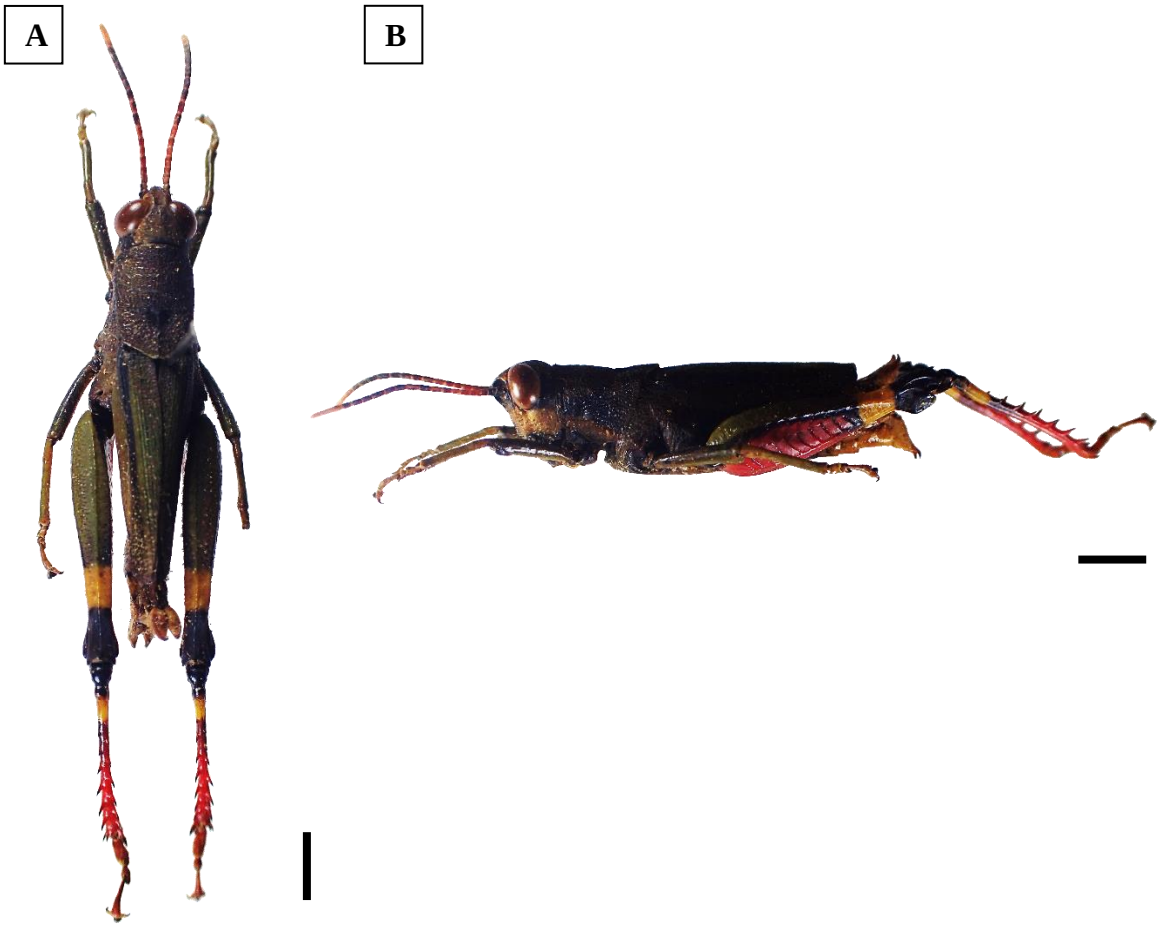


Figure 3.21: *Traulia borneensis*, ♀. **A.** Dorsal view of type; **B.** Lateral view of type. Scale = 5 mm.

Traulia sanguinipes sanguinipes Stål, 1878

Figure 3.22, Figure 3.23

Traulia sanguinipes Stål, 1878: 72; Brunner, 1898: 250, 251; Kirby, 1910: 475; Bolivar, 1917: 610, 630; Willemse, 1921: 28, 33; Willemse, 1935: 141; Ramme, 1941 [1940]: 184, 192; Willemse, 1957: 390

Materials examined. 13 specimens (♂: 6, ♀: 7). **BORNEO: EAST MALAYSIA: SARAWAK: Kapit:** Belaga, Dulit Range, 20.X.1983, Lippa Akeng, 1♀ (FN.83-1147) (RDID). **Kuching:** Bau, Singai, Kg. Atas, 02.III.2018, Bernadine Sara Aras, 1♀ (UIRC).

Kubah National Park, 05.IV.2014, Azmi M. A., 1♂ (UIRC). Stutong, 11.V.2016, Tan Jin Kiet, 1♂ (UIRC). **Marudi:** Baram, Beluru Forest Reserve, 14.VIII.1987, Ainie Ismuni, 1♀ (FN.87-0042) (RDID). **Miri:** Niah, 24.II.1979, A. A. Hamid, 1♂ (FN.01390) (RDID); 16.I.1985, Manis Lintang, 1♀ (FN.85-0139) (RDID); 23.VIII.1985, Mahmud Merdek, 1♀ (FN.85-0807) (RDID); 17.V.1987, Mahmud Merdek, 1♀ (FN.87-0191) (RDID). **Samarahan:** UNIMAS, PITAS, 27.III.2018, Nur Shafarina Md Salleh, 1♀ (UIRC). **Serian:** Annah Rais, 14.IV.2016, Woo Chee Yoong, 1♂ (UIRC). Ranchan Recreation Park, 11.V.2016, Tan Jin Kiet, 1♂ (UIRC). **Simunjan:** Sabal Forest Reserve, 10.X.1997, Ento Team, 1♂ (SFR05881) (RDID).

Diagnosis. *Traulia sanguinipes sanguinipes* can be distinguished from other species of the genus based on the colour of its legs; outer face of hind femur with yellow band on the upper marginal area, red-orange spot on the medial area to lower marginal area basally and red-orange ring before hind knee, inner face of hind femur with reddish orange colouration in the medial area to lower marginal area basally; hind tibia black without any pattern.

Description. Male: Body small to medium, total length 21.01 mm – 23.29 mm. **Colouration:** Body in two forms; black form with bright and clear yellow bands, dark brown form less shiny. Head: Front of face with yellow band transversely from below frontal ocellus and frons, not reaching the anterior margin of clypeus, extending to post-gena; clypeus with yellow transverse line; vertex with two yellow lateral bands from frontal ridge above frontal ocellus reaching post-occipital line; palpi pale yellow. *Antennae*: Dark brown to black with pale or white tip. Thorax: Dorsum of pronotal disc with two lateral yellow bands from the anterior margin of prozona to posterior margin of metazona; lateral lobe on both sides with yellow band from the anterior to posterior margin; metathorax with two

slanted lines reaching the coxae of second and third pair of feet; three yellow spots above the mesosternal and metasternal interspace, and below the metasternal interspace reaching posterior margin of metasternum respectively. *Legs*: Outer face of hind femur with red-orange elongate spot basally from the lower half of medial area to the median area of inner face and red-orange ring before hind knee; hind tibia and tarsi dark brown or black. *Wings*: Tegmen black with two yellow bands dorsally almost reaching apex of wings. *Abdomen*: black or dark brown with a tinge of yellow spots irregularly distributed across the abdomen. **Structure:** Body small and robust. Head: Sub-rectangular in frontal view, frons vaguely sub-triangularly to vertex of head with obtuse angle of over 40 degree in profile; eyes big, long oval, vertical diameter greater than horizontal diameter of eye, exceeding the outline of head, as high as vertex of head laterally, inter-ocular distance much wider than width of frontal ridge, lateral carinae projected with thick ridge, foveolae weakly projected triangularly with irregular depression, distance from anterior margin of eyes to apex of fastigium much shorter than the horizontal diameter of eye in profile, anterior apex of head slightly projecting forward away from eyes dorsally, lacking transverse groove at base of fastigium, apex of fastigium deeply excavated to the vertex of head with median carina vaguely projected to the post-occipital margin; frontal ridge of head elongate towards clypeus; frontal costa between antennae obviously projected forward forming an arch above median ocellus in profile; frontal costa above frontal ocellus with small and deep punctures, frons with thick irregular ridges below scapus and thick ridges forming deep punctures apically. *Antennae*: Longer than the combined length of pronotum and head; filiform-like shaped. Thorax: Prosternal process simple conical structure, short and stout, straight, apex of tubercle rounded; pronotum short and wide, not selliform; width as wide as head but slightly broader on the lateral lobe of metazonal area; prozona much longer than metazona;

expanding caudally from dorsal view and slightly constricted in the middle; median carina barely discernible dorsally, straight with three faint incisions of narrow and very low ridges laterally, crossed by three sulci, pronotal disc with faintly impressed incision by transverse sulci, first and second transverse sulci cutting median carina on dorsum of prozona, shallow incision by principal sulcus, median carina on prozona flat dorsally but with thin, narrow and rounded ridges, lacking lateral carinae; median posterior margin of metazona broadly angular and not concave; pronotal disc strongly carinulated irregularly; dorsum of prozona with thick ridges forming deep punctures, lateral lobe of prozona distinctly wrinkled and irregularly ridges forming irregular punctures; dorsum of metazona with distinctly thickened ridges; posteroventral margin of lateral lobe roundly angular and slightly arched; anterior border of mesosternum very slightly arched, mesosternal lobe laterally wider than vertical length, mesosternal interspace elongated with horizontal length broader than its vertical length, inner posterior corners of lobe obtusely round; metasternal lobe weakly separated medially, almost contiguous. *Legs*: Upper carinae of hind femur prominently serrated, lower carinae smooth, basal lobe slightly longer dorsally compared to its ventral lobe, dorsal and ventral genicular lobe rounded distally, distal end of dorsal carina acutely pointed; hind tibia lacking outer apical spine, number of spines on outer margin 7, distance between first and second spines on inner margin as long as any other inter-spine distance, distal half of hind tibia not obviously broadened towards apex. *Wings*: Tegmen macropterous, male wings developed in contact with each other above abdomen; distal margin round, cell of distal part long rectangular. Genitalia: Cerci expanding and round, compressed laterally, broad, curving inwards and downwards posteriorly, apex of cerci round; supra-anal plate scutatiform, furcula very short forming two obtuse angle with over 40 degree, basal field smooth without any tubercles near lateral margin, lateral groove very faintly developed on the middle field,

lacking transverse groove on middle and apical field, lacking tubercles on sides of middle and apical field, tubercle weakly projected on the apical field; subgenital plate simple conical structure, apex not divided, very short with length slightly shorter than basal width, vaguely tapering towards apex with rounded end, tubercle small and short.

Female: Larger than male, total length 26.84 mm – 31.57 mm. Colouration, vestiture and texture as in male. **Structure:** Mostly resemble male specimens, body robust. Genitalia: Ovipositor curved in profile, dorsal and ventral valves with equal length; dorsal valves weakly convergent, with one apical tooth, lowly serrulate on the superior margin, non-bidentate and lacking notch on apex; ventral valves very narrow, external margins faintly serrated dorsally and weakly constricted laterally in the middle field, external lateral teeth weakly projected outward; subgenital plate weakly triangularly projected posteriorly in the middle, apex bidentate, lacking lateral teeth on posterior margin.

Food plant. Unknown.

Ecology. Unknown.

Distribution. Malaysia (Sarawak) (Cigliano et al., 2021).

Remarks. The male and female of genus *Traulia* at times differ in the colouration and skin texture. Some of the female specimens possessed velvety and hairy dark brown to black body colour, while male of the genus is shiny and glossy dark brown to black colouration. *T. sanguinipes sangunipes* shares certain similarity with members of the genus with the exceptions on the pattern of hind femora and hind tibiae. Hind femora of this species portrayed red circular rings not reaching the anterior margin on the basal region of the femora, and the pre-genicular rings were complete covered with yellow rings and black hind

knees. Apart from that, the difference between the species in comparison with other members of the genus includes the unicolourous dark brown to black hind tibiae.



Figure 3.22: *Traulia sanguinipes sanguinipes*, ♂. **A.** Dorsal view of type; **B.** Lateral view of type. Scale = 5 mm.

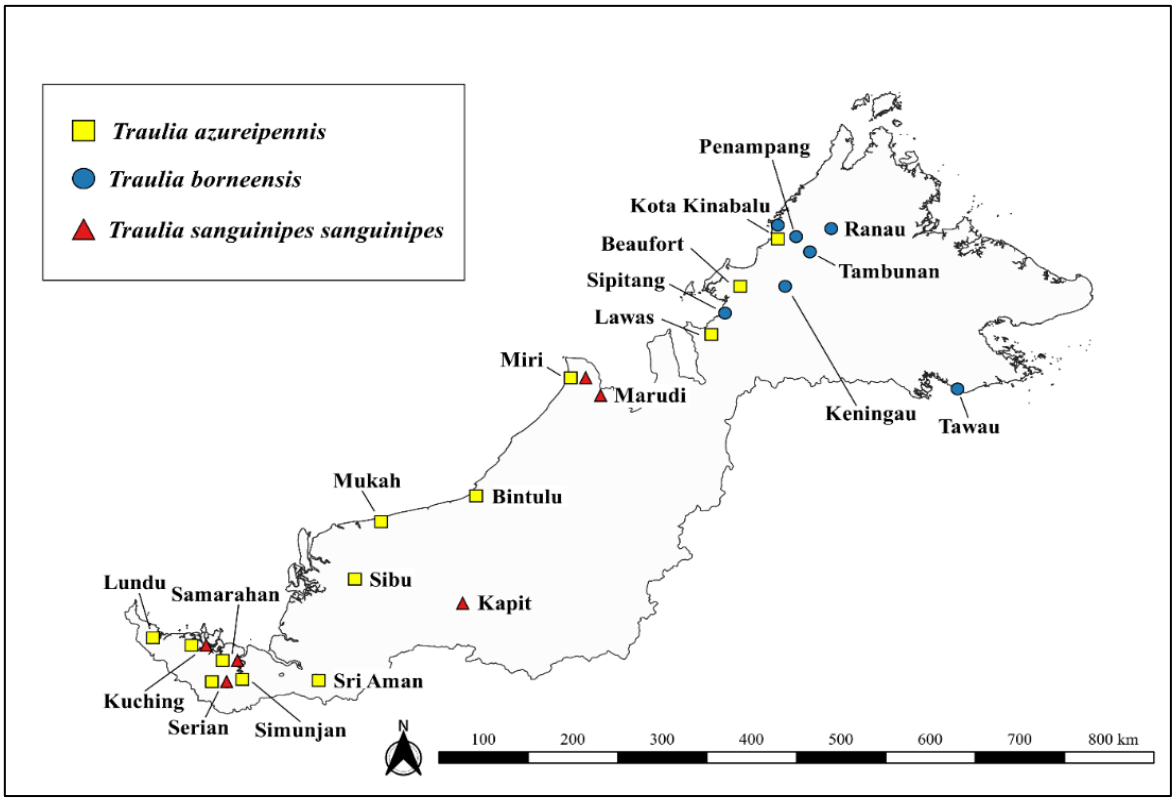


Figure 3.23: Distribution map of genus *Traulia* from subfamily Catantopinae in Malaysian Borneo.

Genus *Xenocatantops* Dirsh, 1953

Xenocatantops humilis (Serville, 1838)

Figure 3.24, Figure 3.25

Acridium humile Serville, 1838: 662; Walker, 1870a: 590

Caloptenus dominans Walker, 1870b: 705

Caloptenus signatipes Walker, 1870b: 706

Caloptenus strictus Walker, 1870b: 707

Cyrtacanthacris punctipennis Walker, 1871: 60

Catantops humilis Stål, 1873: 71; Wattenwyl & Fea, 1893: 162; Bruner, 1915: 255 (61); Karny, 1915: 88; Uvarov, 1929: 561; Willemse, 1930: 195

Xenocatantops humilis humilis Dirsh & Uvarov, 1953: 237

Catantops (Xenocatantops) humilis Willemse, 1957: 472

Materials examined. 130 specimens (♂: 60, ♀: 70). **BORNEO: EAST MALAYSIA: SARAWAK: Bintulu:** Bintulu, 17.I.2004, Zhe Ling Ling, 1♀ (UIRC). Jelalong, Sg. Mayop, 28.X.2000, Ento Team, 1♀ (FN.00-1461), 3♂ (FN.00-1459, FN.00-1465, FN.00-1525) (RDID). Labang Forest Reserve, 12.I.1985, Manis Lintang, 1♂ (FN.85-0112) (RDID); 24.XI.1989, caught in flight, Jamil, 1♀ (RDID). Sg. Sibiyu, 10.I.1985, Lippa Akeng, 1♂ (FN.85-0062) (RDID). **Kuching:** Bako National Park, 21.IX.1985, Ento Team, 1♀ (RDID). Batu Kawa, 16.II.2000, Jessie, 1♀ (UIRC). Bau, Adis Buan, 15.III.2019, Adi Azizan, 1♀ (UIRC). Bau, Dered Krian National Park, 27.IX.2016, Ento Team, 1♂ (DKNP0027) (RDID). Bau, Fairy Cave, 20.IV.2016, Clementine M. & Nickitta D., 1♀ (UIRC). Bau, Gunung Singai, 10.III.2018, Amanda Wilson, 1♀, Kong Zhi Kent, 1♀ (UIRC). Bau, Serikin, 26.III.2016, Ooi Yee Min, 1♂ (UIRC). Matang, 09.XII.2003, Ratnawati H., 1♀ (UIRC). Matang, Gunung Serapi, 08.V.1979, C. W. L Mercer & E. T. Yeo, 2♀ (FN.01648, FN.01649) (RDID); 05.IV.1983, Lippa Akeng, 1♂ (FN.83-0692) (RDID); 11.XII.1984, Peter, Lippa & Rahman, 1♂ (RDID); 10.II.1989, attracted to lights, Wong & Joheng, 1♀ (RDID). Padawan, Gunung Regu, 19.VIII.2009, Insect Group, 2♀ 1♂ (UIRC). Semariang, 01.V.2016, Nur Zakirah Jasni, 1♂ (UIRC). Sri Muara, 06.II.2000, Volianta, 1♀ (UIRC). **Lundu:** Gunung Gading National Park, 13.VII.1987, Ento Team, 1♂ (FN.87-0331) (RDID); 13.IV.2017, Nur Najlaa Nabilah Mohammed, 1♂ (UIRC). Sampadi Forest Reserve, 12.VIII.1987, Ento Team, 1♀ (FN.87-0346) (RDID). Samunsam Wildlife Sanctuary,

24.IX.1988, Lippa Akeng, 1♀ (FN.88-0611), 2♂ (FN.88-0612, FN88-0613) (RDID). Sematan, 22.III.1997, caught at night, Wan Ali, 1♂ (UIRC). Sematan Beach Forest, 19.V.1984, Haidir Nusi, 1♂ (RDID). Tanjung Datu, 25.X.2000, Ento Team, 1♀ (FN.00-1927) (RDID). **Miri:** Lambir Hills National Park, 22.I.1999, caught by UV light, Ento Team, 1♀ (H0018) (RDID). Niah, 29.III.1984, Ento Team, 1♀ (FN.84-0371) (RDID); 31.III.1984, Manis Lintang, 1♀ (FN.84-0437), 1♂ (FN.84-0436) (RDID); 01.IV.1984, Lippa Akeng, 2♂ (FN.84-0536, FN.84-0537) (RDID); 09.III.1989, Mahmud Merdek, 1♂ (FN.89-0044) (RDID). **Samarahan:** Kota Samarahan, 07.VII.2002, Ang Swee Kim, 1♀ (UIRC); 11.II.2003, Camel, 1♀ (UIRC); 12.I.2004, Joshua Juan, 1♀ (UIRC); 02.II.2010, Nas' Aqilah Ismail, 1♀ (UIRC). Muara Tuang, 13.VI.1984, Lippa, A. Rahman & Bunsu, 1♀ 1♂ (RDID). Sadong Jaya, 18.VII.2019, Ento Team, 3♀ 1♂ (UIRC); 19.VII.2019, Ento Team, 1♂ (UIRC); 20.VII.2019, Ento Team, 1♀ (UIRC). UNIMAS, 28.I.1995, 1st year student, 1♀ (O1136) (UIRC); 05.III.1997, Pauline Liew, 1♀ (UIRC); 03.I.2000, Maria, 1♀ (UIRC); 03.II.2000, Winnie, 1♀, Norlida, 1♀ (UIRC); 27.VII.2002, Aini, 1♂ (UIRC); 15.VIII.2002, Tan Siew Khim, 1♀ (UIRC); 08.XII.2003, James Boyd J., 1♀ (UIRC); 15.III.2016, Nur Nadhirah, 1♀ (UIRC); 17.III.2016, Marina Maliyana, 1♀ (UIRC); 16.IV.2017, F. Ustar, F. Bakri, I. Ismail, 1♂ (UIRC); 02.III.2018, Azyyati Azizi, 1♀ (UIRC); 21.III.2018, Ahmad Faiz, 1♂ (UIRC); 19.II.2019, Ketty Loh Siew Lan, 1♀ (UIRC); 07.III.2019, Lee Chin Woon, 1♀ (UIRC). UNIMAS, External Laboratory, 24.XI.2017, Kathleen M. I., 1♀ (UIRC). UNIMAS, Kolej Bunga Raya, 17.IV.2017, Shirly Olvy Sumil, 1♂ (UIRC). UNIMAS, Kolej Rafflesia, 28.II.2018, Shahaidatul Amirah, 1♀ (UIRC). UNIMAS, PITAS, 07.V.2016, Nur Hassanah Hassan, 1♂ (UIRC); 12.IV.2017, Athirah, 1♀ (UIRC); 28.II.2019, Annebel, 1♀ (UIRC). **Sarikei:** Bintagor, 21.III.2009, Boon Siaw Khim, 1♀ (UIRC). **Serian:** Serian, 02.IV.2016, Faridah & Hazwani, 1♀ (UIRC). Balai Ringin P. I., 17.XI.1998, Ento Team,

1♀ 2♂ (RDID); 18.XI.1998, Ento Team, 1♀ (RDID); 19.XI.1998, Ento Team, 1♂ (RDID). Semenggoh, 16.III.1979, A. A. Hamid, 1♀ (FN.01374) (RDID); 03.XII.1982, feeding on the grass, Badery Suad, 1♀ (RDID). Semenggoh, Ulu Landeh, 26.I.1984, caught at agricultural plot, Ento Team, 2♀ (FN.84-0029, FN.84-0030) (RDID). **Simunjan:** Sabal Forest Reserve, 21.X.1982, A. A. Hamid, 1♂ (FN.82-223) (RDID); 10.XI.1982, Ento Team, 1♂ (FN.82-0704) (RDID); 27.XI.1983, Lippa Akeng, 2♀ (FN.83-1292, FN.83-1294), 1♂ (FN.83-1293) (RDID); 01.XII.1983, Ento Team, 1♀ (FN.83-1267) (RDID); 17.V.1984, Ento Team, 1♀ (FN.84-0926) (RDID); 18.V.1984, Ento Team, 1♀ (FN.84-0924) (RDID); 19.V.1984, Ento Team, 2♂ (FN.84-0923, FN.84-0932) (RDID); 20.V.1984, Ento Team, 1♀ (FN.84-0925) (RDID); 10.I.1997, Ento Team, 1♀ (SFR01802) (RDID); 17.III.1997, Ento Team, 1♂ (SFR03198) (RDID); 31.III.2014, Ento Team, 1♂ (GC3573) (RDID); 26.VI.2014, Ento Team, 2♂ (GC4531, GC4633) (RDID); 03.III.2015, Ento Team, 2♀ (GC5593, GC5617), 6♂ (GC5591, GC5592, GC5618 – GC5621) (RDID). **Sri Aman:** Lingga, 15.IV.2017, Nur Nabihah Mohd Tinin, 1♂ (UIRC). SK. Jaong, 13.IV.2016, Hazel Annessa Doblin, 1♂ (UIRC). **SABAH: Keningau:** Taman Banjaran Crocker, Liawan River, 27.III.1996, Gunik G., 1♂ (OR/96/00168) (SPM). **Kota Kinabalu:** Bukit UMS, 01.V.2017, caught on leaves by aerial net, Lia M., 1♂ (UMS); 13.V.2017, caught by aerial net, Rechyana, 1♂ (UMS). Kionsom, 21.I.2001, transect manual, Junainah & Jamu, 1♀ (ORT-1091) (UMS). UMS, ITBC, 22.II.2017, caught by sweep net, Tan Qin Zhi, 1♂ (UMS); 23.IV.2017, caught by aerial net, Cheh Wai Mun, 1♂ (UMS); 13.XI.2017, caught in forest by sweep net, Amiruddin, 1♂ (UMS). Pulau Gaya, 18.XII.1998, Johny L., 1♀ (OR/98/00170) (SPM); 19.V.1999, Johny L., 1♀ (OR/99/00144) (SPM). Pulau Manukan, 18.V.1999, Johny L., 1♂ (OR/99/00167) (SPM). **Kota Marudu:** Kg. Kandawayon Tagas, 19.IV.2017, caught by aerial net, Arlinie Jim, 1♂ (UMS). Sub Station Sorinsim, 07.XII.2001, Johny L., 1♂

(OR/01/00696) (SPM). **Kudat:** Pulau Balambangan, 20-29.V.2003, Ekspedisi Tun Mustafa, Zoology Unit, 1♀ (SP/EOR/01311) (SPM). **Penampang:** Inobong Sub Station, 28.XI.2002, Zoology Staff, 1♂ (OR/02/00781) (SPM). **Semporna:** Pulau Bohey Dulang, 17.XI.1998, Johny L., 1♀ (OR/98/00172) (SPM). Pulau Bohey Dulang, Taman Merin Tun Sakaran, 03.VII.2006, Johny L., 1♀ (SP/EOR/01279) (SPM). **Tenom:** Kg. Purulon Tenom, 11.XI.1998, Yusilie K., 1♂ (OR/98/00169) (SPM).

Diagnosis. *Xenocatantops humilis* is recognised by the following combination of characters: lateral lobes of pronotum without yellow spots; hind femur with two transverse dark brown bands on the outer face, inner face reddish orange; hind tibia reddish orange; male subgenital plate short, apex obtusely pointed.

Description. Male: Body small to medium, total length 20.22 mm – 25.40 mm. **Colouration:** Ground colour brownish yellow or dark brown with occasional irregular dark spots. *Antennae*: Pale brownish yellow to brownish red. Thorax: Pale to dark brown with no distinct pattern. *Legs*: Hind femur pale yellow or dark brown, outer face with two transverse black bands, inner face reddish orange; hind tibia and tarsi reddish orange. *Wings*: Tegmen dark brown with pale irregular small spots distributed unevenly on tegminal surface. **Structure:** Body small and robust. Head: **S**ub-rectangular in frontal view, frons vaguely sub-triangularly to vertex of head with an obtuse angle of over 40 degree in profile; eyes big, long oval, vertical diameter greatly longer than horizontal diameter of eye, exceeding the outline of head, eyes slightly higher than vertex of head laterally, inter-ocular distance narrower than the width of frontal ridge, lacking foveolae, lateral ocellus big, lateral carina with thick ridge not reaching apex of fastigium, distance from anterior margin of eyes to apex of fastigium much shorter than the horizontal diameter of eye in profile, anterior apex

of head linear and quite close to eyes forming vertically elongated isosceles trapezoid shape dorsally, lacking transverse groove at base of fastigium, fastigium not excavated but vertex of head with shallow groove formed by thick lateral carinae; frontal ridge of head elongated towards clypeus; frontal costa between antennae slightly projected forward, forming weak arch above median ocellus in profile; frontal costa above frontal ocellus with small and deep punctures, frons with deep and thick punctures. *Antennae*: Longer than the combined length of pronotum and head; filiform-like shaped. Thorax: Prosternal process cylindrical, short and stout, straight; pronotum saddle-shaped; longer and slightly wider than head; prozona slightly longer than metazona; expanding caudally from dorsal view and slightly constricted in the middle with metazonal area fairly wider and broader than the prozona; median carina barely visible dorsally, straight with three faint incisions of narrow and very low ridges laterally, crossed by three sulci, pronotal disc with shallowly impressed incision by transverse sulci, first and second transverse sulci cutting the median keel on dorsum of prozona, slightly impressed incision by principal sulcus, median carina on prozona flat dorsally with thin, narrow and rounded ridges, lacking lateral carinae; median posterior margin of metazona broadly angular and not concave; pronotal disc irregularly punctured; dorsum of prozona with deep punctures, lateral lobe of prozona distinctly wrinkled forming irregular ridges; dorsum of metazona with ridges forming numerous small pits; posteroventral margin of lateral lobe roundly angular and vaguely arched with an angle of slightly over 90 degrees; mesosternum slightly shorter than metasternum ventrally; anterior border of mesosternum straight, mesosternal lobe laterally much wider than vertical length, mesosternal interspace with equal length of horizontal and vertical length, anterior margin of interspace widely concave almost straight, with extended transverse line parallel to the posterior margin almost reaching the margin of sternum, inner posterior corners of lobe

obtusely round; metasternal lobe contiguous. *Legs*: Upper carinae of hind femur prominently serrated, lower carinae smooth, basal lobe slightly longer dorsally compared to the ventral lobe, dorsal and ventral genicular lobe rounded distally, distal end of dorsal carina spined, narrowly obtuse-angular; hind tibia lacking outer apical spine, number of spines on outer margin 9 to 10, distance between first and second spines on inner margin as long as any other inter-spine distance, distal half of hind tibia not obviously broadened towards apex. *Wings*: Tegmen macropterous, male wings developed in contact with each other above abdomen; distal margin round, cell of distal part long rectangular. Genitalia: Cerci narrowing towards apex, slightly compressed laterally, highly elongated and curving inwards and slightly upward posteriorly, apex of cerci slightly bifurcated; supra-anal plate triangular, elongate, furcula very short to almost absent, basal field smooth without tubercles near lateral margin, lateral groove deeply developed on the middle field, lacking transverse groove on middle and apical field, lacking tubercles on sides of middle and apical field; subgenital plate with simple conical structure, apex not divided, short with length equal to basal width, gradually tapering towards apex with rounded end, tubercle small and short.

Female: Larger than male, total length 27.83 mm – 39.02 mm. Colouration, vestiture and texture as in male. **Structure:** Mostly resemble male specimens, body robust. Genitalia: Ovipositor curved in profile, dorsal and ventral valves with equal length; dorsal valves convergent dorsally, with one apical tooth, very weakly serrulate on the superior margin, non-bidentate and lacking notch on apex; ventral valves very narrow and long, external margins weakly serrated dorsally and strongly constricted laterally in the middle field, external lateral teeth obtusely angular and obviously projected outward; subgenital plate strongly triangularly projected posteriorly in the middle, lacking lateral teeth on posterior margin.

Food plant. Cacao, coconut, coffee, groundnut, kapok, mulberry, rice, rubber, cover crops in rubber plantations such as *Calopogonium mucunoides*, *Centrosema pubescens*, *Desmodium ovalifolium*, *Moghania macrophylla* and *Pueraria phaseoloides*, sweet potato, teak and tobacco (Roffey, 1979; COPR, 1982; Willemse, 2001).

Ecology. Agricultural plot, forest edge, formerly cultivated land, gardens and plantations, grasses and herbs, old secondary forest, open grasslands, paddy clearing, rain forest, rice fields, streams (C. Willemse, 1938; Roffey, 1979; COPR, 1982; L. Willemse, 2001; Tan & Kamaruddin, 2016).

Distribution. Andaman Islands, Bangladesh, Brunei, China, eastern India, Indonesia, Malaysia, Myanmar, Nepal, the Philippines, Singapore, Sri Lanka, Thailand, Vietnam (C. Willemse, 1938; F. Willemse, 1968; Roffey, 1979; COPR, 1982; L. Willemse, 2001; Mahmood et al., 2007; Tan, 2010a, 2010b, 2012; Tan & Kamaruddin, 2016; Cigliano et al., 2021).

Remarks. *Xenocatantops humilis* portrays similar physical features with *Heteropternis obscurella*, such as the stouter body shape, brownish body colouration, red hind tibiae and vague pale and dark spots on forewings with the exceptions of the dark transverse bands on hind femora that is not present on *H. obscurella*. Apart from that, the head of *X. humilis* does not reclinate above the pronotal disc from lateral view which is eminent in *H. obscurella*.

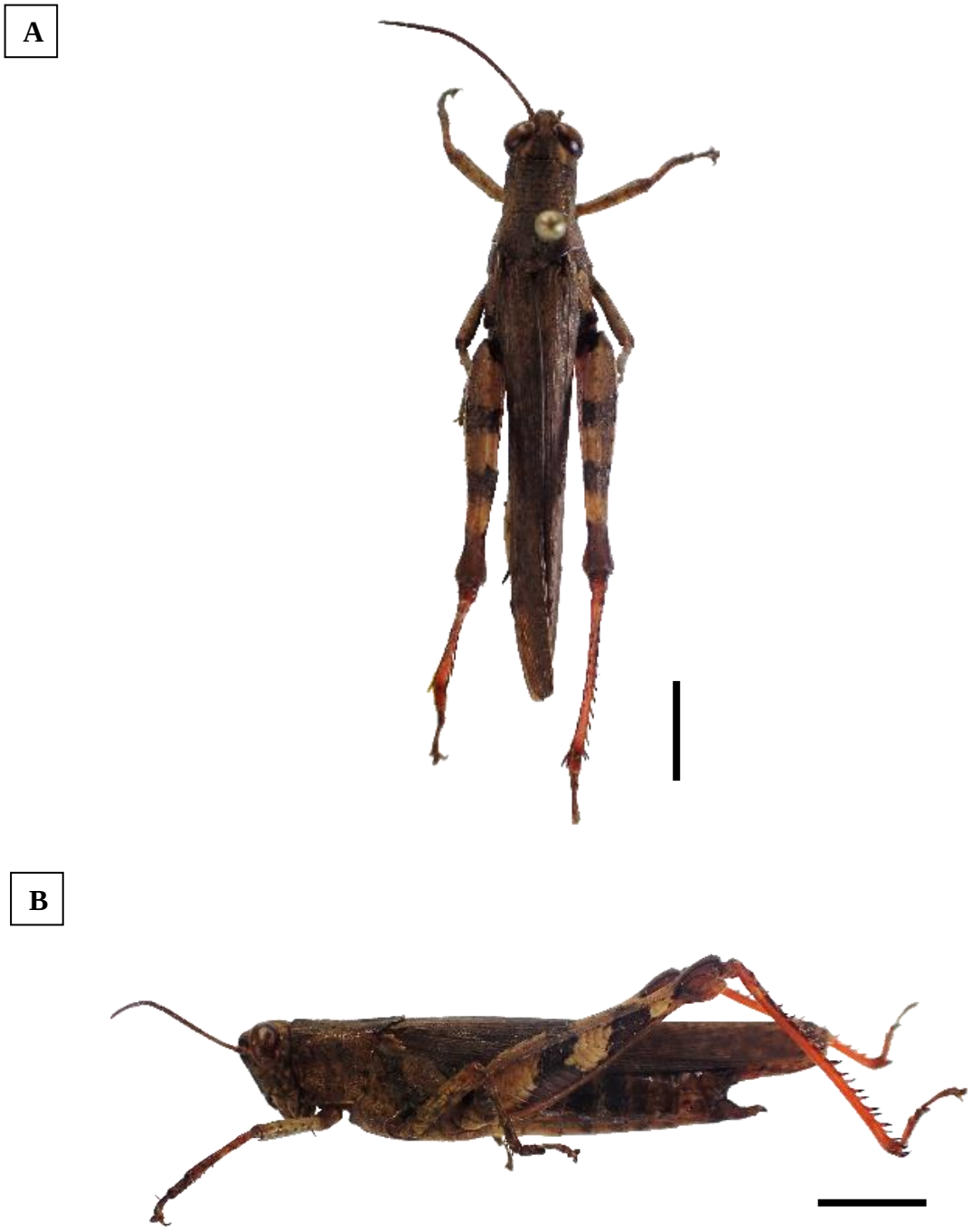


Figure 3.24: *Xenocatantops humilis*, ♀. **A.** Dorsal view of type; **B.** Lateral view of type. Scale = 5 mm.

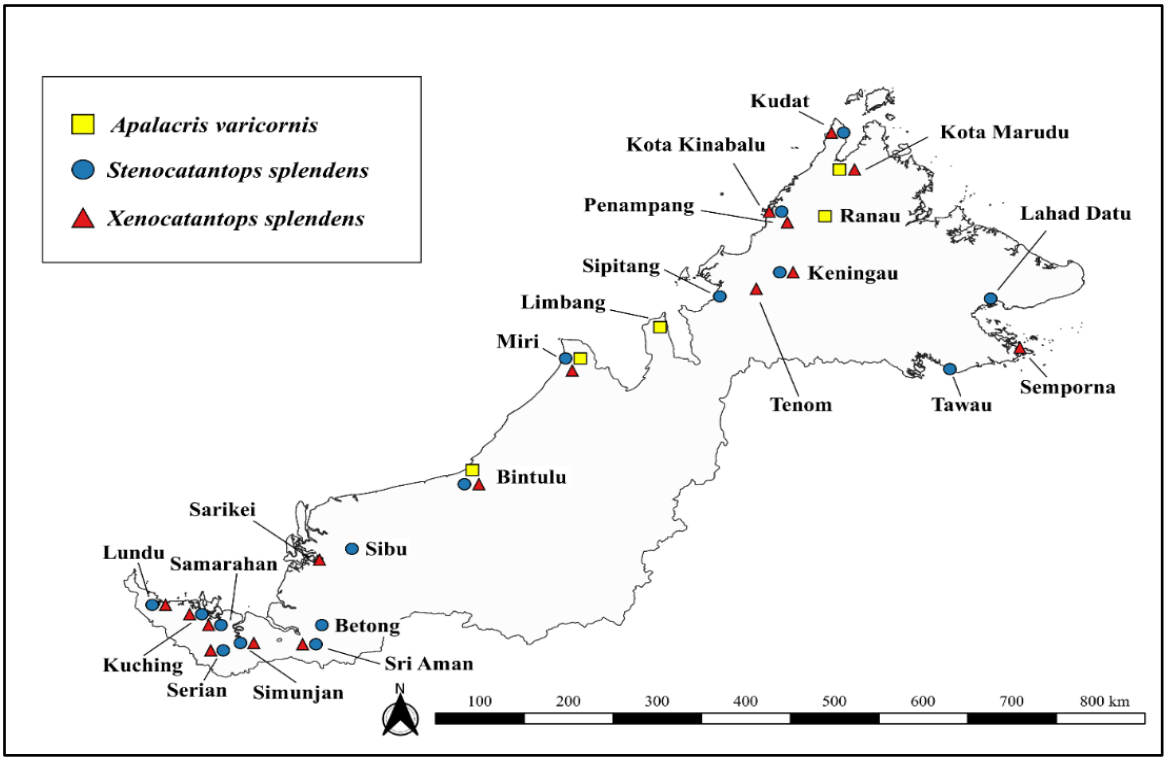


Figure 3.25: Distribution map of *Apalacris varicornis*, *Stenocatantops splendens* and *Xenocatantops humilis* from subfamily Catantopinae in Malaysian Borneo.

Subfamily Cyrtacanthacridinae Kirby, 1910

Genus *Patanga* Uvarov, 1923

Diagnosis. Body size large and long; antennae filiform, reaching beyond the posterior margin of pronotal disc; head slightly reclinate from dorsal view, lateral carinae between median ocellus with prominent ridges, inter-ocular distance is as broad or broader than the width of frontal ridge; pronotum constricted in the prozona, surface coarsely punctate, anterior margin of pronotum slightly rounded or obtusely angulate, median carinae slightly raised, lateral carinae missing, transverse sulci shallowly impressed, posterior margin of pronotal disc broadly angular; prosternal process straight, narrowing towards apex and long but not reaching the sternum; anterior margin of mesosternum straight, mesosternal lobe vertically longer than its horizontal width with inner margins prominently angulate,

metasternal interspace distinctly contiguous in males and slightly separated in female; tegmina long, almost reaching the last segments of tarsi; hind femora slender and long, almost reaching the tip of abdomen, hind tibiae with 8 to 9 spines on outer margins, without outer apical spine; male cerci elongated, laterally compressed, curved inwards and downwards apically, narrowing towards apex with tip rounded; female supra-anal plate scutatiform with apex rounded or obtuse, ovipositor valves weakly serrulate, subgenital plate triangularly projected posteriorly in the middle.

Patanga luteicornis (Serville, 1838)

Figure 3.26, Figure 3.29

Acridium luteicorne Serville, 1838: 658

Cyrtacanthacris luteicornis Kirby, 1910: 452

Patanga luteicornis Uvarov, 1923: 364; Willemse, 1957: 297

Materials examined. 45 specimens (♂: 24, ♀: 21). **BORNEO: EAST MALAYSIA: SARAWAK: Bintulu:** Labang Forest Reserve, 29.I.1986, Manis Lintang, 1♂ (FN.86-0049) (RDID); 12.XII.1988, attacking paddy and *Acacia mangium* seedling, Ento Team, 1♀ (FN.88-0942), 6♂ (FN.88-0941, FN.88-0943, FN.88-0944, FN.88-0946, FN.88-0947) (RDID). **Lundu:** Sematan, Oil Palm Plantation, 26.IV.2012, caught by light trap, Ento Team, 1♂ (GC2699) (RDID). **Miri:** Lambir Hills National Park, 24.X.1998, caught by UV light, Ento Team, 1♂ (G0122) (RDID); 18.IX.2003, LUBL Project, Kishimoto-Yamada & Itioka, 1♂ (ZB5C-013) (RDID); 19.IX.2003, LUBL Project, Kishimoto-Yamada & Itioka, 1♂ (ZT1A-013) (RDID). Niah, 19.I.1985, Manis Lintang, 1♀ (FN.85-0227) (RDID);

22.VIII.1985, Lippa Akeng, 1♂ (FN.85-0800) (RDID). **Samarahan:** Academia Lane, 10.IV.2017, Tang Yong Shuan, 1♀ (UIRC). UNIMAS, 03.III.1997, Fung, 1♀ (UIRC); 27.I.2000, Noridah, 1♀ (UIRC); 06.XII.2000, Ezani Afzan, 1♀ (UIRC); 29.III.2009, Mary B. Balang, 1♂ (UIRC); 29.I.2010, Leow Tze Chin, 1♂ (UIRC); 15.IV.2015, Fatin, Inda, Nurul & Samiyah, 1♀ (UIRC); 29.IV.2015, Ghazali Muslim, 1♀ (UIRC); 20.X.2015, Khatijahraudah, 1♂ (UIRC); 17.III.2016, Izzah H. & Adilla M., 1♂ (UIRC); 06.IV.2019, Julius Gandhi, 1♂ (UIRC). UNIMAS, Basketball Court, 03.XII.2003, Sandra leg., 1♀ (UIRC). UNIMAS, East Campus, 27.III.2010, Mathew Jenang, 1♀ (UIRC). UNIMAS, PITAS, 09.X.2015, Aina Syakirah, 1♂ (UIRC). **Serian:** Kg. Sebangkoi, 20.IV.2013, Tracy Pail, 1♀ (UIRC). **Sibu:** Oya, 17.XII.1982, Ento Team, 1♂ (FN.82-0774) (RDID). **Simunjan:** Hua Hin Sdn. Bhd., 24.II.1992, Ento Team, 1♂ (FN.92-0040) (RDID). Sabal Forest Reserve, 30.I.1983, Lippa Akeng, 1♀ (FN.83-0021) (RDID); 19.V.1984, Ento Team, 1♂ (FN.84-0902) (RDID); 09.III.1998, Ento Team, 1♀ (SFR06736) (RDID); 13.IV.2000, caught by light trap, Ento Team, 1♀ (FN.00-0675) (RDID). **Sri Aman:** Lingga, Bukit Lesung, 17.III.1991, Sarkawi & Wan Khata, 1♂ (FN.91-0027) (RDID); 23.III.1991, Sarkawi & Wan Khata, 1♀ (FN.91-0070) (RDID). Sri Aman, 21.I.2004, Emylda Dino, 1♀ (UIRC). **SABAH: Beaufort:** Ulu Membakut, 17.II.2000, Alt: 220 m, Sinail D., 1♀ (OR/2000/00521) (SPM). **Keningau:** Nabawan, Sepulot, 23.V.1998, David Kung, 1♂ (ENT:4905) (SM). **Kota Belud:** Kg. Kiau Nuluh, 07.II.2000, Johny L., 1♀ (OR/2000/00530) (SPM). **Ranau:** Kg. Kimolohing, 24.XI.1998, Sulastri S., 1♀ (OR/98/00118) (SPM). Kinabalu Park, Sorinsim, 11-14.III.2010, Muzamil Mustaffa & Hong Men Chin, 1♂ (UMS). **Sandakan:** Telupid, Imbak Valley, 05.VII.2000, Yusilie K., 1♀ (OR/00/00588) (SPM). **Sipitang:** Long Pasia, 20-24.II.2012, Ekspedisi Long Pasia, Alt: 1,100 m, Johny L., 1♀ (SP/EOR/01912) (SPM).

Diagnosis. *Patanga luteicornis* is recognised by having the following combination of characters: body slender and long; body uniformly green; front of face with two longitudinal stripes from inner lateral margin of eyes to posterior margin of mandible; dorsum of head with one longitudinal yellow stripe from fastigium to posterior margin of pronotum; anterior margin of pronotum smoothly round to weakly arched; hind wing pinkish basally; distal end of dorsal carina in hind femora with narrowly obtuse-angular spine; hind tibiae reddish-orange.

Description. Male: Body long, total length 43.25 mm – 53.97 mm. **Colouration:** Almost uniformly green with brown abdominal segments. Head: Olivaceous green; front face with yellow longitudinal stripes from inner lateral margin of eyes to posterior margin of mandible; dorsum of head with one yellow longitudinal stripe narrowing from post-occipital margin to vertex of head slightly smudging on fastigium. *Antennae*: Dark brown. Thorax: Olivaceous green with a yellow longitudinal stripe from anterior to posterior margin of pronotal disc; sternum greenish to yellowish brown. *Legs*: Fore femora olivaceous green; fore tibiae and tarsi reddish brown; hind femur green; hind tibia and tarsi reddish orange, spines yellow basally, black apically. *Wings*: Tegmen greenish basally, hyaline apically; hindwing pinkish basally, hyaline throughout. **Structure:** Body long and slender. Head: Face longer than height of pronotum laterally; sub-rectangular in frontal view; frons slightly oblique, almost right angular to vertex of head in profile; eyes long oval, with vertical diameter significantly greater than its horizontal diameter laterally; not exceeding the outline of head dorsally; eyes lower than vertex of head in profile; inter-ocular distance with equal width of frontal ridge; lateral carinae weakly projected adjacent to anterior margin of compound eyes; lacking foveolae; distance from anterior margin of eyes to apex of fastigium shorter than horizontal diameter of eye in profile; anterior apex of head linear and close to eyes dorsally, forming

vertically elongated isosceles trapezoid with lateral carinae; lacking transverse groove at base of fastigium; fastigium not excavated; integument above frontal ocellus with wide punctures proportionally like the surface of a golf ball; frontal ridge elongate below frontal ocellus reaching clypeal margin; frontal costa between antennae not obviously projected forward and not forming discernible arch below median ocellus in profile; frons distinctly punctured with deep holes. *Antennae*: Longer than the combined length of head and pronotum, filiform-like shaped. Thorax: Prosternal process sub-cylindrical, gradually narrowing towards apex, long and thick, but not reaching anterior margin of mesosternum, slightly compressed laterally, straight, apex rounded; pronotum saddle-like, slightly resembling the hour-glass shape; head slightly wider than pronotal width, but significantly shorter than length of pronotum in dorsal view; expanding caudally and slightly constricted in prozona; median carina almost complete but distinctly visible; flat dorsally; straight and present as low ridge in profile; crossed by three sulci with shallow incision by principal sulcus and minor transverse sulci; lacking lateral carinae; median posterior margin of metazona broadly angular; anterior margin of prozona smoothly round to weakly arched; surface of pronotum coarsely carinulated and punctured; dorsum of prozona with irregularly wrinkled and thickened ridges forming honeycombed sculpture, lateral lobe distinctly wrinkled; dorsum of metazona with thickened ridges forming numerous small pits; posteroventral margin of lateral lobe roundly angular with an angle of over 90 degrees; sternum long; anterior border of mesosternum straight, mesosternal lobe significantly longer vertically than its basal width; mesosternal interspace elongate with vertical length longer than basal width, anterior margin of interspace straight; inner posterior corners of lobe acutely angular; metasternal interspace cordiform, completely contiguous. *Legs*: Upper carinae of hind femur distinctly serrated with blunted spines, lower carinae smooth; basal

lobe with equal length of dorsal and ventral lobe, dorsal and ventral genicular lobe rounded distally, distal end of dorsal carina with narrowly obtuse-angular spine; hind tibia lacking outer apical spine, number of spines on outer margin 8 to 9, distance between first and second spines on inner margin as long as any other inter-spine distance, distal half of hind tibia not obviously broadened towards apex without obvious edges running through the spines. *Wings*: Tegmen macropterous; wings developed in contact with each other basally above abdomen; apex rounded; cell of distal part sub-rectangular. Genitalia: Cerci S-shaped in profile, elongated, curving inwards and downwards apically, narrowing towards apex, compressed laterally, apex rounded; supra-anal plate scutatiform, apex not divided with two tubercles on both sides of apical field, basal field with obtuse-angular tubercles, almost rounded, lacking furcula, lateral groove medially forming slopes on both sides of the field, two small tubercles on each sides of middle field; subgenital plate simple conical structure; apex not divided; long with vertical length greater than basal width ventrally, strongly tapering apically with pointed but rounded apex; lacking tubercle at end of apex.

Female: Larger than male, total length 56.74 mm – 72.59 mm. Colouration, vestiture and texture as in male. **Structure:** Mostly resemble male specimens, body long and slender. Genitalia: Ovipositor long and curved apically in profile, dorsal valves slightly longer than the ventral valves; dorsal valves slightly converging dorsally, with one apical tooth, weakly serrulated on the superior margin, non-bidentate and lacking notch on apex; ventral valves very narrow, external margins weakly serrated and constricted laterally in the middle, external lateral teeth weakly projected outward; subgenital plate triangularly projected posteriorly in the middle, lacking lateral teeth on posterior margin of the plate.

Food plant. This species has been reported as minor pest of coconut, coffee, rice, and sugar cane (Grist & Lever, 1969; Roffey, 1979; COPR, 1982; Willemse, 2001) and were sighted attacking paddy field and *Acacia mangium* seedling .

Ecology. Grasslands, rice fields (Roffey, 1979; COPR, 1982; Willemse, 2001) and sometimes occurring around the montaneous forests with 220 m – 1,100 m elevation.

Distribution. Indonesia, Malaysia, the Philippines, Singapore, Thailand (Uvarov, 1923; Roffey, 1979; COPR, 1982; Willemse, 2001; Cigliano et al., 2021).

Remarks. The key difference between *Patanga luteicornis* and *P. succincta* lies in the body colouration of each species. *P. luteicornis* is homogeneously green or greenish brown with reddish-orange hind tibia while *P. succincta* is usually pale yellow to dark brown in colour. Additionally, other dissimilarities found in both species are the structure of frontal ridge and pre-ocular ridge of *P. luteicornis* that is slightly less projected from dorsal view compared to *P. succincta*, and the body size of *P. luteicornis* that is physically a lot slender than the other, although both species were known to be long and slender species.

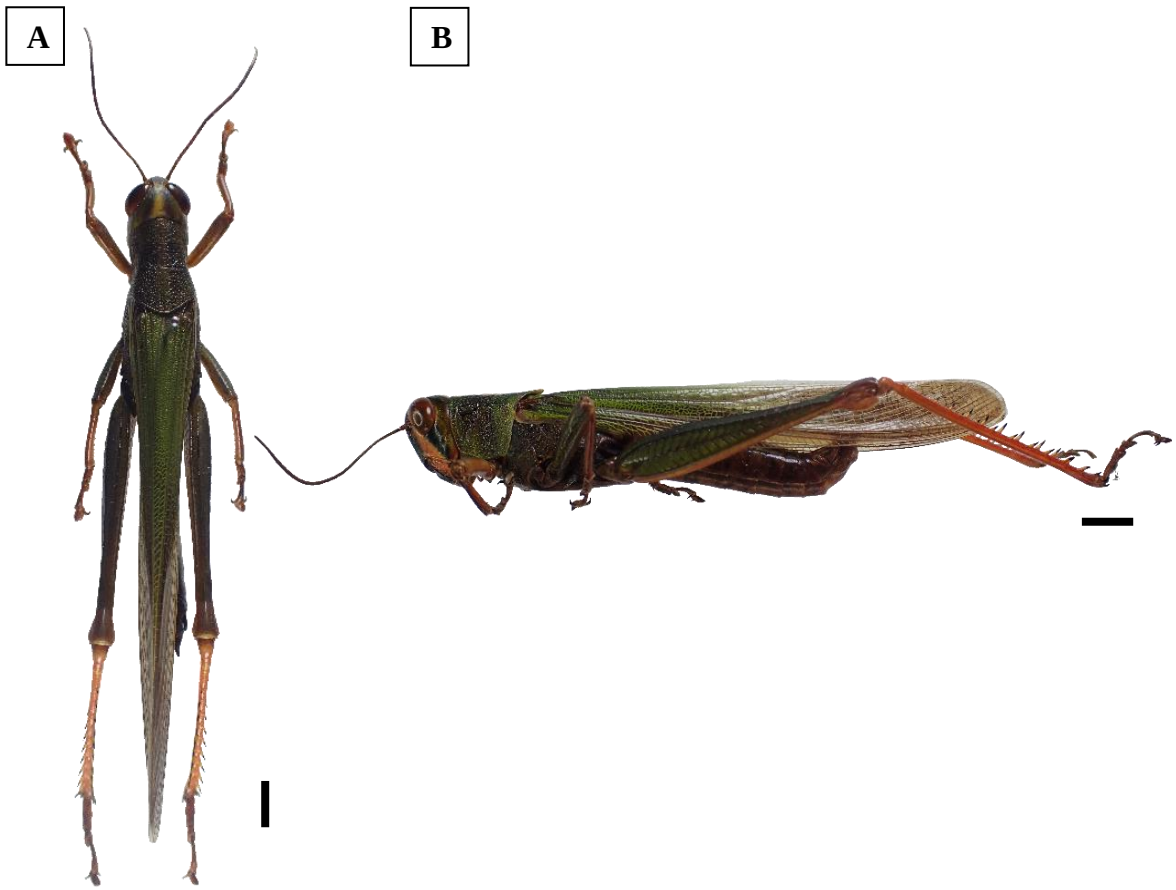


Figure 3.26: *Patanga luteicornis*, ♀. **A.** Dorsal view of type; **B.** Lateral view of type. Scale = 5 mm.

Patanga succincta (Johannson, 1763)

Figure 3.27, Figure 3.29

Gryllus (Locusta) succinctus Linnaeus, 1763: 398

Gryllus (Locusta) succinctus Linnaeus, 1767: 699

Cyrtacanthacris fusilinea Walker, 1870a: 564

Cyrtacanthacris inficita Walker, 1870a: 565

Acridium rubescens Walker, 1870a: 586

Acridium succinctum Walker, 1870a: 588

Acridium elongatum Walker, 1870b: 636

Patanga succincta Willemse, 1957: 298

Materials examined. 16 specimens (♂: 7, ♀: 9). **BORNEO: EAST MALAYSIA: SARAWAK: Bintulu:** Jelalong, Sg. Mayop, 28.X.2000, Ento Team, 1♀ (FN.00-1509), 1♂ (FN.00-1523) (RDID). Sg. Sibiyu Nursery, 12.IX.1988, Mohidin & Hamid, 1♂ (FN.88-0665) (RDID). **Kapit:** Ulu Putai, 12.V.2001, caught by light trap, Ento Team, 1♀ (FN.01-1526) (RDID). **Kuching:** Muara, 01.I.2004, Wilhelmina, 1♀ (UIRC). **Serian:** Tebakang, 22.VI.1983, A.A. Hamid, 4♀ (FN.83-0358, FN.83-0358A, FN.83-0358B, FN.83-0359) (RDID). **Sri Aman:** Sg. Lingga, 05.IV.1991, Sarkawi & Wan Khata, 1♀ (FN.91-0130) (RDID). **SABAH: Lahad Datu:** Silam Mountain (A), 11.IX.1995, Gunik G., 1♂ (OR/95/00120) (SPM). Silam Mountain (B), 12.IX.1995, Johny L., 1♂ (OR/95/00119) (SPM). **Sandakan:** Beluran, Labuk, Sg. Meliau, 01.X.1996, Jelius Gantor, 1♀ (ENT:2470) (SM). Telupid, Imbak Valley, 06.VII.2000, Alt: 145 m, Geoffary G., 1♂ (OR/00/00590), Yusilie K., 1♂ (OR/00/00589) (SPM). **Semporna:** Pulau Bohey Dulang, Taman Merin Tun Sakaran, 1-6.VIII.2009, Sinail D., 1♂ (SP/EOR/01772) (SPM).

Diagnosis. *Patanga succincta* is recognised by having the following combination of characters: body slender and long; body uniformly brown; dorsum of head with pale cream coloured stripe from vertex of head to post-occipital margin, extending with much clearer cream coloured stripe from anterior to posterior margin of pronotal disc; anterior margin of pronotal disc distinctly arched; tegmina with irregular dark spots; hind wing pinkish but not reaching anterior margin of medial area and apex of wings.

Description. Male: Body long, total length 47.35 mm – 52.21 mm. **Colouration:** Generally brownish with a tinge of yellow and cream. Head: Brownish with a tinge of cream colour marks on dorsum and frontal face. *Antennae*: Brown. Thorax: Darker brown with cream coloured stripe from anterior to posterior margin; sternum lighter brown. *Legs*: Pale to dark brown. *Wings*: Tegmen pale brown basally, hyaline apically, with dark brown tegminal veins and irregular dark spots throughout; hindwing pinkish but not reaching anterior margin of medial area and apex of wings. **Structure:** Body long and slender. Head: Face longer than height of pronotum laterally; sub-rectangular in frontal view; frons slightly oblique, almost right angular to vertex of head in profile; eyes long oval, with vertical length significantly greater than its horizontal length laterally; not exceeding the outline of head from dorsal view; eyes slightly lower than vertex of head in profile; inter-ocular distance same as the width of frontal ridge; transverse ridge weakly projected from the anterior margin of compound eyes extending anteriorly with weakly projected lateral carinae, not reaching apex of fastigium; lacking foveolae; distance from anterior margin of eyes to apex of fastigium shorter than horizontal diameter of eye in profile; anterior apex of head linear and close to eyes dorsally, forming vertically elongated isosceles trapezoid with lateral carinae; transverse groove at base of fastigium not interrupting lateral carinae; fastigium slightly excavated; integument above frontal ocellus with numerous small and deep punctures; deep groove surrounding the frontal ocellus; frontal ridge elongated below median ocellus reaching clypeal margin; frontal costa between antennae not obviously projected forward and not forming discernible arch below median ocellus in profile; frons with numerous light punctures and slightly ridged. *Antennae*: Longer than the combined length of head and pronotum; filiform-like shaped. Thorax: Prosternal process sub-cylindrical, gradually narrowing towards apex, short and thick, not reaching anterior margin of mesosternum, not

compressed laterally, slanted towards mesosternum in profile, apex rounded, pronotum hour-glass shape, head slightly wider than prozonal width, but shorter than length of pronotum in dorsal view; expanding caudally and constricted in prozona; median carina almost complete but distinctly visible; flat dorsally; straight and present as low ridge in profile; crossed by three sulci with shallow incision by principal sulcus and minor transverse sulci; lacking lateral carinae; median posterior margin of metazona broadly angular; anterior margin of prozona broadly projected in the middle, forming discernible arch; surface of pronotum coarsely carinulated and punctured; dorsum of pronotum with irregularly thickened ridges forming honeycombed shaped sculpture, lateral lobe of prozona lightly punctured; posteroventral margin of lateral lobe roundly angular with an angle of over 90 degrees; sternum long, anterior border of mesosternum straight, mesosternal lobe vertically longer than horizontal length, mesosternal interspace elongate with vertical length longer than basal width, anterior margin of interspace weakly concave, inner posterior corner of lobe acutely angular, metasternal interspace cordiform, completely contiguous. *Legs*: Upper carinae of hind femur prominently serrated with weak serration on upper carinula, lower carinae very weakly serrated, basal lobe dorsally longer than its ventral length, dorsal and ventral genicular lobe rounded distally, distal end of dorsal carina with narrowly obtuse-angular spine; hind tibia lacking outer apical spine, number of spines on outer margin 7 to 8, distance between first and second spines on inner margin as long as any other inter-spine distance, distal half of hind tibia not obviously broadened towards apex without obvious edges running through the spines. *Wings*: Tegmen macropterous; wings developed in contact with each other basally above abdomen; apex rounded, cell of distal part sub-rectangular. Genitalia: Cerci narrowing towards apex; elongated and curving inwards and downwards posteriorly, slightly compressed laterally, apex rounded; supra-anal plate scutatiform, apex not divided

with tubercles on both sides of apical field, basal field two digitiform tubercles near lateral margins, lacking furcula, lateral groove medially forming slopes on both sides of the field, two tubercles on each sides of middle field; subgenital plate with simple conical structure, apex not divided, long with vertical length greater than basal width ventrally, strongly tapering apically with pointed apex, lacking tubercle at end of apex.

Female: Larger than male, total length 49.63 mm – 65.79 mm. Colouration, vestiture and texture as in male. **Structure:** Mostly resemble male specimens, body long and robust. Genitalia: Ovipositor long and curved apically in profile; dorsal valves slightly longer than ventral valves; dorsal valves prominently converging inwards and upwards, with one apical tooth, lowly serrulated on superior margin, non-bidentate and lacking notch on apex; ventral valves very narrow, superior margin weakly serrated and constricted narrowly in the middle, external lateral teeth weakly projected outward; subgenital plate triangularly projected posteriorly in the middle, lacking lateral teeth on posterior margin of the plate.

Food plant. Wide range of food plant associations, such as bamboo, banana, cassava, *Casuarina* sp., cereals, Chinese cabbage, citrus, coconut, cowpea, *Donax canniformis*, *Gardenia florida*, ginger, groundnut, *Imperata cylindrica*, maize, mango, *Mimosa invisa*, mustard, pigeon pea, rice, rubber, soybean, sugar cane, tea, and wild grasses (Grist & Lever, 1969; Roffey, 1979; COPR, 1982; Willemse, 2001; Siwi et al., 2005).

Ecology. Agricultural plot, clearing of primary forest, cultivated upland rice field and rice growing areas, grasslands subjected to seasonal burning (Roffey, 1979; COPR, 1982; Willemse, 2001; Siwi et al., 2005) and montaneous areas, such as foothill of mountains (Willemse, 1938) with 145 m elevation.

Distribution. South-eastern Arabia, Bangladesh, southern China, India, Indonesia, Japan (Ryukyu Islands), Malaysia, Myanmar, Pakistan, the Philippines, Sri Lanka, Taiwan, Thailand, Vietnam (C. Willemse, 1938; Roffey, 1979; COPR, 1982; L. Willemse, 2001; Siwi et al., 2005; Cigliano et al., 2021).

Remarks. *Patanga succincta* is similar to *P. luteicornis* in terms of the shape of mesosternal lobes that defined the genus, which is significantly longer than its breadth, with the inner margins prominently angulated. However, some of the external characters differentiating both species are the pronotal structure of *P. succincta* that is more stout and shorter compared to *P. luteicornis* and the frontal and pre-ocular ridges of *P. succincta* is much more prominent and projected posteriorly in comparison with the other species from dorsal view. In addition, body colouration is one of the distinguishing characters, especially for live specimens as *P. succincta* displayed homogeneously pale yellow to dark brown colour, while *P. luteicornis* usually displayed green or greenish brown colouration.

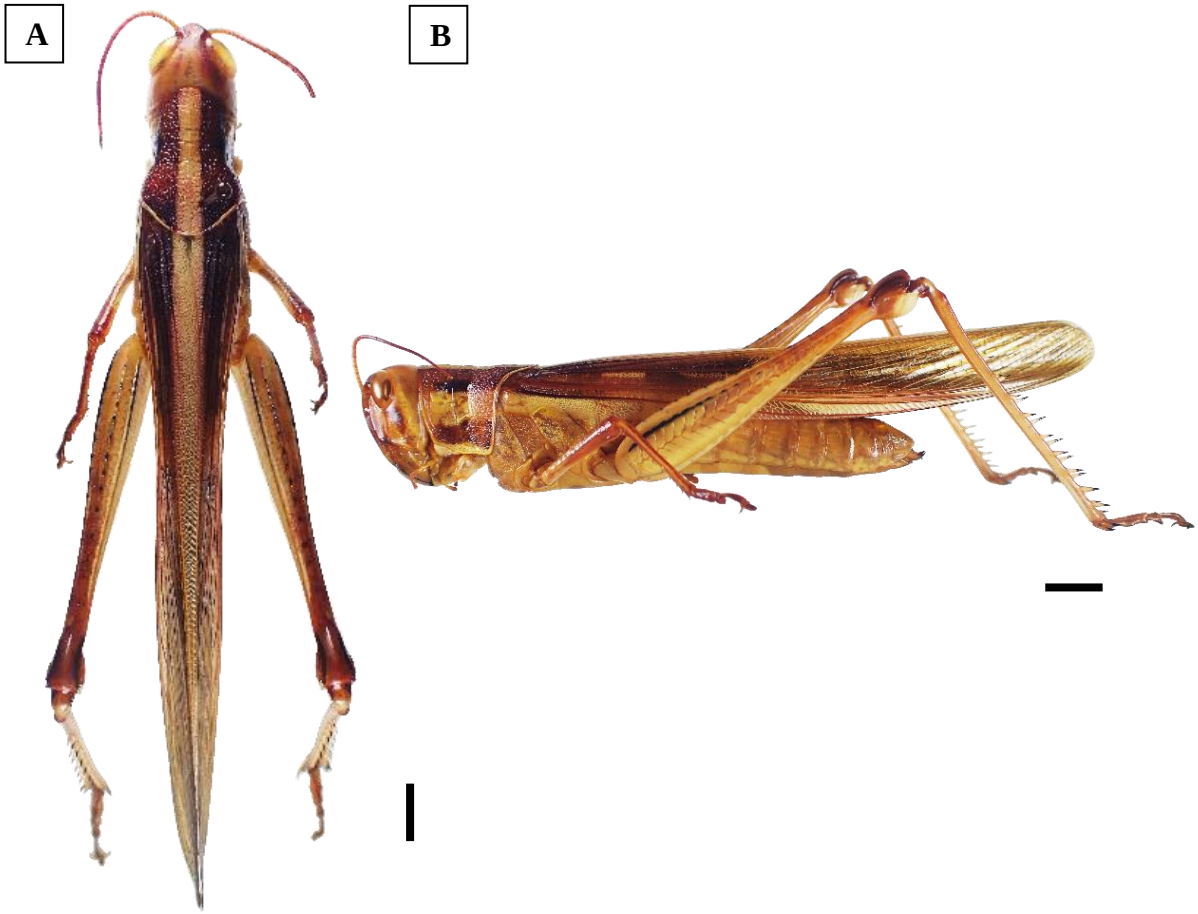


Figure 3.27: *Patanga succincta*, ♀. **A.** Dorsal view of type; **B.** Lateral view of type. Scale = 5 mm.

Genus *Valanga* Uvarov, 1923

Valanga nigricornis (Burmeister, 1838)

Figure 3.28, Figure 3.29

Acridium nigricorne Burmeister, 1838: 629

Acridium melanocorne var. *laetum* Bolivar, 1898: 99

Cyrtacanthacris nigricornis Kirby, 1910: 446

Orthacanthacris nigricornis Kirby, 1914: 228

Valanga nigricornis nigricornis Uvarov, 1923: 352; Willemse, 1957: 265

Materials examined. 180 specimens (♂: 80, ♀: 100). **BORNEO: EAST MALAYSIA: SARAWAK:** Tasik B, 25.VII.2002, Insect Group, 1♀ (UIRC). **Betong:** Skuyat Baru, 16.III.2019, Felycia Rinta, 2♀ 1♂ (UIRC). **Bintulu:** Bintulu, 07.VIII.1988, Adenan Bukra, 1♀ (RDID); 08.IX.1988, Adenan Bukra, 1♂ (RDID). Labang Forest Reserve, 12.IX.1988, Mohidin, 1♂ (FN.88-0664). Similajau National Park, 12.IX.2000, Ento Team, 1♀ (FN.00-1080) (RDID); 13.IX.2000, Ento Team, 1♀ (FN.00-1108), 1♂ (FN.00-1112) (RDID); 15.IX.2000, Ento Team, 2♀ (FN.00-1109, FN.00-1114) (RDID). Sg. Sibiyu Nursery, 21.III.1997, Ento Team, 1♂ (RDID). Universiti Putra Malaysia, 02.I.1980, E. H. Lok, 1♂ (RDID). **Kapit:** Belaga town, 06.XII.1994, caught by light trap, S.H., F.A., Lim & W.M., 1♀ (O1132), 1♂ (O1131) (UIRC). **Kuching:** Batu 6, 21.IX.1996, Christine, 1♂ (UIRC). Bau, Skibang, 29.IV.2017, Damianne Joem, 1♂ (UIRC). Forest Herbarium, 29.IV.1981, Haidir Nusi, 1♀ (RDID). Jalan Arang, 20.II.2000, Chong Tze Fung, 1♀ (UIRC). Kg. Lintang, 03.II.1993, Rosnah Bujang, 1♀ (RDID). Kuching, 05.III.1980, A. A. Hamid, 1♀ (FN.80-0124) (RDID); 25.V.2010, caught by light trap, Ento Team, 1♂ (RDID). Matang, 08.XII.2003, Ratnawati H., 1♀ (UIRC); 09.IV.2016, Marina Maliyana, 1♂ (UIRC). Matang, Synergy Park, 16.III.2016, Jonathan Juliana, 1♂ (UIRC). Matang Jaya, 22.III.2016, Hafis Dillah, 1♀ 1♂ (UIRC). Padawan, Gunung Regu, 19.VIII.2009, Insect Group, 1♀ (UIRC). Rock Road, 17.X.1980, Lim Lian, 1♀ (FN.80-1797) (RDID). Santubong Beach, 01.XI.1976, A. A. Hamid, 1♀ (FN.00018) (RDID). Santubong National Park, 04.XII.2014, Ento Team, 1♀ (GC5444), 1♂ (GC5443) (RDID). Sri Muara, 14.II.2000, Felicia, 1♀ (UIRC). Tabuan Jaya, 07.II.2000, Ang S. Y., 1♂ (UIRC). Taman Stutong Indah, Sama Jaya Forest Reserve,

22.II.2003, Sandra leg., 1♂ (UIRC). **Lundu:** Sampadi Forest Reserve, 24.VII.1985, Lippa Akeng, 1♂ (FN.85-0760) (RDID). Samunsam Wildlife Sanctuary, 22.IX.1988, Manis Lintang, 1♀ (RDID). Sebandi, 18-28.I.2003, Group 3, SLUSE 02/03, 1♂ (UIRC). Sematan, Gunung Pueh, 14.X.2015, Ento Team, 1♂ (GC6558) (RDID). Sematan Beach Forest, 19.V.1984, A. Rahman Osman, 1♂ (RDID). Tanjung Datu, 19.VII.2012, caught by light trap, Ento Team, 2♀ (GC3149, GC3150) (RDID). **Miri:** Lambir Hills National Park, 16.VII.1999, caught by UV light, Ento Team, 1♂ (H0126) (RDID). Niah, 23.VIII.1986, Manis Lintang, 1♀ (FN.86-0195) (RDID); 20.V.1987, Ainie Ismuni, 1♀ (FN.87-0241) (RDID); 08.III.1988, Mahmud Merdek, 1♂ (FN.89-0040) (RDID); 09.III.1989, Mahmud Merdek, 1♀ (FN.89-0038), 4♂ (FN.89-0035 – FN.89-0037, FN.89-0039) (RDID). 21.IX.2014, Ento Team, 1♀ (GC5284), 1♂ (GC5285) (RDID). **Samarahan:** Academia Lane, 03.III.2018, Soon Vivian, 1♀ (UIRC); 30.IV.2019, Tan Dick Shen, 1♂ (UIRC). Desa Ilmu, 07.X.2015, Ainur Nasrin, 1♂ (UIRC); 12.X.2015, Nur Amirah Suhailah, 1♀ (UIRC); 25.X.2015, Nur Nabihah Shaharudin, 1♂ (UIRC); 15.III.2016, Atifah Asri, 1♀ (UIRC); 24.IV.2016, S.A.M. Zaid, 1♀ (UIRC); 17.V.2016, Atifah Asri, 1♀ (UIRC). Kota Samarahan, 15.II.2000, K.1, 1♀ (UIRC); 07.II.2003, Ijau, 1♀ (UIRC); 10.XII.2003, Phyllis Lahang, 1♂ (UIRC); 20.XII.2003, Lily Sir, 1♂ (UIRC); 01.I.2004, Ursula Gilbert, 1♀ (UIRC); 03.I.2004, Jararaj, 1♀ (UIRC); 18.I.2004, Joshua Juan, 1♂ (UIRC). Kota Samarahan, Riveria, 18.II.2019, Vanessa Noni, 1♀ (UIRC). Kota Samarahan, Summer Mall, 18.IV.2016, N. A. A. Rahim, 1♀ (UIRC). Kota Samarahan, Taman Campus Edge, 23.X.2015, Hazel Annessa, 1♀ (UIRC). Kota Samarahan, Taman Desa Ilmu, 18.III.2016, Amirah Damian, 1♀ (UIRC); 23.III.2016, Amirah Damian, 1♂ (UIRC); 06.IV.2016, Amirah Damian, 1♀ (UIRC). Kota Samarahan, Taman Samarax, 24.IV.2016, Hazel Annessa, 1♀ 1♂ (UIRC). Kota Samarahan, Vista Ilmu, 13.V.2018, Nur Amira Mohd Razali, 1♂ (UIRC).

Sebayor, 05.I.2003, Jayaraj, 1♂ (UIRC). Stampin, 18.III.1997, Muyang, 1♀ (UIRC). UNIMAS, 02.III.1997, pinggir hutan, Fadly, 1♀ (UIRC); 15.II.1992, Serdi, 1♀ (UIRC); 25.I.2000, Chong Tze Fung, 1♂ (UIRC); 04.II.2000, Marilyn, 1♀ (UIRC); 20.II.2000, Zaidi Mawek, 1♀ (UIRC); 20.VII.2002, Sze Wooi, 1♀ (UIRC); 29.VII.2002, Aini, 1♀ (UIRC); 14.II.2009, Boon Siaw Khim, 1♀ (UIRC); 07.III.2009, Boon Siaw Khim, 1♀ (UIRC); 22.I.2010, Leow Tze Chin, 1♀ (UIRC); 06.II.2010, Nurul Afiqah Mahadi, 1♀ (UIRC); 04.III.2010, Mira Hafizah Sani, 1♀ (UIRC); 02.V.2018, Muhammad Syafiq, 1♀ (UIRC). UNIMAS, Arboretum, 19.III.2017, Norlin Lau, 1♂ (UIRC). UNIMAS, East Campus, 12.IV.2016, Nur Izzah, 1♂ (UIRC); 24.IV.2019, Nur Azziatul Ain, 1♂ (UIRC). UNIMAS, External Laboratory, 18.IV.2017, Hamdan, 1♀ (UIRC). UNIMAS, FRST, 05.V.2018, Muhd Zhafri Irfan, 1♀ (UIRC). UNIMAS, Kolej Dahlia, 07.IV.2019, Afiqah Aqilah, 1♀ (UIRC). UNIMAS, Panggung Gemilang, 27.IV.2017, Nurkhuzaimah, 1♀ (UIRC). UNIMAS, PITAS, 14.III.2016, Faridah & Hazwani, 1♀ (UIRC); 24.III.2016, Syafiqah J. & Ilya N., 1♂ (URIC); 17.IV.2016, Megat Nadzrin, 1♀ (UIRC); 15.IV.2018, Solomon Laja, 1♀ (UIRC). UNIMAS, Stadium, 18.IV.2017, Naim Che Kamaruddin, 1♂ (UIRC). **Serian:** Annah Rais, 14.II.2003, Sandra leg., 1♀ 1♂ (UIRC). Munggu Limo, 18.XII.2004, Wahap M., 1♀ (UIRC). Ranchan Recreational Park, 27.IV.2019, Arni, 1♀ (UIRC). Semenggoh, 26.III.1979, Azahari Zainudin, 1♀ (FN.01370A) (RDID). Serian, 19.I.2004, Nazahiyah A. R., 1♂ (UIRC); 08.II.2004, Castro M., 1♂ (UIRC); 20.XII.2004, Castro M., 1♂ (UIRC). UPMCS Semenggoh, 04.II.1984, caught at horticulture site, Lilian Lipang Bulan, 1♀ (RDID); 08.II.1984, Bolhan Budeng, 1♂ (Y.84-078) (RDID). **Sibu:** Oya, 21.IV.1983, A. A. Hamid & Yeo, 1♀ (FN.83-0279) (RDID). **Simunjan:** Sabal Forest Reserve, 13.II.1990, caught in flight at durian plot, Mohidin, 1♀ (FN.90-0057) (RDID); 25.III.1990, Mahmud Merdek, 1♀ (FN.90-0069), 2♂ (FN.90-0007, FN.90-0066) (RDID); 30.V.2010, caught by

light trap, Ento Team, 1♀ (RDID); 21.III.2011, caught by light trap, Ento Team, 1♀ (GC0321), 1♂ (GC0126) (RDID); 31.III.2014, Ento Team, 2♀ (GC3569, GC3602), 1♂ (GC3568) (RDID). **Sri Aman:** Lubok Antu, 12.II.1997, Mancha, 1♀ (UIRC). Sri Aman, 21.VII.2002, Tang Kwang Ming, 1♀ (UIRC); 21.I.2004, Emylda Dino, 1♂ (UIRC). **SABAH: Beaufort:** Ulu Membakut, 17.II.2000, Alt: 220 m, Johny L., 1♀ (OR/2000/00523) (SPM). **Keningau:** Bunsit Park, 19.IX.1991, Johairah Abd., 1♀ (ORT-1099) (UMS); 20.IX.1991, Johairah Abd., 1♂ (ORT-0880) (UMS). Keningau, 20.IX.1991, Abd. Manap M., 2♂ (ORT-0878, ORT-0879) (UMS). Taman Banjaran Crocker, 15.VII.1999, Yusilie K., 1♂ (OR/99/00117) (SPM); 7-16.V.2008, Ekspedisi Denai Garam, Johny L., 1♀ (SP/EOR/01374) (SPM). **Kota Belud:** Kg. Kiau Bersatu, 12.III.1999, Sinail D., 1♀ (OR/99/00081) (SPM). Kg. Kiau Nuluh, 13.III.1999, Sinail D., 1♂ (OR/99/00097) (SPM). 05.XII.1999, Torobung K., 1♂ (OR/99/00507) (SPM). Melangkap Tomis, Bukit Sapai Trail, 03.V.2005, Alt: 310 m – 780 m, Johny L., 1♂ (SP/EOR/01137) (SPM). **Kota Kinabalu:** Bukit Padang, 20.I.1987, caught on leaves by hand, M. Hafiz, 1♀ (ORT-1057) (UMS); 08.IX.1988, Alt: 50 m, ZHH, 1♂ (ORT-1101) (UMS). Kampus UKMS, 14.I.1987, caught by hand on flowering tree, Gunik G., 1♂ (ORT-1106) (UMS). Kuala Penyu, Pulau Tiga, 28.XI.1998, Sinail D., 1♀ (OR/98/00083) (SPM). Menggatal, UKMS, 13.III.1987, Zaleha Muga, 1♂ (ORT-1107) (UMS); 01.VIII.1987, Kamariah, 1♀ (ORT-1058) (UMS); 18.XI.1992, Norhayani AB, 1♂ (ORT-1104) (UMS). Muzium Sabah, 10.X.1991, Jelius Gantor, 1♀ (ENT:1719) (SM). Pulau Gaya, 27.VI.-06.VII.2013, Ekspedisi Pulau Gaya, Sinail D., 1♀ (SP/EOR/01891), 1♂ (SP/EOR/01889) (SPM). Pulau Manukan, 18.V.1999, Johny L., 1♀ (OR/99/00091), 1♂ (OR/99/00106) (SPM). Pulau Sulug, 21.V.1999, Johny L., 1♂ (OR/99/00107) (SPM). Taman Pulau Tiga, 26.XI.1999, Wahimah S., 1♀ (OR/99/00506) (SPM). Tanjung Aru, 20.VIII.1989, Haninah ART, 1♀ (ORT-1056) (UMS). UMS Peak,

20.III.2017, caught by aerial net, Lee Jing Wen, 1♂ (UMS); 15.V.2017, caught by hand, Azila N., 1♂ (UMS); 15.XII.2017, caught in forest by aerial net, Amirsson, 1♀ (UMS). UMS, Canselori, 24.III.2014, caught by aerial net, Siti Kauthar, 1♀ (UMS). UMS, Klinik Warganegara, 06.XII.2017, caught by aerial net, Chin Zu Er, 1♀ (UMS). UMS, ODEC, 24.V.2017, caught by hand, Azila N., 1♂ (UMS). UMS, T. Likas, 14.XI.1995, Entomology Unit, 1♂ (ORT-1055) (UMS). **Kudat:** Pulau Balambangan, 20-29.V.2003, Ekspedisi Tun Mustafa, Sinail D., 1♀ (SP/EOR/01309) (SPM). Pulau Banggi, 25-29.VII.2003, Ekspedisi Tun Mustafa, Didacus Lun, 1♂ (SP/EOR/00924) (SPM). **Lahad Datu:** Silam Mountain (A), 11.IX.1995, Gunik G., 1♂ (OR/95/00112) (SPM). Tabin, 29.IX.1988, Alt: 650 m, Ismail Salleh, 1♂ (ORT-1161) (UMS). **Penampang:** Inobong Sub Station, 30.XI.2002, Alt: 450 m, Yusilie K., 1♀ (OR/02/00755) (SPM). **Ranau:** Sayap Kinabalu Park, 28.X.1993, Sinail D., 1♀ (OR/93/00087) (SPM); 28.X.1994, 1,000 m. (a.s.l.), Patrick Gindai, 1♂ (OR/93/00098) (SPM). **Sandakan:** Beluran, Kg. Pulau Keniogan, 11.XI.1997, Gunik G., 1♀ (OR/97/00086) (SPM). **Sipitang:** Muaya, 3-6.VIII.2009, N 04º53'57.8", E 115º45'37.2", Muzamil Mustaffa, Hong Men Chin & Simon Kuyun, 1♀ (UMS). **Tambunan:** Mahua, 09.IX.1999, Yusilie Kumin, 1♂ (OR/99/00116) (SPM). **Tawau:** Tawau Hill Park, 11.V.1997, Sinail Dunsul, 1♂ (OR/97/00113) (SPM); 23.III.1999, caught by light trap, Sinail D., 2♀ (OR/99/00079, OR/99/00084) (SPM). **Tenom:** Kg. Purulon Tenom, 10.XI.1998, Yusilie K., 1♀ (OR/98/00085) (SPM); 11.XI.1998, Yusilie K., 1♀ (OR/98/00082) (SPM). Melalap, 11.V.1999, Wahimah Sulaiman, 1♂ (OR/99/00103), Nora S., 1♂ (OR/99/00108) (SPM). Taman Banjaran Crocker, Pos Kawalan Kikiran, 14-18.VII.2014, Alt: 95 m, Welfred Torimoh, 1♂ (SP/EOR/01946) (SPM).

Diagnosis. *Valanga nigricornis* can be distinguished from other species in the family by having large and robust body; pronotum slightly constricted on prozona region, median

carina on pronotum slightly raised and thick, sometimes linear with the level of head in profile with three distinct transverse sulci on prozona, metazona straight; mesosternum long and rectangular, with margins of mesosternal interspace rectangular to acutely angular; hind wing pinkish basally; hind femur either unicolourous or with irregular transverse dark bands or spots.

Description. Male: Body large, total length 40.25 mm – 55.16 mm. **Colouration:** Body yellowish brown, yellowish or greenish with irregular black spots or bands, in certain individuals. *Antennae*: Scapus and pedicel pale brown, yellowish or green; flagellum black basally, gradually getting lighter to pale brown apically. Thorax: Pronotum with three common forms: dark brown throughout; light green or yellow on the anterior and posterior margin and along the median carina with light or dark brown on the pronotal disc to the lateral lobe of the pronotum; median carina yellow or green, pronotal disc brown or black, lateral side with dark, irregular spots. *Legs*: Hind femur unicolourous, sometimes with irregular dark transverse bands and tiny spots; hind tibia and tarsi olive green, brown or yellow. *Wings*: Tegmen pale or obvious yellow band from base of pronotum to apex of wings, irregular dark spots throughout; hindwing pinkish basally. **Structure:** Body large and robust. Head: Long and sub-rectangular in frontal view, frons obliquely sub-triangularly to vertex of head with an angle of almost 90 degree in profile; eyes big, long oval, vertical diameter significantly longer than horizontal diameter of eye laterally, not exceeding the outline of the head dorsally, eyes slightly lower than the vertex of head laterally, inter-ocular distance sub-equal to the width of frontal ridge, lacking foveolae, lateral carinae with thick ridge not reaching apex of fastigium, distance from anterior margin of eyes to apex of fastigium much shorter than the horizontal diameter of eye in profile, anterior apex of head linear and quite close to compound eyes dorsally without the presence of fastigium ridge,

lacking transverse groove at base of fastigium, fastigium not excavated; frontal ridge of head elongated towards clypeus; frontal costa between antennae not obviously projected forward in profile and not forming discernible arch above median ocellus in profile; frontal costa above frontal ocellus with small and deep punctures, frons lightly ridged. *Antennae*: Longer than the combined length of pronotum and head; filiform-like shaped. Thorax: Prosternal process cylindrical, moderately long and slightly broad, slightly inclined and bent posteriorly but widely separated from mesosternum; pronotum saddle-shaped, slightly tectiform; longer and width as wide as head; prozona longer than metazona, expanding caudally from dorsal view and very faintly constricted in the middle with metazonal area vaguely wider and broader than prozona; median carina appears flat and straight dorsally, slightly elevated with three moderately deep incisions by transverse sulci forming distinct round, narrow and sharp ridges in profile, lacking lateral carinae; median posterior margin of metazona broadly angular and not concave; pronotal disc irregularly carinulate and punctured; dorsum of prozona with irregularly wrinkled ridges not forming obvious punctures, lateral lobe of prozona distinctly wrinkled forming irregular thick but almost flat ridges; dorsum of metazona with ridges forming numerous small pits; posteroventral margin of lateral lobe roundly angular and faintly arched with an angle of slightly over 90 degrees; sternum long, mesosternum and metasternum with approximately equal length; anterior border of mesosternum straight, mesosternal lobe vertically longer than lateral width, mesosternal interspace sub-rectangular, elongate with vertical length longer than basal width, anterior margin of interspace weakly convex, inner posterior corners of lobe acutely angular; metasternal lobe contiguous. *Legs*: Upper carina of hind femur prominently serrated, lower carinae weakly serrated with less acutely pointed spine, basal lobe of hind femur with dorsal lobe as long as ventral lobe, dorsal and ventral genicular lobe rounded distally, distal end of

dorsal carina spined, narrowly obtuse-angular; hind tibia lacking outer apical spine, number of spines on outer margin 8 to 9, distance between first and second spines on inner margin as long as any other inter-spine distance, distal half of hind tibia not obviously broadened towards apex. *Wings*: Tegmen macropterous, male wings developed in contact with each other above abdomen; distal margin round, cell of distal part sub-rectangular. Genitalia: Cerci narrowing towards apex, slightly compressed laterally, highly elongated and curving inwards and downwards posteriorly, apex acutely pointed; supra-anal plate scutatiform, apex divided, furcula very short to almost absent, basal field smooth without tubercles near lateral margin, lateral groove deeply developed on the middle field, lacking transverse groove on middle and apical field, tubercles on sides of middle field weakly projected, tubercles on sides of apical field strongly projected; subgenital plate with simple conical structure, apex not divided, long with vertical length greatly longer than basal width, strongly tapering towards apex with pointed end, lacking tubercle at end of apex.

Female: Larger than male, total length 50.99 mm – 73.32 mm. Colouration, vestiture and texture as in male. **Structure:** Mostly resemble male specimens, body robust. Genitalia: Ovipositor curved in profile, dorsal and ventral valves with equal length; dorsal valves convergent dorsally, with one apical tooth, very weakly serrulate to almost smooth on the superior margin, non-bidentate and lacking notch on apex; ventral valves very narrow and long, external margins almost smooth dorsally and constricted laterally in the middle field, external lateral teeth obtusely angular and obviously projected outward; subgenital plate strongly triangularly projected posteriorly in the middle, lacking lateral teeth on posterior margin.

Food plant. Abaca, *Acacia* sp. (*Acacia mangium* in Sarawak), *Albizia* sp., *Areca* sp., aubergine, banana, betel nut, breadfruit, brinjal, cacao, *Canna* sp., cassava, castor, citrus, coconut, coffee, cotton, *Crotalaria* sp., dadap, fig, *Gliricidia* sp., groundnut, kapok, lime, mahogany, maize, mango, *Mimosa invisa*, oil palm, orange, pepper, pineapple, pomelo, *Pueraria phaseoloides*, rice (upland rice), rubber, sesame, sorghum, sugar cane, sugar palm, tea, teak, *Tephrosia* sp. and tobacco (Han & Chew, 1978; Roffey, 1979; COPR, 1982; Hamid, 1987; Khoo et al., 1991; Willemse, 2001; Siwi et al., 2005).

Ecology. Forest clearings, gardens, grasslands, plantations, previously cultivated areas, rice fields, roadsides, urban areas, watercourses (Roffey, 1979; COPR, 1982; Willemse, 2001; Siwi et al., 2005; Mahmood et al., 2007; Tan & Kamaruddin, 2014) and at foothill or forest edge with 50 m – 2,500 m elevation (Uvarov, 1923).

Distribution. Indonesia (Java, Sumatra, eastwards to Timor, but not Celebes), Malaysia, the Philippines, Singapore, southern Thailand (Uvarov, 1923; Roffey, 1979; COPR, 1982; Willemse, 2001; Siwi et al., 2005; Mahmood et al., 2007; Tan, 2010a, 2012; Tan & Kamaruddin, 2014; Cigliano et al., 2021).

Remarks. *Valanga nigricornis* shares some similarities with *Gastrimargus marmoratus* and *Locusta migratoria manilensis* by the structure of its body. These species are seen in their natural habitat camouflaging with their habitats by having greenish to brownish body colour. The major discrepancy used in differentiating all species are the structure of their pronotum keels. *V. nigricornis* have slightly elevated ridges with three moderately deep incisions by transverse sulci, while *G. marmoratus* have a distinctly elevated median keel with distinctive X-marking and *L. migratoria manilensis* possessed median carina that is elevated but transversely crossed once.



Figure 3.28: *Valanga nigricornis*, ♂. **A.** Dorsal view of type; **B.** Lateral view of type. Scale = 5 mm.

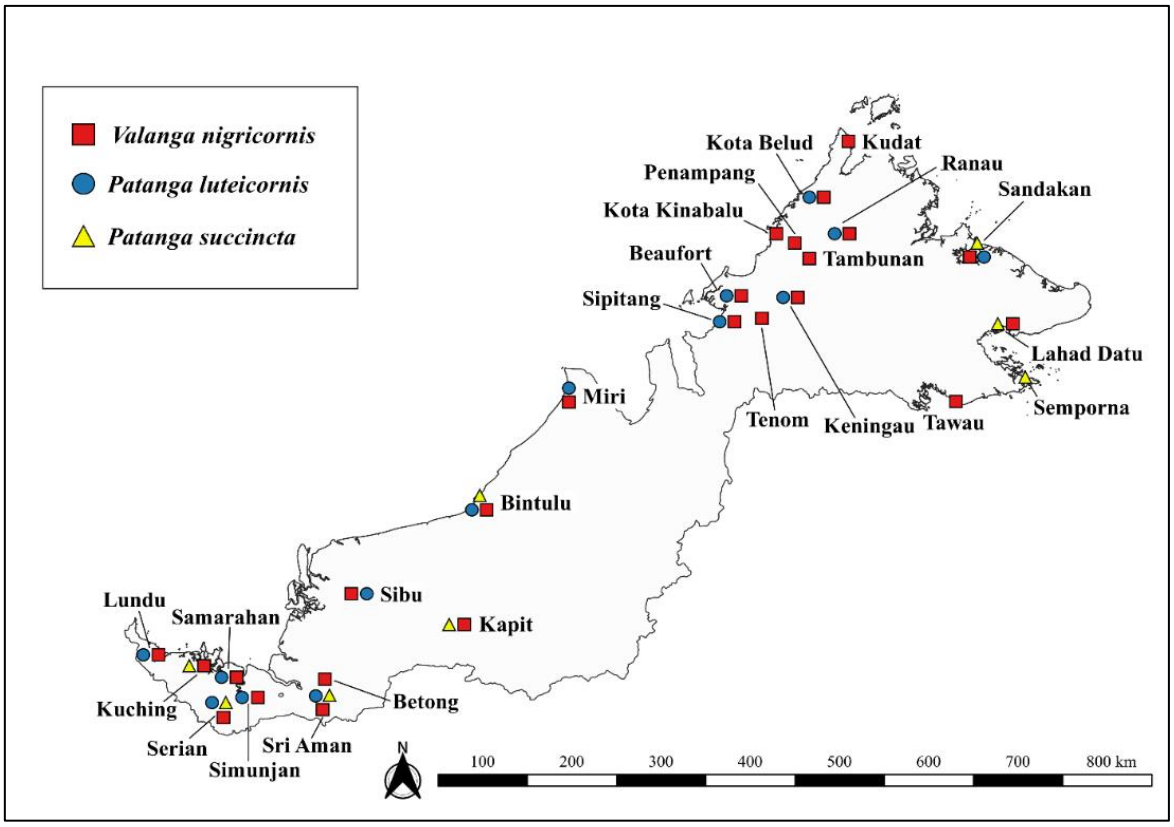


Figure 3.29: Distribution map of subfamily Cyrtacanthacridinae in Malaysian Borneo.

Subfamily Oedipodinae Walker, 1871

Genus *Aiolopus* Fieber, 1853

Aiolopus thalassinus tamulus (Fabricius, 1798)

Figure 3.30, Figure 3.35

Gryllus tamulus Fabricius, 1798: 195

Gomphocerus? tamulus Walker, 1870b: 784

Epacromia rufostriata Kirby, 1888: 550

Epacromia famulus Bolivar, 1895: 378 (misspelling)

Epacromia tamulus Bolivar, 1902: 600

Aiolopus tamulus Rehn, 1902: 631; Karny, 1915: 84

Aeolopus tamulus Kirby, 1910: 192; Kirby, 1914: 122

Ailopus tamulus Sjöstedt, 1920: 10

Materials examined. 84 specimens (♂: 31, ♀: 53). **BORNEO: EAST MALAYSIA: SARAWAK: Bintulu:** Sungai Sibiyu, 10.I.1985, Lippa Akeng, 2♀ (FN.85-0007, FN.85-0008) (RDID). **Kuching:** Bako National Park, 20.VIII.1989, Mahmud Merdek, 1♀ (FN.89-0646), 1♂ (FN.89-0647) (RDID). Bau, Samunsam, 24.VI.1994, Zaidi, 2♀ (O1137, O1180) (UIRC). Kuching, 1-15.VIII.2002, Cici Edward, 1♂ (UIRC). Matang, 22-26.VII.2002, Fatimah & Rosni, 1♀ (UIRC); 06.XII.2003, Ratnawati H., 1♀ (UIRC). **Lundu:** Jangkar Waterfall, 07.IV.2017, Atiqah Azizi, 1♀ (UIRC). Sebandi, 18-28.I.2003, Group 3, SLUSE 02/03, 1♀ (UIRC). Sematan Beach Forest, 09.XI.1986, Ento Team, 1♀ (FN.86-0257), 1♂ (FN.86-0258) (RDID). **Miri:** Bario, Kelabit Uplands, 10.IV.1995, caught in light trap, S. H., F. A., Lim & W. M., 1♂, 1♂ (O1174) (UIRC). Lambir Hills National Park, 01.IX.1992, caught by UV light, Ento Team, 1♀ (A0035) (RDID); 14.I.1994, caught by UV light, Ento Team, 1♂ (C0145) (RDID); 22.IV.1996, caught by UV light, Ento Team, 1♂ (E0096) (RDID); 11.IV.1997, caught by UV light, Ento Team, 1♂ (F0107) (RDID); 10.V.1997, caught by UV light, Ento Team, 1♂ (F0128) (RDID); 17.V.1999, caught by UV light, Ento Team, 1♀ (U0086) (RDID); 13.II.2002, caught by UV light, Ento Team, 1♂, 1♂ (K0012) (RDID); 16.II.2002, caught by UV light, Ento Team, 1♂ (K0025) (RDID); 12.V.2002, caught by UV light, Ento Team, 1♀ (K0059) (RDID). **Samarahan:** Kota Samarahan, 05.II.2003, Ijau, 1♀ (UIRC), Yenny, 1♂ (UIRC); 11.XII.2003, Wahap M., 1♀ (UIRC). Samarahan Park, 29.XI.2003, Sandra leg., 1♂ (UIRC). UNIMAS, 28.II.1997, Ervina, 1♀

(UIRC); 12.III.1997, Rimons, 1♀ (UIRC); XII.1999, Insect Group, 1♀ (UIRC); 07.II.2000, Majineh, 1♀ (UIRC); 05.VI.2002, Djzamani, 1♀ (UIRC); 13.VII.2002, Djzamani, 1♀ (UIRC); 05.VIII.2002, Tan Siew Khim, 1♀ (UIRC); 19.III.2016, Kok Cze Jhin, 1♀ (UIRC); 27.IV.2016, Jonathan Juliana, 1♀ (UIRC); 23.IV.2018, Linda, 1♀ (UIRC). UNIMAS Arboretum, 29.III.2017, Priscilla Thecla Felix, 1♀ (UIRC); 16.IV.2017, Siti Nor Mahmmod, 1♀ (UIRC). UNIMAS, Basketball Court, 01.VIII.2002, Insect Group, 1♂ (UIRC). UNIMAS, East Campus, 15.III.2016, Noor Najilah Anifah, 1♀ (UIRC). UNIMAS, FRST, External Laboratory, 10.V.2016, Nur Azwa Mohd Faizal, 1♀ (UIRC). UNIMAS, Kolej Rafflesia, 04.V.2016, Anisa Grace Robert, 1♀ (UIRC). UNIMAS, PITAS, 15.V.2016, Rahmawati S. & Fatimah, 1♀ (UIRC). UNIMAS, West Campus, 20.III.2016, Ashekin Muhammad Ali, 1♀ (UIRC). **Simunjan:** Sabal Forest Reserve, 26.VI.2014, Ento Team, 1♀ (GC4634) (RDID). **SABAH: Kota Kinabalu:** Karamunsing, 10.VIII.1990, Salmin, 1♀ (ORT-0984) (UMS). Likas Wetland, 17.IX.2001, Ito Gen, 7♂ (ORT-2657 – ORT-2659, ORT-2664, ORT-2665, ORT-2667, ORT-2668) (UMS); 22.X.2001, Ito Gen, 2♂ (ORT-2672, ORT-2673) (UMS). Menggatal, UKMS, 16.VII.1990, Salmin, 1♀ (ORT-0978) (UMS). Tanjung Aru, 29.VII.1990, Salmin, 1♀ (ORT-0983) (UMS). Universiti Malaysia Sabah, 28.IV.2001, Ito Gen, 1♂ (ORT-2654) (UMS). **Keningau:** Kg. Baliau, 26.VIII.1990, Salmin, 5♀ (ORT-0979 – ORT-0982, ORT-0986) (UMS); 27.VIII.1990, Salmin, 4♀ (ORT-0974 – ORT-0977) (UMS); 28.VIII.1990, Salmin, 2♀ (ORT-0972, ORT-0973) (UMS). Taman Banjaran Crocker, Ulu Mogiudanau, 10.IX.2002, Ekspedisi Taman Banjaran Crocker, Alt: 100 m, Johny L., 1♂ (OR/02/00797), Sinail D., 1♂ (OR/02/00799) (SPM). Taman Banjaran Crocker, Ulu Senagang, 17-19.X.1999, Ito Gen, 1♂ (ORT-2671) (UMS). **Kinabatangan:** Kg. Tidung, 17-24.X.2003, Ekspedisi Lower Segama, Johny L., 1♀ (SP/EOR/00941) (SPM). **Kudat:** Kudat, 20-29.V.2003, Ekspedisi Tun Mustafa, Yusilie K.,

1♀ (SP/EOR/00929), 1♂ (SP/EOR/00930) (SPM). Pulau Malawali, 03.V.2017, Johny Lapidin, 2♀ (SPM). **Papar:** Taman Pulau Tiga, 30.I.2001, Johny L., 1♂ (OR/01/00647) (SPM). **Ranau:** Tomboyokan, 24-29.IX.2005, Ekspedisi Tomboyokan, Alt: 335 m – 599 m, Johny L., 1♂ (SP/EOR/01147) (SPM). **Sandakan:** Beluran, Pulau Jambungan, 08.X.1997, Yusilie K., 1♀ (OR/97/00153) (SPM). **Tambunan:** Tambunan, 13.IX.1986, Alleda, 1♀ (ORT-0985) (UMS).

Diagnosis. *Aiolopus thalassinus tamulus* is recognised by the following combination of characters: foveolae sub-rectangulate; pronotum with stripes resembling a faint 'X' marking dorsally; tegmina with yellow longitudinal stripes laterally not reaching half of the abdominal sternite; hind femur with faint yellow pre-genicular ring; hind tibia with yellow, blue, and red band.

Description. Male: Body size small, total length 15.08 mm – 23.02 mm. **Colouration:** Body generally rusty brown. Head: Brown with subtle yellow longitudinal stripe along the sub-ocular groove; fastigium to post-occipital margin subtle yellow. *Antennae*: Pale to dark brown. Thorax: Pronotum uniformly brown with transverse yellow stripe with black stripe lining dorsally converging between the principal sulci and second transverse sulci into two small lines on each parallel side. *Sternum*: generally rusty brown, sometimes pale yellow. *Legs*: Outer face of hind femur generally rusty brown with yellow band near dark hind knee, inner face dark brown to nearly black with two yellow bands; hind tibia multicolourous, pale-yellow ring dividing dark basal part from apical part coloured blue and red; tarsus uniformly pale yellow, sometimes brownish. *Wings*: Tegmen uniformly hyaline dorsally with scattered pale brown small spots basally, darker paler brownish black with bigger and scattered pale brownish black spots anally, yellowish opaque band laterally from the base of

the pronotum stopping midway through the tegmen. *Abdomen*: Generally brown, sometimes pale yellow. **Structure:** Body robust and medium long. Head: Sub-rectangular in frontal view, frons sub-triangular to vertex obliquely formed in profile, fastigium sub-triangular dorsally; eyes sub-ovate, large, exceeding the outline of head, as high as frontal ridge of head laterally, distance from anterior margin of eyes to the apex of fastigium less than the horizontal diameter of eye in profile, inter-ocular distance distinctly wider than width of frontal ridge, lateral carinae present, foveolae sub-rectangulate; anterior apex of head distinctly projecting forward away from eyes dorsally; apex of fastigium faintly excavated, lacking transverse groove basally; frontal ridge of head extending slightly midline below median ocellus; frontal costa between antennae not obviously projected, not forming discernible arch above median ocellus; frontal costa above frontal ocellus lightly punctured, and frons slightly ridged. *Antennae*: Slightly longer than the combined length of pronotum and head; filiform-like shaped. Thorax: Pronotum scutatiform, width as wide as head, lacking prosternal process, metazona longer than prozona, expanding caudally from dorsal view and weakly constricted in the middle, transverse sulci shallowly impressed on pronotal disc, median carina crossed by one sulcus, first and second transverse sulci not cutting the median keel, median keel on prozona distinctly flat dorsally and straight in lateral view, shallow incision by principal sulcus with no additional incisions by minor transverse carina, lateral carinae very weakly elevated, median carina present as low ridge, median posterior margin broadly rounded and concave, pronotal surface weakly carinulated, dorsum and lateral lobe of prozona lightly but distinctly punctured, dorsum of metazona with no basic sculpting pattern, posteroventral margin of lateral lobe not concave and roundly angular; anterior border of mesosternum slightly arched, nearly straight; mesosternal lobe laterally wider than vertical length, interspace between mesosternal lobes wide, vertical margin as

long as lateral length, inner posterior corners of lobe obtusely round, metasternal lobe separated medially. *Legs*: Upper and lower carinae of hind femur smooth, basal lobe dorsally longer than ventral length, dorsal and ventral genicular lobe roundly angular distally, distal end of dorsal carina slightly broadly angular; hind tibia lacking outer apical spine, male with 10 spines on outer margin, distance between first and second spines of inner margin as long as any other inter-spine distance, distal half broadened slightly broadened toward apex, with distinct outer and inner edges running through the spines. *Wings*: Tegmen macropterous, fully winged, male wings developed at least in contact with each other above abdomen; distal margin round, cells of distal part irregular intermixed with rectangular. Genitalia: Cerci short triangular, straight, narrowing toward apex, apex pointed; supra-anal plate scutatiform, heavily constricted in the middle, lacking furcula, smooth without tubercles on lateral margins, lacking transverse groove on apical field, lacking tubercles on sides of apical and middle field, transverse ridge present on middle field with lateral groove formed basally extending to the middle part of supra-anal plate; subgenital plate simple conical structure, apex not divided, very short, length equal to basal width, gradually tapering toward apex with blunted end dorsally, tubercle at end of apex present and short.

Female: Larger than male, total length 23.21 mm – 29.62 mm. Colouration, vestiture and texture as in male. **Structure:** Mostly as in male, body robust. *Legs*: hind tibia with 11 spines on outer margin. Genitalia: Ovipositor curved in profile; dorsal and ventral valves equal in length; dorsal valves convergent apically, with one apical tooth, lacking notch, non-bidentate on apex, weakly serrulated on the superior margin; ventral valves very narrow, external margins lowly serrate, external teeth strongly projected outward; subgenital plate triangularly projected weakly posteromedially, lateral teeth weakly projected on lateral sides posteriorly.

Food plant. Arrowroot, bulrush millet, cacao, citrus, coconut, cotton, *Eleocharis* sp., finger millet, fodder crops, *Imperata cylindrica*, maize, pepper, rice and other grains, *Sesbania* sp., sorghum, sugar cane, tobacco and wheat (Roffey, 1979; COPR, 1982; Willemse, 2001 Mahmood et al., 2008).

Ecology. Fallow lands, grassy areas, irrigated land, primary white sand forest, salt marshes and upland rice fields (C. Willemse, 1938; Roffey, 1979; COPR, 1982; L. Willemse, 2001; Tan & Kamaruddin, 2014) with 100 m – 600 m elevation.

Distribution. Africa, Andaman Islands, Australia, Bangladesh, Brunei, southern China, India, Indonesia, Japan, Lord Howe Island, Malaysia, Mariana Islands, Marshall Islands, Myanmar, Nicobar Islands, Papua New Guinea, the Philippines, Singapore, Sri Lanka, Taiwan, Thailand (C. Willemse, 1938; Hollis, 1968; Roffey, 1979; COPR, 1982; L. Willemse, 2001; Mahmood et al., 2008; Tan, 2010a, 2010b, 2012; Tan & Kamaruddin, 2014; Cigliano et al., 2021).

Remarks. *Aiolopus thalassinus tamulus* resembles *Gastrimargus marmoratus* with regards to the faint 'X' marking on the dorsum of pronotal disc and the fact that both species were categorised in the same subfamily Oedipodinae, thus lacking the prosternal processes that are present in other subfamilies. However, a lot of other characters are lacking in *A. thalassinus tamulus* which differentiates both species, such as the major discrepancy in their body size. *A. thalassinus tamulus* is smaller than *G. marmoratus* and does not portray an elevated median keel as the latter. Plus, hind tibiae of *A. thalassinus tamulus* are tricoloured with yellow, blue, and red band, whereas hind tibiae of *G. marmoratus* are unicolourous.

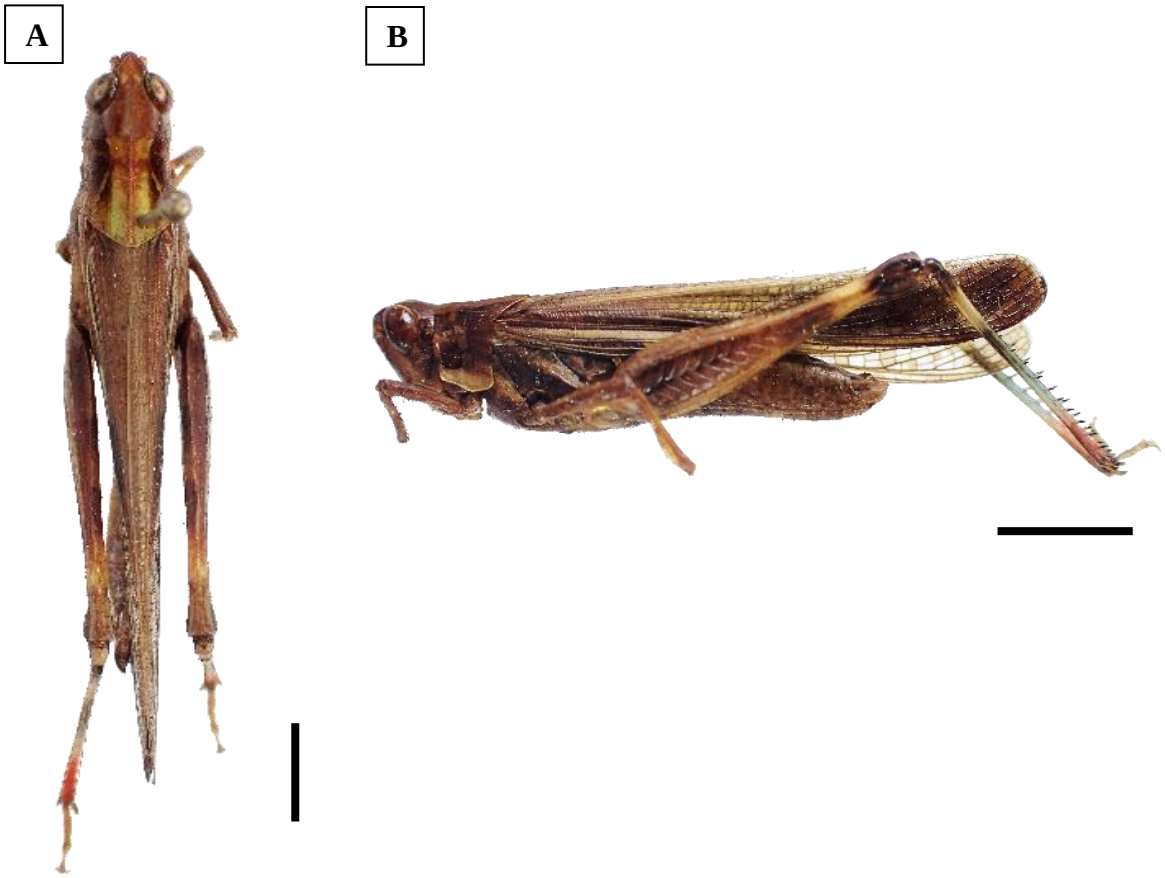


Figure 3.30: *Aiolopus thalassinus tamulus*, ♂. **A.** Dorsal view of type; **B.** Lateral view of type. Scale = 5 mm.

Genus *Gastrimargus* Saussure, 1884

Gastrimargus marmoratus (Thunberg, 1815)

Figure 3.31, Figure 3.35

Gryllus flavus Stoll, 1813: 25

Gyllus marmoratus Thunberg, 1815: 232

Gryllus transversus Thunberg, 1815: 233

Gryllus assimilis Thunberg, 1815: 246

Oedipoda citrina Burmeister, 1838: 645

Oedaleus marmoratus var. *sundaicus* Saussure, 1884: 113

Oedaleus (Gastrimargus) marmoratus var. *grandis* Saussure, 1888: 39

Oedaleus (Gastrimargus) marmoratus var. *sundaicus* Saussure, 1888: 39

Oedaleus (Gastrimargus) marmoratus var. *minor* Saussure, 1888: 39; Ritchie, 1982: 247

Oedaleus (Gastrimargus) marmoratus Krauss, 1891: 659

Oedaleus marmoratus Schulthess, 1898: 187; Bolivar, 1902: 601

Gastrimargus marmoratus Rehn, 1901: 371; Kirby, 1902: 71; Sjöstedt, 1910: 173; Willemse, 1930: 63; Uvarov, 1937: 15; Ritchie, 1982: 262

Gastrimargus assimilis Kirby, 1910: 226

Gastrimargus sundaicus Kirby, 1910: 228; Bruner, 1915: 251 (57)

Materials examined. 55 specimens (♂: 25, ♀: 30). **BORNEO: EAST MALAYSIA: SARAWAK: Bintulu:** Bintulu, 06.IX.1988, Adenan Bukra, 1♂ (RDID). Labang Forest Reserve, 18.II.1987, Lippa Akeng, 1♀ (FN.87-0099) (RDID); 12.XII.1988, caught while eating paddy leaf, M. Jamil Obeng, 1♂ (FN.88-0499) (RDID). Sungai Sibiyu, 10.I.1985, Lippa Akeng, 2♂ (FN.85-0005, FN.85-0006) (RDID). **Kapit:** Ulu Putai, 12.V.2001, caught by light trap, Ento Team, 1♀ (FN.01-1527) (RDID). **Kuching:** Matang, 09.II.1985, Lippa Akeng, 1♂ (FN.85-0315) (RDID). **Lundu:** Gunung Gading National Park, 14.VII.1987, Ento Team, 2♀ (FN.87-0314, FN.87-0315), 2♂ (FN.87-0316, FN.87-0318) (RDID). Sampadi Forest Reserve, 23.VII.1985, Mahmud Merdek, 1♂ (FN.85-0759) (RDID);

23.IV.1987, Lippa Akeng, 1♀ (FN.79-0137) (RDID); 31.V.2011, caught by light trap, Ento Team, 1♀ (GC0685), 1♂ (GC0724) (RDID); 04.VIII.2011, caught by light trap, Ento Team, 1♀ (GC2275) (RDID). **Miri:** Bario, Sungai Mada, 14.III.1988, Lippa Akeng, 1♂ (FN.88-0047) (RDID). Marudi, Loagan Bunut, 02.II.1995, Ento Team, 1♀ (FN.90-0220) (RDID). Mulu National Park, 23.IV.1986, caught at helipad, Lippa Akeng, 3♀ (FN.86-0079 – FN.86-0081), 4♂ (FN.86-0088 – FN.0091) (RDID). **Samarahan:** Kota Samarahan, 12.VIII.2002, Insect Group, 1♀ (UIRC). UNIMAS, 28.II.1997, Soon H. B., 1♀ (UIRC); 07.II.2000, Lancer, 1♀ (UIRC); 27.III.2019, Anis, 1♂ (UIRC). **Sarikei:** Julau, Sungai Ensiring, 13.XII.1993, caught in cicada trapping, Ento Team, 1♀ (RDID). **Serian:** Tarat, Agriculture Resource Station, 23.III.1979, A. A. Hamid, 1♀ (FN.01367A) (RDID). UPMCS Semengoh, 27.IX.1982, Roslan, 1♀ (FN.83-0179) (RDID). **Sibu:** Oya, 18.XII.1982, Lippa Akeng, 2♀ (FN.82-0885, FN.82-0886), Ento Team, 1♂ (FN.82-0785) (RDID); 20.XII.1982, Lippa Akeng, 1♀ (FN.82-0884) (RDID); 13.I.1989, A. A. Hamid, 1♂ (FN.89-0031) (RDID). **Simunjan:** Gedong, Sungai Tersak, 19.VI.2011, Ento Team, 1♀ (RDID). Sabal Forest Reserve, 27.XI.1983, Lippa Akeng, 1♂ (FN.83-1295) (RDID); 01.XII.1983, caught at newly established mahogany plot, Ento Team, 1♂ (FN.83-1268) (RDID); 18.V.1984, Ento Team, 1♂ (FN.84-0928) (RDID); 08.V.1997, caught by light trap, Ento Team, 1♂ (SFR04276) (RDID); 02.IV.1998, caught by light trap, Ento Team, 1♂ (SFR07463) (RDID); 21.III.2011, caught by light trap, Ento Team, 1♀ (GC03383) (RDID). **SABAH: Keningau:** Taman Banjaran Crocker, Ulu Mogiudanau, 10.IX.2002, Ekspedisi Taman Banjaran Crocker, Alt: 100 m, Johny L., 1♀ (OR/02/00759) (SPM). **Kota Kinabalu:** Menggatal, UKMS, 23.X.1992, Carole A. J., 1♀ (ORT-2679) (UMS). Ulu Kionsom, 22.IX.1991, Rosalia T., 1♀ (ORT-2682) (UMS). UMS, T. Likas, 16.XI.1995, Entomology Unit, 1♀ (ORT-2680) (UMS); 18.XI.1995, Entomology Unit, 1♂ (ORT-2681) (UMS). UKMS, 11.IV.1997, caught

by aerial net, low tree, by day, Han Kwai Hui, 1♀ (ORT-2684) (UMS). **Lahad Datu:** Lembah Danum, 24.VIII.1992, Carole A. J., 1♀ (ORT-2683) (UMS). Silam Mountain (A), 10.IX.1995, Johny L., 1♀ (OR/95/00124) (SPM). Silam Mountain (B), 12.IX.1995, Yusilie K., 1♂ (OR/95/00165) (SPM). **Tambunan:** Mahua, 26.X.1999, Sinail D., 1♀ (OR/99/00125) (SPM). **Tenom:** Kg. Purulon Tenom, 11.XI.1998, Yusilie K., 1♂ (OR/98/00166) (SPM).

Diagnosis. *Gastrimargus marmoratus* is defined by the following combination of characters: raised median keel with distinct 'X' marking from posterior margin of compound eyes to posterior margin of pronotal disc, prozona slightly constricted, posterior margin of metazona formed acute angle; width of head smaller than pronotum and abdomen from dorsal view; lacking tubercle process; forewings mottled brown or green, sometimes with whitish hyaline spots, hindwings with brownish sub-circular band from anteromedial margin to posteroapical margin with inner region whitish to pale yellow and outer region brownish hyaline.

Description. Male: Body medium to large, total length 25.46 mm – 42.61 mm. **Colouration:** General colouration is in two forms of colour morphs; brown or green. Head: Generally brownish yellow with dark-brown sub-ocular mark; two pair of black longitudinal stripes between posterior margin of compound eyes to post-occipital margin dorsally; lateral carinae dark brown to black. *Antennae*: Pale to dark brown. Thorax: Pronotum dark brown to black longitudinal stripes resembling X-marking along the pronotum dorsally; lateral lobe with dark irregular spot from the anterior pronotal margin to the principal sulcus; sternum uniformly pale brown to yellow. *Legs*: Hind femur pale yellow to brown, genicular lobe of hind knee with black margin, outer face with black spots on the upper and lower carinula

from medial to apical margins, inner face with black spots along the upper and lower carinula margins; hind tibia pale red, sometimes reddish orange; tarsus brownish red or brown. *Wings*: Tegmen dark brown with irregular transverse white stripes with dark spots medial to apical area; hindwing pale yellow basally with distinctive dark band. *Abdomen*: Uniformly brownish yellow. **Structure:** Body medium to large and robust. Head: Sub-rectangular in frontal view, frons sub-quadrangular to vertex of head in profile; eyes sub-ovate, vertical diameter of eye slightly greater than its horizontal diameter, not exceeding the outline of head, slightly lower than vertex of head laterally, distance from anterior margin of eyes to apex of fastigium equal to the horizontal diameter of eye in profile, inter-ocular slightly distance wider than the width of frontal ridge, lateral carinae distinctly projected, lacking foveolae; anterior apex of head linear and close to compound eyes, fastigium ridge formed vertically elongated adjacent to lateral carinae with transverse groove weakly projected and not interrupting lateral carinae of vertex; apex of fastigium very weakly excavated; frontal ridge of head weakly elongated below median ocellus; frontal costa between antennae not obviously projected forward, not arched above median ocellus; frontal costa above frontal ocellus lightly punctured, frons sparsely punctured. *Antennae*: Longer than the combined length of pronotum and head; filiform-like shaped. Thorax: Pronotum long, tectiform; width as wide as head; lacking prosternal process; prozona slightly shorter than metazona, lateral lobe of metazona slightly expanded dorsally; expanding caudally from dorsal view and longitudinal margins parallel with median carina; median carina crossed by one sulcus, transverse sulci shallowly impressed on pronotal disc, lacking additional incisions on median carina by minor transverse sulci, median carina highly elevated medially, shallow incision on median carina by principal sulcus, lacking lateral carinae; median posterior margin of metazona convexly projected into acute angle; dorsum of prozona and metazona roughly

tuberculated, lateral lobe of prozona distinctly wrinkled; posteroventral margin of lateral lobe slightly angular and not concave; anterior border of mesosternum slightly arched to almost straight, mesosternal lobe slightly wider laterally than its vertical length, mesosternal interspace wide with horizontal length equal to vertical length, inner posterior corners of lobe angularly round; metasternal lobe separated medially. *Legs*: Upper carinae of hind femur weakly serrated, lower carinae smooth, basal lobe dorsally longer than its vertical length, dorsal and ventral genicular lobe roundly angular distally, distal end of dorsal carina spined, narrowly obtuse-angular; hind tibia lacking outer apical spine, number of spines on outer margin 12 to 14, distance between first and second spines on inner margin as long as any other inter-spine distance, distal half of hind tibia not obviously broadened toward apex. *Wings*: Tegmen macropterous, male wings developed in contact with each other above abdomen; distal margin round, cells of distal part sub-rectangular. Genitalia: Cerci short triangular, straight, narrowing toward apex, apex of cerci pointed; supra-anal plate triangular, convexly projected anteriorly with transverse ridge on middle field forming two lateral lobes, lacking furcula and smooth without tubercles near lateral margins; subgenital plate with simple conical structure, apex not divided, very short with length equal to basal width, gradually tapering toward apex with blunted end dorsally, tubercle at end of apex short.

Female: Larger than male, total length 39.07 mm – 46.21 mm. Colouration, and vestiture and texture as in male. **Structure:** Mostly resembling male specimens, body robust. Genitalia: Ovipositor curved in profile, dorsal and ventral valves equal in length; dorsal valves convergent, with one apical tooth, weakly serrulate on the superior margin, non-bidentate and lacking notch on apex; ventral valves wide, external margins weakly serrated dorsally and slightly expanding laterally in the middle field, external lateral teeth not

prominent to almost lacking; subgenital plate broadly rounded to almost straight posteriorly in the middle, lacking lateral teeth on posterior margin.

Food plant. Primarily feed on monocotyledons such as *Imperata cylindrica*, *I. arundinacea*, maize, oil palm, paddy, sorghum, sugar cane, and dicotyledons such as cacao and citrus (Roffey, 1979; COPR, 1982; Willemse, 2001).

Ecology. Agricultural plantation such as maize and paddy, cleared forest areas, mahogany plot, natural vegetation, open grassland with tall grass, paddies on mountain slopes and shrubs (Roffey, 1979; Kalshoven, 1981; COPR, 1982; Willemse, 2001) with 100 m elevation.

Distribution. Africa, Bangladesh, China, eastern India (Assam), Indonesia, Japan, Kashmir, Korea, Malaysia, Myanmar, the Philippines, Singapore, Taiwan, Thailand, Vietnam (Ritchie, 1982; Willemse, 2001; Mahmood et al., 2008; Tan, 2010b; Cigliano et al., 2021).

Remarks. *Gastrimargus marmoratus* is similar to *Locusta migratoria manilensis* in terms of the absence of prosternal processes and raised median carinae. However, median keel of *G. marmoratus* is significantly raised forming slight indentation and apparent 'X' marking on the pronotal disc from dorsal view. Furthermore, *G. marmoratus* displayed brownish sub-circular band from the anteromedial margin to posteroapical margin of its hindwings, a pattern lacking in *L. migratoria manilensis*.

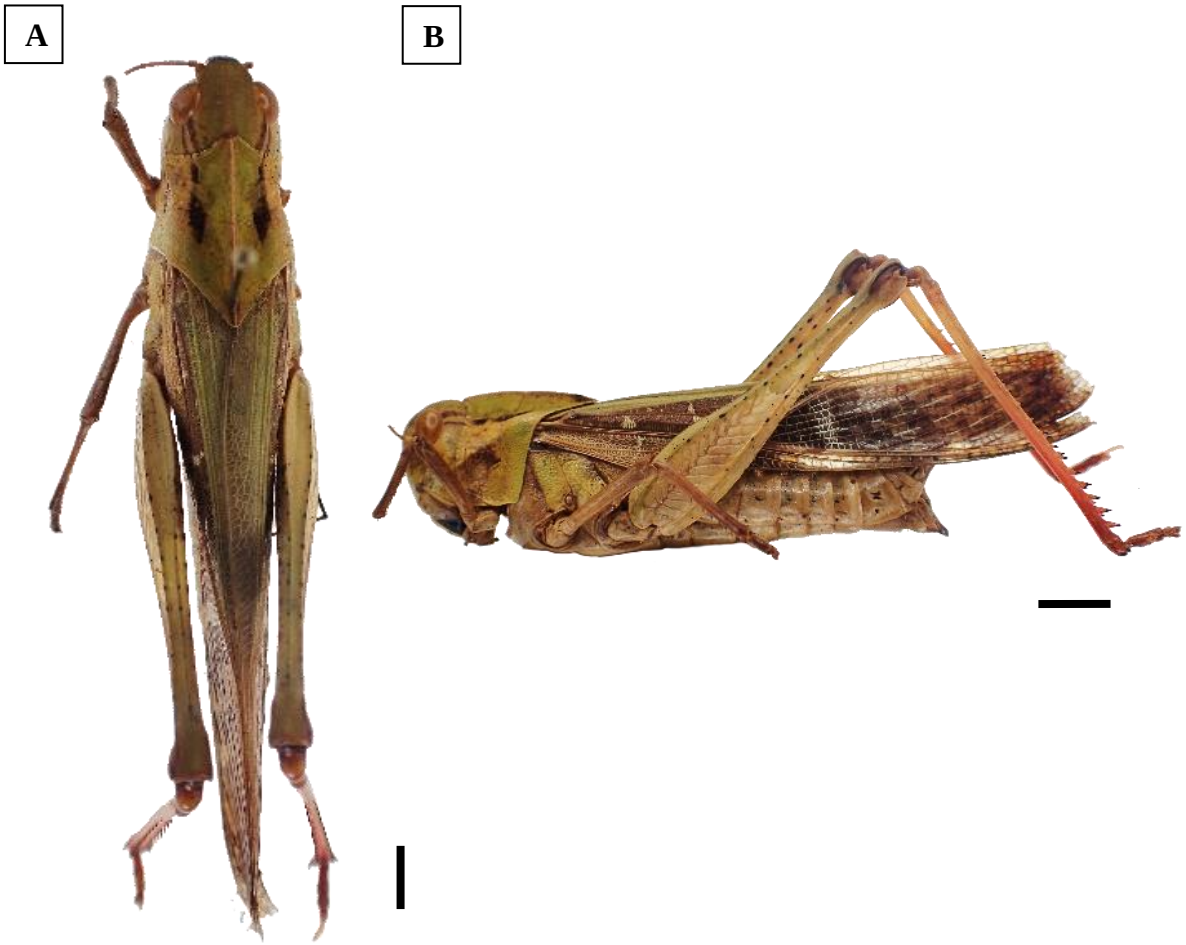


Figure 3.31: *Gastrimargus marmoratus*, ♀. **A.** Dorsal view of type; **B.** Lateral view of type. Scale = 5 mm.

Genus *Heteropternis* Stål, 1873

Heteropternis obscurella (Blanchard, 1853)

Figure 3.32, Figure 3.35

Oedipoda obscurella Blanchard, 1853: 375

Stenobothrus? *obscurellus* Walker, 1870b: 765

Heteropternis obscurella Saussure, 1884: 130; Kirby, 1910; 220; Bruner, 1915: 252 (58); Sjöstedt, 1920: 10; Uvarov, 1937: 15

Materials examined. 5 specimens (♂: 4, ♀: 1). **BORNEO: EAST MALAYSIA: SABAH: Keningau:** Kg. Baliau, 28.VIII.1990, Salmin, 1♂ (ORT-2688) (UMS). **Kota Kinabalu:** Likas, 17.IX.2001, Ito Gen, 1♂ (ORT-2685) (UMS). UMS, T. Likas, 20.XI.1995, Entomology Unit, 1♀ (ORT-2689) (UMS). UMS, 28.IX.2001, Ito Gen, 2♂ (ORT-2686, ORT-2687) (UMS).

Diagnosis. *Heteropternis obscurella* is recognised by having the following combination of characters: foveolae sub-triangular; metazona slightly longer than prozona dorsally; median carina crossed by only one sulcus; mesosternal lobe of mesosternum elongated laterally; lacking prosternal process; tegmina dark brown with irregular cream to yellowish spots; hind femora lacking obvious patterns; hind tibia orange-red; male subgenital plate strongly tapering towards apex, curving upwards in profile with apex rounded.

Description. Male: Body small to medium, total length 18.82 mm – 21.12 mm. **Colouration:** Generally rusty brown to yellowish brown with irregular black markings on head, pleuron and hind femur. Head: Dorsum with faint yellow longitudinal stripe from anterior margin of compound eyes to posterior margin of pronotal disc. *Legs*: Hind femur rusty brown with no obvious patterns; hind tibia reddish orange. *Wings*: Tegmen dark brown with irregular pale yellow to cream-coloured markings. **Structure:** Body small to moderately long, robust and stout. Head: Slightly reclinate towards pronotum; sub-rectangular in frontal view; frons oblique, sub-triangular to vertex of head with an angle of over 40 degrees in profile; eyes sub-circular, vertical diameter slightly longer than horizontal width in profile; not exceeding the outline of head dorsally; eyes distinctly higher than vertex of head from lateral view; distance from anterior margin of eyes to apex of fastigium less than horizontal diameter of eye in profile; inter-ocular distance distinctly wider than width

of frontal ridge; lateral carinae distinctly projected lightly from the anterior margin of compound eyes forming groove on apex of fastigium; foveolae sub-triangular; anterior apex of head projecting forward away from eyes; lacking transverse groove at base of fastigium; frontal ridge obliterate below median ocellus; frontal costa between antennae not obviously projected forward, without discernible arch above median ocellus in profile; front of face smooth without any obvious sculpture and patterns. *Antennae*: Longer than the combined length of head and pronotum; filiform-like shaped. Thorax: Prosternal process absent; pronotum saddle-shaped; pronotum as wide as head from dorsal view; faintly constricted in the metazona; prozona shorter than metazona; expanding caudally from dorsal view; median carina flat dorsally, straight and present as very low ridge laterally; crossed by one sulcus with shallow impression by principal sulcus; lacking lateral carinae; median posterior margin of pronotum broadly angular; surface of pronotum finely sculptured; dorsum of prozona with irregularly wrinkled ridges; dorsum of metazona with no basic sculpting pattern; lateral lobe distinctly wrinkled; posteroventral margin right angular; anterior border of mesosternum slightly arched in the middle; mesosternal lobe laterally wider than vertical length; mesosternal interspace elongated laterally, with basal width longer than its vertical length; anterior margin of interspace straight; inner posterior corner of lobe angularly round; metasternal interspace cordiform, distinctly contiguous. *Legs*: Upper and lower carinae of hind femur smooth; basal lobe dorsally a bit longer than length of ventral lobe in profile; dorsal genicular lobe rounded distally; ventral genicular lobe roundly angular distally; distal end of dorsal carina acutely pointed; hind tibia lacking outer apical spine; number of spines on outer margin 9; distance between first and second spines on inner margin as long as any other inter-spine distance; distal half of hind tibia not obviously broadened towards apex without obvious edges running through the spines. *Wings*: Tegmen macropterous, male

wings developed in contact with each other above abdomen; distal margin round, cell of distal part rectangular. Genitalia: Cerci narrowing towards apex, short triangular, straight in profile, apex round; supra-anal plate scutatiform, lacking furcula, lacking tubercles near lateral margins; subgenital plate simple conical structure, apex not divided, long, vertical length greater than basal width, strongly tapering towards apex, apex lacking tubercle and rounded.

Female: Larger than male, total length 22.56 mm. Colouration, vestiture and texture as in male. **Structure:** Mostly resemble male specimens, body robust and stout. Genitalia: Ovipositor curved posteriorly in profile; dorsal and ventral valves with equal length laterally; dorsal valves convergent posteriorly, with one apical tooth, lowly serrulated to almost smooth on the superior margin, apex non-bidentate, lacking notch apically; ventral valves very wide, external margins weakly serrated on the posterior margin, constricted laterally in the middle, external lateral teeth prominently projected outward; subgenital plate broadly rounded posteriorly, lacking lateral teeth on posterior margin from ventral view.

Food plant. This species has been reported feeding on foliage of young sugar cane (Roffey, 1979; COPR, 1982; Willemse, 2001).

Ecology. Medium to tall open grasslands (Roffey, 1979; COPR, 1982; Willemse, 2001).

Distribution. Australia, Indonesia, Malaysia (Sabah), New Caledonia, Papua New Guinea, the Philippines, Solomon Islands, Vanuatu (Roffey, 1979; COPR, 1982; Willemse, 2001; Cigliano et al., 2021).

Remarks. *Heteropternis obscurella* resembles *Xenocatantops humilis* in terms of the body colouration where both displayed red to reddish-orange hind tibiae and general body

colouration are yellowish brown to dark brown, with the exceptions of the absence of yellow transverse bands on hind femora and slightly reclinate head in profile. Additionally, body structure of *H. obscurella* is physically shorter and stouter than *X. humilis*, and *H. obscurella* does not possessed prosternal tubercle between forelegs.

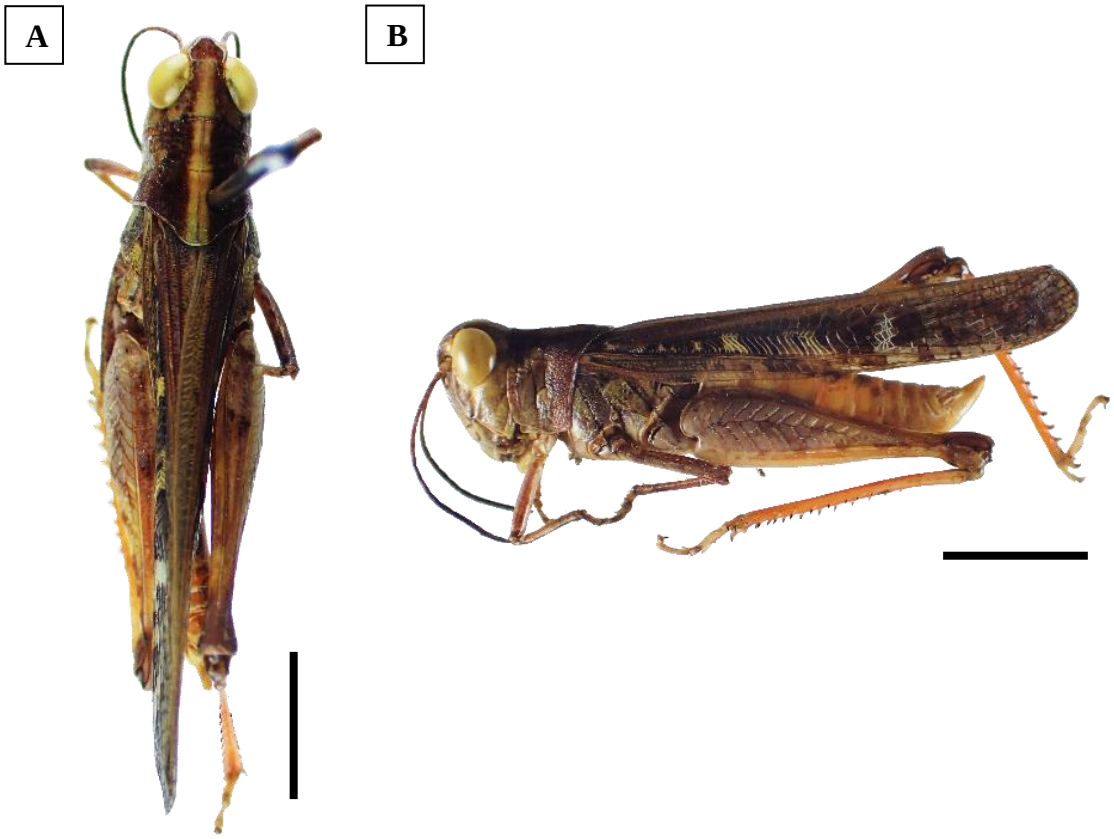


Figure 3.32: *Heteropternis obscurella*, ♂. **A.** Dorsal view of type; **B.** Lateral view of type. Scale = 5 mm.

Genus *Locusta* Linnaeus, 1758

Locusta migratoria manilensis (Meyen, 1835)

Figure 3.33, Figure 3.35

Acrydium manilense Meyen, 1835: 197

Oedipoda migratorioides Ferret & Galinier, 1847: 430

Pachytylus migratorioides Walker, 1870b: 724; Saussure, 1884: 120; Schulthess, 1898: 188

Pachytylus capito Saussure, 1884: 120

Locusta capito Kirby, 1910: 229

Locusta migratoroides Kirby, 1910: 229; Kirby, 1914: 146

Acridium manilense Bruner, 1915: 257 (63)

Locusta migratorioides Uvarov, 1921a: 150

Locusta migratoria phase *migratorioides* Willemse, 1930: 73

Locusta migratoria Uvarov, 1937: 15

Locusta migratoria capito Dirsh, 1963: 277

Materials examined. 14 specimens (♂: 8, ♀: 6). **BORNEO: EAST MALAYSIA: SARAWAK: Kuching:** Matang, Gunung Serapi, 19.V.1983, Ento Team, 1♀ (FN.83-0313) (RDID). **Lundu:** Sematan, Oil Palm Plantation, 26.IV.2012, caught by light trap, Ento Team, 1♀ (GC2695) (RDID). **Serian:** UPMCS Semengoh, 06.II.1983, Suhaili Wis, 1♀ (FN.83-0203) (RDID). **Sibu:** Balingian, 27.III.1998, caught by light trap, Ento Team, 1♂ (FN.98-0287) (RDID). **Simunjan:** Sabal Forest Reserve, 18.V.1984, Ento Team, 1♂ (FN.84-0929) (RDID); 20.V.1984, Ento Team, 1♂ (FN.84-0930) (RDID); 04.VII.2000, caught by light trap, Ento Team, 1♂ (FN.00-0824) (RDID). **Sri Aman:** Lubok Antu, 23.XI.1976, caught on paddy site, B. H. Voon, 1♂ (C.I.E.11170(5)) (RDID). **SABAH:** Power Station Road, 15.XI.1983, Wahab & R. Chiew, 1♀ (OR/83/00123) (SPM).

Keningau: Keningau, 20.IX.1991, Quek Kia Fatt, 1♂ (ORT-2693) (UMS). Taman Banjaran Crocker, 27.X.1998, Alt: 900 m, Geoffary G., 1♂ (OR/98/00146) (SPM). **Kota Kinabalu:** Kota Kinabalu, 20.XI.1987, Adenan Bukra, 1♀ (ORT-2694) (UMS). Menggatal, 30.VIII.1990, Ismail Samah & Tukimat Lihan, 1♀ (ORT-2695) (UMS). **Kudat:** Pitas, 16.IX.1981, caught on cocoa plant, V. F. Wong, 1♂ (ORT-2696) (UMS).

Diagnosis. *Locusta migratoria manilensis* can be distinguished from other members of the family based on the combination of the following characters: vertex of fastigium broad with no significant depression; slightly raised median carinae of pronotum that transversely crossed once, significantly ridged, pronotum marginally constricted in the middle separating prozona and metazona; first segment of the abdomen slightly visible; forewings mottled brown, hindwings unicolourous hyaline.

Description. Male: Size of body is medium to large, total length 33.14 mm – 38.62 mm. **Colouration:** Body rusty brown. Head: Generally brownish yellow with dark-brown longitudinal mark along the sub-ocular groove, extending to the mandible and from the fastigium to frontal costa with black frontal and lateral carinae; frons yellowish from lateral ocelli to clypeus and labrum. *Antennae*: Pale to dark brown. Thorax: Pronotum uniformly rusty brown with dark brown or black median keel; sternum generally rusty brown, sometimes pale yellow. *Legs*: Outer face of hind femur mostly rusty brown or pale yellow with row of parallel black dots on upper carina and upper carinula, ventral genicular lobe yellow with black margin dorsally, inner face generally dark brown with two pale yellow stripes near genicular lobes or knee; hind tibia generally bright red to pale red, sometimes pale yellow in certain individuals; tarsus uniformly pale to dark brown, sometimes pale yellow. *Wings*: Tegmen mottled with brown maculation and pale-yellow base, opaque on

the apical area, hyaline on anal area. *Abdomen*: Generally brown, sometimes pale yellow. **Structure:** Body robust and long. Head: Sub-rectangular in frontal view; frons sub-quadrangular to vertex of head in profile; eyes sub-ovate, large, not exceeding the outline of head, as high as frontal ridge of head laterally; distance from anterior margin of eyes to the apex of fastigium less than the horizontal diameter of eye in profile; inter-ocular distance wider than width of frontal ridge, lateral carinae present; lacking foveolae; anterior apex of head linear and close to compound eyes dorsally, lacking transverse ridge; apex of fastigium weakly excavated; frontal ridge of head obliterated below median ocellus; frontal costa between antennae not obviously projected, not forming discernible arch above median ocellus; frontal costa and frons lightly punctured and slightly wrinkled. *Antennae*: Slightly longer than the combined length of pronotum and head; filiform-like shaped. Thorax: Prosternal process absent; pronotum tectiform, width as wide as head, metazona slightly longer than prozona, expanding caudally from dorsal view and constricted in the middle, transverse sulci shallowly impressed on pronotal disc, median carina crossed by one sulcus, first and second transverse sulci not cutting the median carina, median carina distinctly elevated dorsally and straight in lateral view, shallow incision by principal sulcus with no additional incisions by minor transverse carina, lateral carinae absent, median carina present as narrow and sharp ridge, median posterior margin of metazona convexly projected into acute angle, pronotal disc moderately granulated, dorsum of prozona tuberculated, lateral lobe of prozona distinctly wrinkled, dorsum of metazona with small and numerous ridges forming small pits, posteroventral margin of lateral lobe broadly round and slightly arched; anterior border of mesosternum weakly arched, almost straight, mesosternal lobe laterally wider than vertical length, interspace between mesosternal lobes slightly longer than broad, inner posterior corners of lobe obtusely round, metasternal lobe separated medially. *Legs*:

Upper carinae of hind femur prominently serrulate, lower carinae smooth, basal lobe dorsally longer than ventral length, dorsal and ventral genicular lobe roundly angular distally, distal end of dorsal carina spined, narrowly obtuse-angular; hind tibia lacking outer apical spine, number of spines on outer margin 10 on the left hind tibia, 11 on the right hind tibia, distance between first and second spines of inner margin as long as any other inter-spine distance, distal half slightly broadened toward apex, without distinct outer and inner edges running through the spines. *Wings*: Tegmen macropterous, fully winged, male wings developed at least in contact with each other above abdomen; distal margin round, cells of distal part irregular intermixed with rectangular. Genitalia: Cerci short triangular; straight, narrowing toward apex, apex pointed; supra-anal plate triangular, lacking furcula, smooth without tubercles near lateral margins; lacking transverse groove on apical field and tubercles on sides of apical and middle field, transverse ridge present forming semi-circle dorsally on middle field, lateral groove present on middle field; subgenital plate simple conical structure, apex not divided, long, length greater than basal width but not more than 1.5 times ventrally, gradually tapering toward apex with rounded end dorsally, tubercle at end of apex present and short.

Female: Larger than male, total length 42.42 mm – 49.32 mm. Colouration, vestiture and texture as in male. **Structure:** Mostly as in male, body robust. *Antennae*: Fairly longer than the combined length of pronotum and head. Genitalia: Ovipositor curved in profile, dorsal and ventral valves equal in length; dorsal valve convergent apically, with one apical tooth, lacking notch on apex, lowly serrulate on the superior margin, not bidentate; ventral valve wide, external margins prominently serrate apically, weakly constricted laterally in the middle field, external lateral teeth weakly projected outward; subgenital plate weakly

triangulated posteriorly in the middle, lacking lateral teeth on posterior margin from ventral view.

Food plant. Bamboo, banana, bean, betel nut, cassava, coconut, groundnut, *Imperata arundinacea*, *I. cylindrica*, lablab, maize, paddy, pigeon pea, pineapple, potato, reed, rubber, sago palm, sisal, sorghum, soybean, sugar cane, sweet potato, and tobacco (Grist & Lever, 1969; Roffey, 1979; COPR, 1982; Willemse, 2001; Siwi et al., 2005).

Ecology. Low-lying grasslands, tropical grasslands developed due to the clearance of forest as part of the shifting cultivation (Uvarov, 1966; Roffey, 1979; COPR, 1982; Khoo et al., 1991; Willemse, 2001).

Distribution. Africa, Australia, Indonesia, Malaysia, the Philippines (Roffey, 1979; COPR, 1982; Willemse, 2001; Siwi et al., 2005; Mahmood et al., 2008; Cigliano et al., 2021).

Remarks. *Locusta migratoria manilensis* shared the same physical attributes with *Gastrimargus marmoratus* and *Valanga nigricornis*, where all species mentioned can conceal and disguise themselves in their habitats with their ground-coloured bodies. Nonetheless, *L. migratoria manilensis* and *G. marmoratus* are distinctly smaller in size than *V. nigricornis* and both species do not possess prosternal processes between forelegs. *L. migratoria manilensis* resembles *G. marmoratus* as both have slightly constricted prozona with the exceptions of the patterns on hindwings where *L. migratoria manilensis* displayed unicolourous hyaline hindwings.

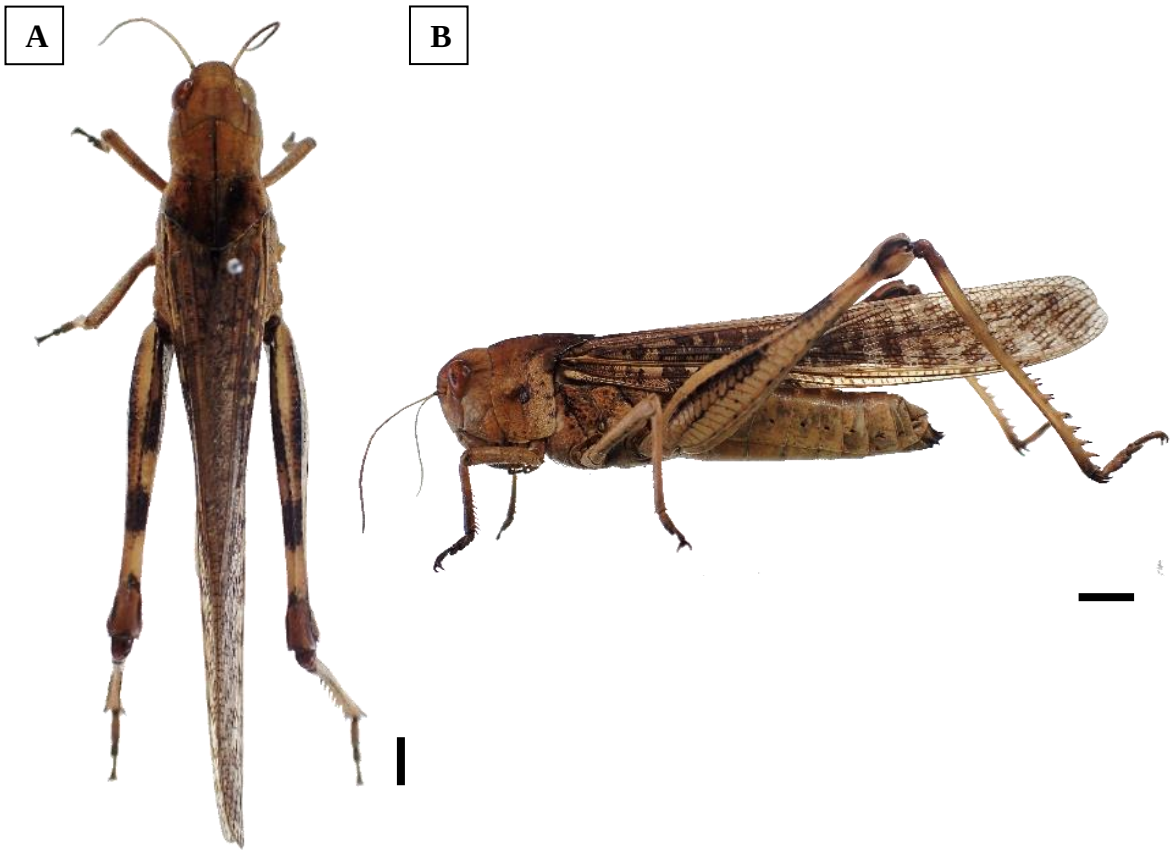


Figure 3.33: *Locusta migratoria manilensis*, ♂. **A.** Dorsal view of type; **B.** Lateral view of type. Scale = 5 mm.

Genus *Trilophidia* Stål, 1873

Trilophidia annulata (Thunberg, 1815)

Figure 3.34, Figure 3.35

Gryllus annulatus Thunberg, 1815: 234

Oedipoda? *vulnerata* Walker, 1870b: 743

Epacromia aspera Walker, 1870b: 775

Trilophidia annulata var. *ceylonica* Saussure, 1884: 158

Trilophidia annulata Bolivar, 1902: 604; Kirby, 1914: 149; Karny, 1915: 85; Uvarov, 1921b: 488; Uvarov, 1929: 546; Willemse, 1930: 57

Trilophidia ceylonica Kirby, 1910: 244

Trilophidia vulnerata Kirby, 1910: 244

Trilophidia cristella Kirby, 1910: 244; Bruner, 1915: 253 (59)

Trilophidia aspera Uvarov, 1921b: 488; Uvarov, 1929: 546

Materials examined. 64 specimens (♂: 24, ♀: 40). **BORNEO: EAST MALAYSIA: SARAWAK: Bintulu:** Sungai Sibiyu, 10.I.1985, Lippa Akeng, 2♀ (FN.85-0011, FN.85-0012), 2♂ (FN.85-0010, FN.85-0013) (RDID). Similajau National Park, 13.IX.2000, Ento Team, 1♀ (FN.00-1113) (RDID). **Miri:** Bario, 12.IV.1995, day trail, in quarry area, S. H., F. A., Lim, W. M., 1♀ (UIRC). Lambir Hills National Park, 02.VII.1995, caught by UV light, Ento Team, 1♀ (D0182) (RDID); 12.IX.1996, caught by UV light, Ento Team, 1♀ (E0511) (RDID); 29.IV.1998, caught by UV light, Ento Team, 1♀ (G0009) (RDID). Niah, 01.IV.1984, Lippa Akeng, 1♀ (FN.84-0519), 1♂ (FN.84-0520) (RDID); 17.I.1985, Manis Lintang, 1♂ (FN.85-0154) (RDID). **Kuching:** Bau, 25.VII.2002, Monijane, 1♂ (UIRC). Borneo Highland Resort, 19.IV.2017, Hidayah Zulkefli, 1♀ (UIRC). Lanjak Entimau Wildlife Sanctuary, 20.VIII.1998, Nafri & Mat, 1♂ (FN.98-0547) (RDID). Tabuan Jaya, 18.I.2000, Alvin Bong, 1♀ (UIRC). Taman Malihah Jaya I, 18.VIII.2018, Farah Aidil Fitri, 1♂ (UIRC). **Samarahan:** Kota Samarahan, 10.II.2003, Lynn, 1♀ (UIRC); 11.XII.2003, Wahap M., 1♀ (UIRC); 28.XII.2003, Phyllis Lahang, 1♀ (UIRC); 10.III.2016, Rahmawati S. & Fatimah, 1♀ (UIRC); 16.IV.2019, Syahizi Haikal, 1♀ (UIRC). UNIMAS, 06.III.1997, Fiona, 1♂ (UIRC); 09.II.2000, Volianta, 1♀ (UIRC); 12.II.2000, Jay Sandin, 1♀ (UIRC).

UNIMAS, PITAS, 21.III.2017, Firdaus, 1♂ (UIRC). **Serian:** Serian, 31.I.2004, Nazahiyah A. R., 1♂ (UIRC). **Simunjan:** Sabal Forest Reserve, 18.V.1984, Ento Team, 1♀ (FN.84-0917) (RDID); 27.X.1996, Ento Team, 1♂ (SFR00198) (RDID); 12.XII.1996, caught by light trap, Ento Team, 1♀ (SFR00927) (RDID); 15.XII.1996, caught by light trap, Ento Team, 1♀ (SFR01126) (RDID); 13.III.1997, caught by light trap, Ento Team, 1♂ (SFR02783) (RDID); 10.X.1997, Ento Team, 1♀ (SFR05882) (RDID); 11.IV.2000, caught by light trap, Ento Team, 1♂ (FN.00-0606) (RDID). **SABAH: Keningau:** Taman Banjaran Crocker, Ulu Senagang, 17-19.X.1999, Ito Gen, 6♀ (ORT-2645, ORT-2649 – ORT-2653), 3♂ (ORT-2646 – ORT-2648) (UMS). Taman Banjaran Crocker, Sub Stesen Ulu Senagang, 27.X.-01.XI.2011, Yusilie K., 1♀ (SP/EOR/01789) (SPM). Taman Banjaran Crocker, Tenom, Pos Kawalan Kikiran, 14-18.VII.2014, Alt: 95 m, Welfred Torimoh, 1♀ (SP/EOR/01945) (SPM). **Kinabatangan:** Kg. Tidung, 17-24.X.2003, Ekspedisi Lower Segama, Johny L., 1♂ (SP/EOR/00946) (SPM). Sukau, Gomantong, 24.VI.2014, found on leaves by using aerial net, Ika Rafika, 1♀ (UMS). **Kota Kinabalu:** Likas Wetland, 22.X.2001, Ito Gen, 2♀ (ORT-2643, ORT-2644) (UMS). **Lahad Datu:** Tomanggong, 19.V.1997, Alt: 20 m, Akira Kashizaki, 1♀ (ENT: 3557) (SM). **Penampang:** Sub Stesen Inobong, 12-13.VII.2007, Alt: 500 m, Yusilie K., 1♂ (SP/EOR/01250) (SPM). **Ranau:** Kg. Singgaron Baru, 22-29.IV.2016, Eksplorasi Hutan Simpan Komuniti, Johny L., 1♂ (SP/EOR/01981) (SPM). Kinabalu Park, Narumad, 12.III.2000, Alt: 700 m, Ito Gen, 1♀ (ORT-2642), 2♂ (ORT-2640, ORT-2641) (UMS). Kinabalu Park, Sub Stesen Monggis, 3-7.X.2009, Muzamil Mustaffa, Cornelius Peter & Hong Men Chin, 1♀ (UMS). Poring, 27.IV.1987, A. Ueda & N. Dean, 1♀ (ORT-1297) (UMS). Tomboyokan, 24-29.IX.2005, Ekspedisi Tomboyokan, Alt: 335 m – 599 m, Johny L., 1♀ (SP/EOR/01145) (SPM). **Tawau:** Maliau Basin, Agathis Camp, 12-19.V.2001, found in open grassland, Ito Gen & Azrie A.,

1♂ (ORT-1230) (UMS). Taman Bukit Tawau, Sub Stesen Balung, Jalan Air Panas, 27.IV.2012, Johny L., 1♂ (SP/EOR/01824) (SPM). Taman Bukit Tawau, Sub Stesen Balung, 28.IV.2012, Alt: 120 m, Sinail D., 1♂ (SP/EOR/01825) (SPM). Taman Bukit Tawau, Sub Stesen Merotai, 5-10.XII.2016, Alt: 185 m, Johny L., 1♀ (SP/EOR/01961) (SPM). **Tenom:** Lingkangan, 20.VIII.1986, M. Noor, 1♀ (ORT-1296) (UMS). **Tuaran:** Tamparuli, Malangang Lama Kiulu, 27-29.VII.2003, Nancy Jipanis, 1♀ (SP/EOR/00931) (SPM).

Diagnosis. *Trilophidia annulata* can be distinguished from other members in family Acrididae on the basis of the presence of two highly elevated tooth-like projections on the prozona cutting the end of first transverse sulci and two transversely thick ridges on vertex of head, hind margin of lateral lobes of pronotum right angulate; body small with dark brown and blackish spots; hind tibiae black with two pale yellow bands.

Description. Male: Body small to medium, total length 13.84 mm – 17.25 mm. **Colouration:** Body rusty brown with blackish spots. Head: Rusty to dark brown with black spots all over head. *Antennae*: Pale to dark brown. Thorax: Pronotum dark brown with black spots throughout pronotal discs; median carina on metazona dark brown to black; sternum uniformly brown to pale yellow. *Legs*: Outer face of hind femur mostly rusty brown with three irregular spots on the upper carinula, inner face black with pale yellow ring before genicular lobes; hind tibia uniformly black or dark brown with two yellow rings; tarsus generally black or dark brown. *Wings*: Tegmen mottled with yellow maculation and dark brown to almost black base, opaque on anal area; hindwing yellow to yellowish green basally. *Abdomen*: Uniformly brown to pale yellow. **Structure:** Body robust and medium long. Head: Sub-rectangular in frontal view, frons sub-quadrangular to vertex of head in

profile; eyes sub-ovate, not exceeding the outline of head, as high as frontal ridge of head laterally, distance from anterior margin of eyes to the apex of fastigium less than the horizontal diameter of eye in profile, inter-ocular distance distinctly wider than width of frontal ridge, lateral carinae present, foveolae sub-triangular adjacent to lateral ocelli; anterior apex of head linear and close to compound eyes, lateral ridge formed longitudinal depression in the middle, lacking transverse groove at the base of fastigium; apex of fastigium deeply excavated; vertex of head with two thick transverse tubercles; frontal ridge of head elongate below median ocellus nearing anterior margin of clypeus; frontal costa between antennae very faintly projected forward, vaguely arched above median ocellus; frontal costa above frontal ocellus with wide punctures, integument between pre-ocular ridge and frontal ridge with sparse pebbled surface. *Antennae*: As long as the combined length of pronotum and head; filiform-like shaped. Thorax: Pronotum scutatiform, width as wide as head, lacking prosternal process, metazona distinctly longer than prozona, expanding caudally from dorsal view and slightly constricted in the middle, median carina crossed by two sulci, transverse sulci deeply impressed on pronotal disc, minor transverse sulcus cutting median carina on dorsum of prozona with two tubercles parallel to first elevated median keel, median carina strongly elevated medially forming two round ridges with tooth-like projections laterally, deep incision on median carina by principal sulcus, lateral carinae slightly elevated, not contiguous from anterior to posterior margin of pronotum dorsally, median carina projected as thick ridge, median posterior margin of metazona convexly projected into acute angle, pronotal disc coarsely tuberculated, dorsum of prozona roughly tuberculate, lateral lobe of prozona distinctly wrinkled, dorsum of metazona with no basic sculpting pattern, posteroventral margin of lateral lobe roundly angular and slightly arched; anterior border of mesosternum weakly arched, almost straight, mesosternal lobe laterally

wider than vertical length, interspace between mesosternal lobes elongate with longitudinal length broader than vertical length, inner posterior corners of lobe roundly angular, metasternal lobe separated medially. *Legs*: Upper and lower carinae of hind femur smooth, dorsal lobe dorsally longer than vertical length, dorsal and ventral genicular lobe round distally, distal end of dorsal carina spined, narrowly obtuse-angular; hind tibia lacking outer apical spine, number of spines on outer margin 7 to 8, distance between first and second spines on inner margin as long as any other inter-spine distance, distal half not obviously broadened towards apex without distinct edges running through the spines. *Wings*: Tegmen macropterous, fully winged, male wings developed at least in contact with each other above abdomen; distal margin round, cell of distal part rectangular. Genitalia: Cerci short triangular, straight, narrowing toward apex, apex of cerci pointed; supra-anal plate scutatiform, concave anteriorly, lacking furcula and smooth without two digitiform tubercles near lateral margins, lacking transverse groove and tubercles on sides of apical field, lacking transverse ridge and tubercles on sides of middle field; subgenital plate simple conical structure, apex not divided, very short, length equal to or less than basal width, gradually tapering toward apex with rounded end dorsally, tubercle at end of apex present and short.

Female: Larger than male, total length 15.15 mm – 22.76 mm. Colouration, vestiture and texture as in male. **Structure:** Mostly as in male. Genitalia: Ovipositor curved in profile, dorsal and ventral valves equal in length; dorsal valves convergent, with one apical tooth, lowly serrulate on the superior margin, non-bidentate and lacking notch on apex; ventral valves very narrow, external margins weakly serrated dorsally and weakly constricted laterally in the middle field, external lateral teeth very weakly projected outward; subgenital plate broadly rounded posteriorly in the middle, lacking lateral teeth on posterior margin.

Food plant. Plants such as *Amaranthus* sp., *Blumea* sp., *Imperata cylindrica*, *Saccharum spontaneum* and *Santalum album*, and crops such as bermuda grass, cacao, coconut, maize, mulberry, paddy, sandalwood, sorghum, sugar cane, sweet potato, teak, and tobacco (Roffey, 1979; COPR, 1982; Willemse, 2001).

Ecology. Along roadsides, gardens, irrigated areas, jungle outskirts, moss forest, old secondary forest, open grasslands, places overgrown with grasses, plantations (oil palm, sugar cane), primary white sand forest, secondary vegetation (C. Willemse, 1938; Roffey, 1979; COPR, 1982; L. Willemse, 2001; Mahmood et al., 2008; Tan & Kamaruddin, 2014, 2016) and montane forest with 20 m – 700 m elevation.

Distribution. Afghanistan, Bangladesh, Brunei, China, India, Indonesia, Japan, Kashmir, Malaysia, Mongolia, Myanmar, Nepal, Pakistan, the Philippines, Singapore, South Korea, Sri Lanka, Thailand, Vietnam (C. Willemse, 1938; Hollis, 1965; Roffey, 1979; COPR, 1982; L. Willemse, 2001; Mahmood et al., 2008; Tan, 2010a, 2010b, 2012; Tan & Kamaruddin, 2014, 2016; Cigliano et al., 2021).

Remarks. *Trilophidia annulata* barely share any visible external similarities with other members of the subfamily other than the absence of prosternal process between forelegs. Due to their unique external morphology, which is dark brown with blackish spots or at times greyish in colour, it provides this species the ability to camouflage and hide from predators efficiently. Apart from that, the prominent characters distinguishing *T. annulata* from other species are the presence of two transversely thick ridges on the vertex of head, as well as two teeth-like projections on median carinae.



Figure 3.34: *Trilophidia annulata*, ♂. **A.** Dorsal view of type; **B.** Lateral view of type. Scale = 5 mm.

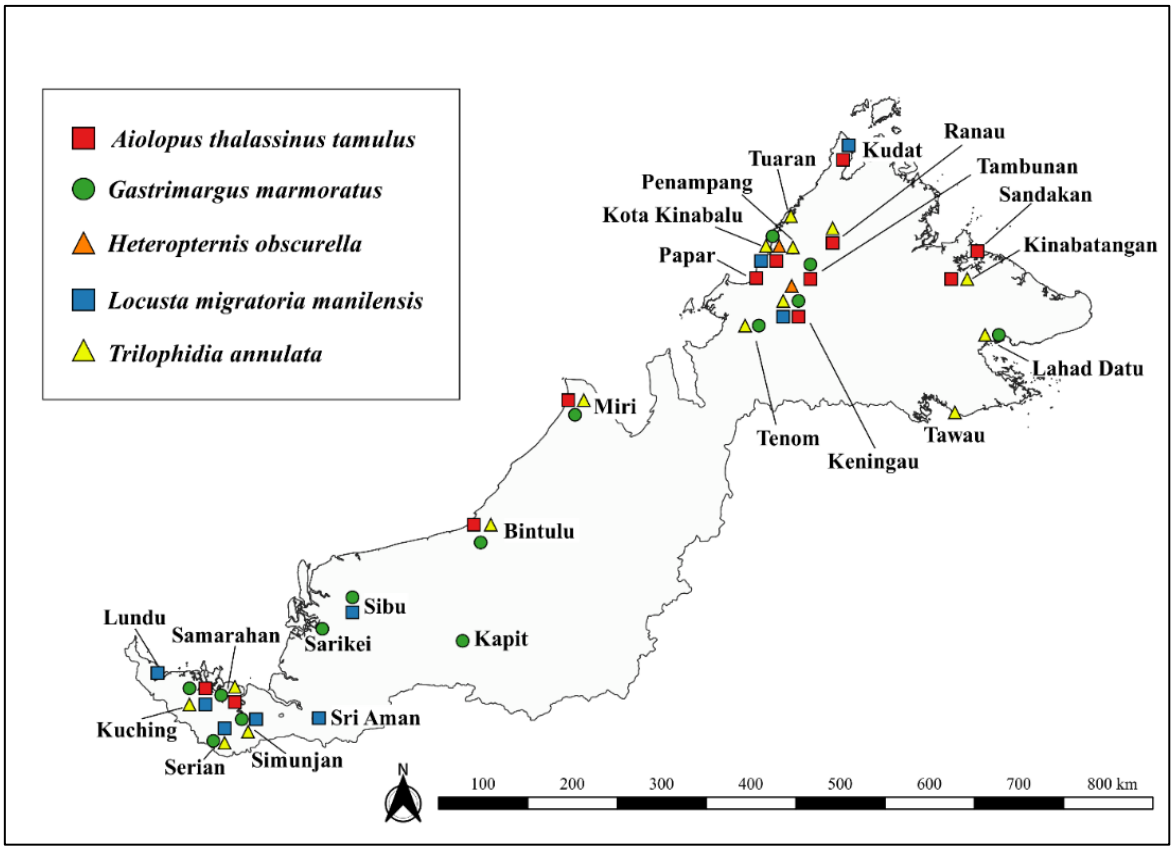


Figure 3.35: Distribution map of subfamily Oedipodinae in Malaysian Borneo.

Subfamily Oxyinae Brunner von Wattenwyl, 1893

Genus *Oxya* Serville, 1831

Diagnosis. Body size small to medium and slender; antennae filiform, reaching posterior margin of pronotal disc; head slightly reclinate with frontal ridge not projecting between the antennae from dorsal view; pronotum cylindrical, lateral carinae missing, median carinae present with very thin ridges, transverse sulci very shallowly impressed, posterior margin of pronotal disc angulately rounded; anterior border of mesosternum broadly projected in the middle sometimes angulated, mesosternal lobe with equal length or vertically longer than lateral width, metasternal interspace distinctly contiguous; tegmina macropterous or brachypterous; knees of hind femora pointed, hind tibiae with 8 to 9 spines on outer margins,

with outer apical spine; male cerci conical with apex truncated or bifurcated; female ovipositor valves with prominent teeth all over the margin.

Oxya hyla intricata (Stål, 1861)

Figure 3.36, Figure 3.39

Acridium (Oxya) intricatum Stål, 1861: 335

Oxya intricata Walker, 1870b: 647; Stål, 1873: 82; Wattenwyl & Fea, 1893: 153; Bolivar, 1902: 613; Burr, 1903: 235; Kirby, 1910: 394; Kirby, 1914: 200; Bruner, 1915: 256 (62); Bolivar, 1918b: 16; Willemse, 1925: 57; Willemse, 1930: 122; Willemse, 1956: 149

Oxya universalis Willemse, 1925: 21

Oxya insularis Willemse, 1925: 34

Oxya siamensis Willemse, 1925: 37

Oxya hyla intricata Hollis, 1971: 287

Materials examined. 31 specimens (♂: 24, ♀: 7). **BORNEO: EAST MALAYSIA: SARAWAK: Betong:** Skuyat Baru, 16.III.2019, Felycia Rinta, 1♂ (UIRC). **Kuching:** Padawan, Borneo Highlands, 11.IV.2016, Ammelia, 1♂, Nurulhidayah, 1♂ (UIRC). **Samarahan:** Kota Samarahan, 16.III.2016, Siti Zulaikha, 1♂ (UIRC). Sadong Jaya, 19.VII.2019, Ento Team, 1♂ (UIRC); 20.VII.2019, Ento Team, 1♂ (UIRC). Unijaya, 16.III.2016, Clementine M. & Nickitta D., 1♂ (UIRC); 17.III.2018, Yonlly Yonjuni, 1♂ (UIRC). UNIMAS, 11.II.2000, Ika Liana Khalid, 1♀ (UIRC); 21.IV.2018, Hadirah, 1♂

(UIRC). UNIMAS, Basketball Court, 03.XII.2003, Sandra James, 1♂ (UIRC). UNIMAS, East Campus, 26.III.2016, Zakirah Jasni, 1♂ (UIRC); 24.III.2017, Siti Nor Mahmmod, 1♂ (UIRC). UNIMAS, External Laboratory, 06.V.2016, Aina & Syafinaz, 1♂ (UIRC). UNIMAS, Kolej Allamanda, 14.IV.2016, Emira Izzati Aziz, 1♂ (UIRC); 26.IV.2016, S.A.M. Zaid, 1♂ (UIRC). UNIMAS, Kolej Dahlia, 18.III.2016, Aina & Syafinaz, 1♂ (UIRC). UNIMAS, Kolej Rafflesia, 18.V.2016, N.A.A. Rahim, 1♂ (UIRC). UNIMAS, PITAS, 16.IV.2016, Syafiqah J. & Ilya N., 1♂ (UIRC); 20.III.2019, Azimah, 1♂ (UIRC). **Serian:** Ranchan Recreation Park, 14.IV.2018, Amanda Wilson, 1♀ (UIRC). **Simunjan:** Sabal Forest Reserve, 31.III.2014, Ento Team, 1♀ (GC3580), 2♂ (GC3576, GC3579) (RDID). Sebuyau, 13.VIII.2015, Ento Team, 1♀ (GC6331) (RDID). **Sri Aman:** Lingga, 15.IV.2017, Nur Nabihah, 1♂ (UIRC). **SABAH: Kinabatangan:** Kg. Tidong, 17-24.X.2003, Ekspedisi Lower Segama, Johny L., 1♂ (SP/EOR/00943) (SPM). **Kota Kinabalu:** UMS Peak, 15.V.2017, caught in bushes by aerial net, Azila N., 1♀ (UMS). **Sandakan:** Beluran, Kg. Keniogan, 11.XI.1997, Sinail D., 1♂ (OR/97/00202) (SPM). Beluran, Kuala Sapi, 12.XI.1997, Gunik G., 1♀ (OR/97/00201) (SPM). **Tuaran:** Tuaran, 14.V.2017, caught by hand, Jabir & Mohd Rosyaidi, 1♀ (UMS).

Diagnosis. *Oxya hyla intricata* is recognised by having the following combination of characters: hind femora unicolourous pale yellow or brown, hind knees dark brown to black; hind tibiae pale to dark brown, sometimes with a tinge of pale cobalt blue on the inner and outer edges of tibiae; inner margin of hind tibia with 10 spines; male cercus slender, apex truncated; ovipositor valves of female ovipositor long and narrow; female subgenital plate without longitudinal ridges on ventral surface, posterior margin with a pair of acutely pointed and small lateral teeth.

Description. Male: Body small, total length 18.14 mm – 21.38 mm. **Colouration:** Body yellowish green or pale brown. Head: Yellowish green or pale brown, dorsum of head pale green or yellowish green, sometimes pale brown with a pair of dark brown longitudinal stripes dorso-laterally. *Antennae*: Pale yellow to brown. Thorax: Pronotum with a pair of dark brown longitudinal stripes dorso-laterally contiguous from head. *Legs*: hind femur unicolourous yellow or pale brown, hind knees with dark brown or black marking; hind tibia pale to dark brown, sometimes with a tinge of pale cobalt blue on the inner and outer edges of tibia; tarsi yellow or pale brown. *Wings*: Tegmen green or pale-yellow continuing from posterior margin of pronotum to the apex of tegmen, darker brown on lateral side. **Structure:** Body robust and small. Head: Sub-rectangular in frontal view, frons oblique, sub-triangularly to vertex of head with an angle of over 40 degrees in profile; eyes long oval, vertical diameter significantly longer than horizontal diameter of eye laterally, exceeding the outline of head dorsally, eyes slightly higher than vertex of head in profile, inter-ocular distance same as the width of anterior margin of frontal ridge, lacking foveolae and lateral carinae, distance from anterior margin of eyes to apex of fastigium much shorter than the horizontal diameter of eye in profile, anterior apex of head sub-triangular slightly projecting forward away from eyes, lacking transverse groove at base of fastigium, fastigium very weakly excavated sometimes almost non-discernible; frontal costa above frontal ocellus smooth without any pattern and widely impressed projecting thick frontal ridge that elongate towards clypeus; frontal costa between antennae slightly projected forward but not forming discernible arch above frontal ocellus in profile; frons with pebbled surface; mandible very weakly projected broader than width of pronotum dorsally. *Antennae*: antennae as long as the combined length of pronotum and head; filiform-like shaped. Thorax: Prosternal process cylindrical, slightly compressed, straight, apex of tubercle almost reaching anterior margin

of mesosternum; pronotum saddle-shaped, pronotum longer than head, slightly narrower than head, prozona significantly longer than metazona, pronotum with slightly expanded metazona dorsally and slightly constricted on metazoan, median carina barely discernible to almost absent and flat dorsally, straight and present as very low ridge in profile, crossed by three sulci, shallow incision by principal sulcus and minor transverse sulci, lacking lateral carinae, median posterior margin of metazona broadly angular and not concave, surface of pronotum irregularly punctured and thinly carinulated, dorsum of prozona and lateral lobe irregularly thinly punctured, dorsum of metazona with ridges forming numerous small and shallow pits, posteroventral margin of lateral lobe angular with an angle of more or equal to 90 degrees and slightly arched; sternum long, anterior border of mesosternum broadly projected in the middle, mesosternal lobe vertically longer than lateral width, mesosternal interspace sub-rectangular, resembling the hour-glass shape, elongate with vertical length almost twice as long as the basal width, anterior margin of interspace straight, inner posterior corners of lobe obtusely round, metasternal lobe contiguous. *Legs*: Upper and lower carinae of hind femur smooth, basal lobe dorsally longer than ventral lobe, dorsal genicular lobe rounded distally, ventral genicular lobe with acutely pointed spine, distal end of dorsal carina with narrowly obtuse-angular spine; hind tibia with outer apical spine, number of spines on outer margin 8, distance between first and second spines on inner margin as long as any other inter-spine distance, distal half of hind tibia obviously broadened towards apex with distinct outer and inner edges running through the spines. *Wings*: Tegmen macropterous, male wings developed in contact with each other above abdomen; distal margin round, cell of distal part sub-rectangular. Genitalia: Cerci narrowing towards apex, elongated conical, slightly compressed laterally, straight in profile, apex truncated; supra-anal plate scutatiform with lateral side expanded, apex not divided, lacking furcula and smooth without tubercles near

lateral margins, lateral groove deeply impressed on the middle field not reaching the medial area of the plate and on sides of middle field, tubercles on sides of middle field; subgenital plate sub-triangular ventrally with apex blunted and not divided, short with vertical length equal or less than basal width, not tapering with end truncated, lacking tubercle at end of apex.

Female: Slightly larger than male, total length 19.13 mm – 28.09 mm. Colouration, vestiture and texture as in male. **Structure:** Mostly resemble male specimens, body robust. Genitalia: Ovipositor long and slightly curved apically in profile, dorsal and ventral valves with equal length; dorsal valves slightly convergent dorsally, with one apical tooth, prominent teeth all over the margin, non-bidentate and lacking notch on apex; ventral valves very narrow and long, with prominent teeth all over the margin, slightly constricted laterally in the middle field; subgenital plate concavely rounded posteriorly in the middle, a pair of narrowly obtuse angular lateral teeth projected posteriorly.

Food plant. Barley, citrus, cotton, *Cyperus* sp., maize, rice, sugar cane, sweet potato, and wheat (Roffey, 1979; COPR, 1982; Willemse, 2001).

Ecology. Along roadsides, bushes, low-lying grasslands, paddy fields, swampy areas (Roffey, 1979; COPR, 1982; Willemse, 2001; Tan & Kamaruddin, 2016).

Distribution. East to the Caroline Islands, southern China, Indonesia, Japan, Malaysia, Myanmar, Palau Islands, the Philippines, Singapore, Taiwan, Thailand, Vietnam (Hollis, 1971; COPR, 1982; Willemse, 2001; Mahmood et al., 2007; Tan, 2010a, 2012; Tan & Kamaruddin, 2016; Cigliano et al., 2021).

Remarks. *Oxya hyla intricata* shared most of its physical attributes with *O. japonica japonica* which can be seen in female subgenital plate, where the surface of the plate consisted of lateral longitudinal ridges with spines on the apical region. However, one significant character used to differentiate the species is the colour of hind tibiae which appears to be yellowish brown or greenish in *O. hyla intricata* and bluish black in *O. japonica japonica*.

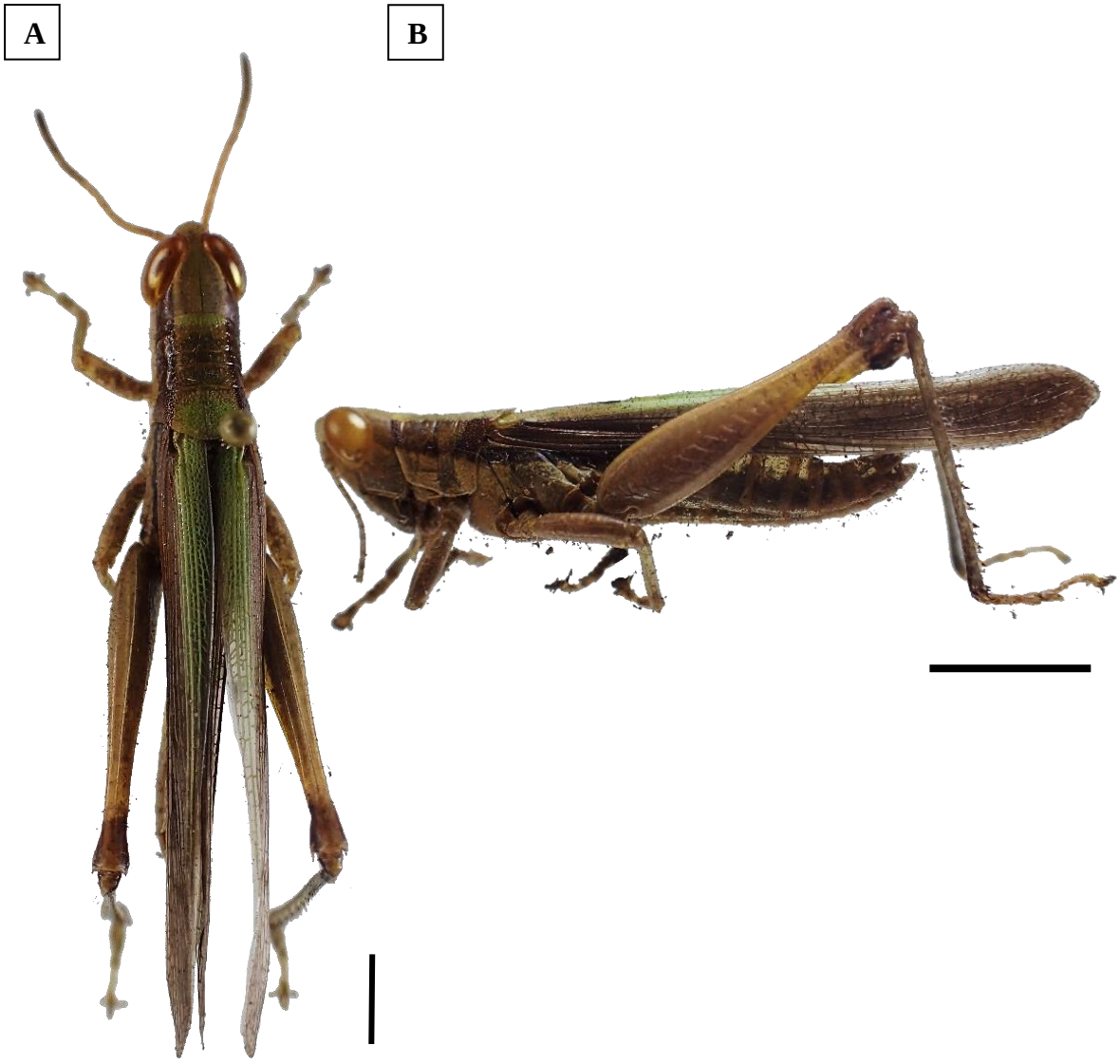


Figure 3.36: *Oxya hyla intricata*, ♂. **A.** Dorsal view of type; **B.** Lateral view of type. Scale = 5 mm.

Oxya japonica japonica (Thunberg, 1824)

Figure 3.37, Figure 3.39

Gryllus japonicus Thunberg, 1824: 429

Acridium sinense Walker, 1870b: 628

Heteracris straminea Walker, 1870b: 666

Heteracris simplex Walker, 1870b: 669

Oxya simplex Kirby, 1910: 394; Bruner, 1915: 256 (62)

Oxya velox Kirby, 1910: 393; Bolivar, 1918b: 15; Bei-Bienko & Mishchenko, 1963: 174 (eng ver.); Hollis, 1971: 297; Hollis, 1975: 221

Oxya asinensis Willemse, 1925: 32

Oxya sinensis Willemse, 1925: 49

Oxya rufostriata Willemse, 1925: 33; Uvarov, 1929: 553; Bei-Bienko & Mishchenko, 1963: 174 (eng ver.)

Oxya japonica Willemse, 1925: 31; Bei-Bienko & Mishchenko, 1963: 181 (eng ver.); Hollis, 1971: 301; Hollis, 1975: 221

Oxya japonica japonica Hollis, 1971: 302

Materials examined. 134 specimens (♂: 30, ♀: 104). **BORNEO: EAST MALAYSIA: SARAWAK: Bintulu:** Labang Forest Reserve, 12.XII.1988, caught while eating paddy leaf, M. Jamil Obeng, 1♀ (FN.88-0498) (RDID). **Kuching:** Bau, Adis Buan, 03.IV.2018,

Farah Aidil Fitri, 1♀ (UIRC). Jalan Arang, 21.II.2000, Chong Tze Fung, 1♀ (UIRC). Jalan Matang-Batu Kawa, Taman Malihah Jaya 1, 23.XI.2018, Abu Hasan Aidil Fitri, 1♀ (UIRC). Matang, 22.XI.2003, James Boyd J., 1♀ (UIRC); 09.XII.2003, Ratnawati H., 1♀ (UIRC). Matang, Gunung Serapi, 05.IX.1983, Lippa Akeng, 4♀ (FN.83-0688 – FN.83-0690, FN.83-0695), 1♂ (FN.83-0694) (RDID); 11.XII.1984, Peter, Lippa & Rahman, 2♀ 1♂ (RDID). Matang, Telaga Air, PNK Satang Biru, LKIM, 27.VIII.2018, Muazmil Hadi, 1♀ (UIRC). Padawan, Borneo Highland Resort, 11.IV.2016, Ammelia, 1♀ (UIRC); 14.IV.2017, Sim Pey Nee, 1♀, Wong Sing Lien, 1♀ (UIRC); 17.III.2018, Nisa, 1♀ (UIRC). Petra Jaya, Lorong Haji Gobil 1A, 25.IV.2018, Nabila Nurshuhadah, 1♀ (UIRC). Tabuan Laru, 24.IV.2016, Veronica Martin, 1♀ (UIRC). **Lundu:** Gunung Gading National Park, 14.VII.1987, Ento Team, 1♀ (FN.87-0317) (RDID). Pandan Beach, 19.V.1984, Lippa Akeng, 1♀ (RDID). Sebandi, 18-28.I.2003, Group 3, SLUSE 02/03, 1♀ (UIRC). **Miri:** Bario, 17.IV.1995, Gunik G., 1♀ (OR/95/00203) (SPM). Lambir Hills National Park, 13.III.1995, caught by UV light, Ento Team, 1♀ (C0295) (RDID); 30.III.1995, caught by UV light, Ento Team, 1♀ (D0103) (RDID); 31.III.1995, caught by UV light, Ento Team, 1♂ (D0104) (RDID); 19.IV.1996, caught by UV light, Ento Team, 1♀ (E0099) (RDID); 20.V.1996, caught by UV light, Ento Team, 1♂ (E0157) (RDID); 22.V.1996, caught by UV light, Ento Team, 1♂ (E0153) (RDID); 20.VI.1996, caught by UV light, Ento Team, 1♀ (E0242) (RDID); 23.I.2001, caught by UV light, Ento Team, 1♂ (J0013) (RDID); 13.V.2002, caught by UV light, Ento Team, 1♀ (K0045) (RDID). Marudi, Loagan Bunut, 02.II.1995, Ento Team, 1♀ (RDID). Niah, 22.II.1979, A. A. Hamid, 1♀ (FN.01282) (RDID); 01.IV.1984, Manis Lintang, 1♀ (FN.84-0534) (RDID); 22.VIII.1985, Lippa Akeng, 1♀ (FN.85-0801) (RDID); 22.III.1997, Ento Team, 1♂ (RDID). **Samarahan:** Kota Samarahan, 23.XI.2003, Lizawati R., 1♂ (UIRC); 07.X.2015, Veronica Martin, 1♂ (UIRC); 10.X.2015, Atieqah Arzemi, 1♀ (UIRC);

16.III.2016, Siti Zulaikha, 1♂ (UIRC); 21.III.2016, Rahmahwati & Fatimah, 1♀ (UIRC); 01.IV.2016, Rahmahwati & Fatimah, 1♀ (UIRC); 09.III.2019, Nur Ruzana, 1♂ (UIRC). Kota Samarahan, Desa Ilmu, 17.IV.2016, Marina Maliyana, 1♀ (UIRC). Kota Samarahan, Vista Ilmu, 16.III.2017, A. Abdullah, B. Teepol, F. Fizy, 1♂ (UIRC); 27.III.2018, Nur Qayrunissa Tahir, 1♀ (UIRC). UNIMAS, 28.I.1995, 1st Year Student, 1♀ (O1138) (UIRC); 29.VII.2002, Syamsuria, 1♀ (UIRC); 10.VIII.2002, Iema, 1♀, Ida, 1♂ (UIRC); 11.VIII.2002, Linda, 1♂ (UIRC); 08.XII.2003, Ratnawati H., 1♀ (UIRC); 04.IV.2010, Mira Hafizah Sani, 1♀ (UIRC); 10.X.2015, ARS, 1♀ (UIRC); 14.III.2016, Muhammad Khairul Hafizul, 1♀ (UIRC); 17.III.2016, Radin Azreena, 1♀, Izzah H. & Adilla M., 2♀ (UIRC); 20.III.2016, Amirah, 1♂ (UIRC); 19.IV.2016, Radin Azreena, 1♀ (UIRC); 20.IV.2016, Maisharah, 1♀ (UIRC); 10.V.2016, Nur Najihah Isahak, 2♀ (UIRC); 11.V.2016, Radin Azreena, 1♂ (UIRC); 15.III.2017, F. Ustar, F. Bakri & I. Ismail, 1♂, A. Abdullah, B. Teepol & F. Fizy, 1♂ (UIRC); 21.IV.2017, F. Ustar, F. Bakri & I. Ismail, 1♀ (UIRC); 27.II.2018, Azman, 1♀ (UIRC); 25.IV.2018, Evonne Soh Geok Han, 1♀ (UIRC); 08.III.2019, Lamuel Lazlus, 1♀ (UIRC); 19.III.2019, Nuratiqa, 1♀ (UIRC); 27.III.2019, Suraya, 1♂ (UIRC). UNIMAS, Arboretum, 20.IV.2017, Michelle Kuik Chin Zhe, 1♀ (UIRC). UNIMAS, Basketball Court, 01.VIII.2002, Insect Group, 1♀ (UIRC). UNIMAS, East Campus, 04.II.2016, Woo Chee Yoong, 1♀ (UIRC); 27.III.2017, Syazwan, 1♂ (UIRC). UNIMAS, Kolej Allamanda, 25.IV.2018, Hafisa Syafina, 1♀ (UIRC). UNIMAS, Kolej Bunga Raya, 21.IV.2017, Jessica Mentie, 1♀ (UIRC); 02.V.2017, Jessica Mentie, 1♀ (UIRC). UNIMAS, Kolej Kenanga, 19.III.2017, Julius Georgy, 1♀ (UIRC); 30.IV.2018, Ilina, 1♀ (UIRC). UNIMAS, Kolej Rafflesia, 01.V.2016, Anisa Grace Robert, 1♀, Nurhanis Hafizah, 1♀ (UIRC). UNIMAS, Kolej Tun Ahmad Zaidi, 28.X.2015, Nickitta Danny, 1♀ (UIRC). UNIMAS, PITAS, 15.X.2015, Farah Aidil Fitri, 1♀ (UIRC); 11.III.2016, W. T. Ng, 1♂

(UIRC); 19.III.2016, Insect Group, 1♀ (UIRC); 20.III.2016, Insect Group, 1♀ (UIRC); 21.III.2016, Insect Group, 1♀ (UIRC); 25.III.2016, Atifah Asri, 1♀ (UIRC); 03.V.2016, Syafiqah J. & Ilya N., 1♀ (UIRC); 07.V.2016, Ezzati Zainal, 1♀ (UIRC); 19.V.2016, Atieqah & Illiana, 1♀ (UIRC); 20.V.2016, Ooi Yee Min, 1♂ (UIRC); 12.III.2017, Amirah Aqilah, 1♀ (UIRC); 07.III.2018, Chiu Pei Yi, 1♀ (UIRC); 17.III.2018, Santie, 1♂ (UIRC); 25.III.2018, Muhd Zhafri Irfan, 1♀ (UIRC); 05.II.2019, Nurhidayah Nizar, 1♀ (UIRC); 05.III.2019, Faezah, 1♂ (UIRC); 03.IV.2019, Chew Yan Er, 1♀ (UIRC); 07.V.2019, Ierwan, 1♀ (UIRC). UNIMAS, Stadium, 10.IV.2017, Naim Che Kamaruddin, 1♀ (UIRC); 19.IV.2017, Atiqah Azizi, 1♀ (UIRC). **Serian:** Annah Rais, 17.IV.2016, Lim Lee Lian, 1♂ (UIRC). Ranchan Recreation Park, 16.IV.2016, Muhammad Affan, 1♀ (UIRC); 25.III.2017, Liana Saidi, 1♀ (UIRC). Semenggoh, 23.III.1979, A. A. Hamid, 1♀ (FN.01372) (RDID); 27.II.1984, Lippa Akeng, 1♀ (FN.84-0237) (RDID); 14.X.1988, Lippa Akeng, 1♂ (FN.88-0671) (RDID). Serian, 06.VIII.2002, Insect Group, 1♂ (UIRC); 22.III.2017, Natasya, 1♀ (UIRC). **Sibu:** Sg. Rasau, Batang Igan, 04.IV.2001, Ento team, 1♀ (FN.01-0675) (RDID). Panasu Camp, 30.X.1997, Ento Team, 1♀ (FN.97-0146) (RDID); 01.XI.1997, Ento Team, 1♀ (RDID). **Simunjan:** Gedong, Sg. Tersak, 19.VI.2011, caught by light trap, Ento Team, 1♀ (GC2149) (RDID). Sabal Forest Reserve, 25.X.1996, caught by light trap, Ento Team, 1♀ (SFR00074) (RDID); 09.V.1997, caught by light trap, Ento Team, 1♀ (SFR04352) (RDID). **Sri Aman:** Kg. Sabu, 24.III.2018, Ivy, 1♀ (UIRC). **SABAH: Keningau:** Taman Banjaran Crocker, 07.XI.2001, Alt: 950 m, Tinus Ampayas, 1♂ (SP/EOR/01348) (SPM). **Kota Kinabalu:** Bukit UMS, 13.V.2017, caught by sweep net, Clarice, 1♀ (UMS). UMS Peak, 08.IV.2017, caught by sweep net, Norfarhain Jefri, 1♀ (UMS); 15.XII.2017, caught in forest by aerial net, Amirsson, 1♀ (UMS). **Lahad Datu:** Tomanggong, 20.V.1997, Jelius Gantor, 1♀ (ENT:3626) (SM). **Ranau:** Kinabalu Park, 05.XII.1993, Martin M., 1♀

(OR/93/00197) (SPM). Kinabalu Park, Sub Station Monggis, 19-23.X.2004, Alt: 310 m, Yusilie K., 1♀ (SP/EOR/01022) (SPM). Mount Kinabalu HQ, 22.IX.1999, Ito Gen, 1♀ (OR/99/00549) (SPM). **Sandakan:** Telupid, Imbak Canyon, 30.III.-04.IV.2007, Johny L., 1♂ (SP/EOR/01280) (SPM). **Tawau:** Maliau Basin, Agathis Camp, 12-19.V.2001, caught in open grassland, Ito Gen & Azrie A., 1♀ (ORT-1263), 1♂ (ORT-1264) (UMS). Sub Station Merotai, 13.III.2000, Yusilie K., 1♀ (OR/2000/00548) (SPM).

Diagnosis. *Oxya japonica japonica* is recognised by the following combination of characters: hind femora yellowish green or yellowish brown, hind knee dark; hind tibiae cobalt blue, paler in older specimen; inner margin of hind tibia with 10 spines; male cercus slender, apex bifurcated; ovipositor valves of female ovipositor long and narrow; female subgenital plate with raised longitudinal ridges forming tiny spines at apex but not reaching the posterior margin of the plate on ventral surface, posterior margin of subgenital plate with two pair of lateral teeth, first pair from the middle acutely pointed, second pair with obtusely angular spine.

Description. Male: Body small, total length 17.61 mm – 23.44 mm. **Colouration:** Body bright green, yellowish green or pale brown. Head: Dark spots on front of face from apex of fastigium to clypeus, dorsum of head with two forms: vertex bright green, yellowish green or pale brown with two dark longitudinal stripes dorso-laterally, or with a pair of thin yellow stripes and a pair of thicker dark brown stripes on the dorso-lateral area. *Antennae*: Scapus and pedicel bright green or pale yellow; flagellum ranges from dark brown to pale yellow, sometimes reddish brown. Thorax: Pronotum with two forms: bright green, yellowish green or brown with two longitudinal dark brown stripes dorso-laterally contiguous from the head, or with a pair of thin pale-yellow stripes and darker brown stripes dorso-laterally, also

contiguous from the head. *Legs*: Hind femur unicolourous, bright green, yellowish green or pale brown with dark brown to black hind knee; hind tibia cobalt blue, paler in some specimens; tarsi pale cobalt blue to pale brown. *Wings*: Tegmen pale green or yellow continuing from posterior margin of pronotum to the apex of tegmen and darker brown on the lateral side. **Structure:** Body robust and small. Head: Sub-rectangular in frontal view, frons sub-triangularly to vertex of head with an angle of over 40 degrees in profile; eyes long oval, vertical diameter significantly longer than horizontal diameter of eye laterally, not exceeding the outline of the head dorsally, eyes as high as the vertex of head in profile, inter-ocular distance slightly wider than width of anterior margin of frontal ridge, lacking foveolae and lateral carinae, distance from anterior margin of eyes to apex of fastigium much shorter than the horizontal diameter of eye in profile, anterior apex of head sub-triangular slightly projecting forward away from eyes, lacking transverse groove at base of fastigium, fastigium very weakly excavated sometimes almost non-discernible; frontal costa deeply impressed projecting thick frontal ridge, frontal ridge of head elongated towards clypeus; frontal costa between antennae slightly projected forward in profile, not forming discernible arch above frontal ocellus in profile; frontal costa above frontal ocellus smooth without any pattern; frons faintly ridged, almost smooth; mandible slightly wider than width of pronotum dorsally. *Antennae*: As long as the combined length of pronotum and head; filiform-like shaped. Thorax: Prosternal process cylindrical, moderately long and thick, slightly compressed laterally, straight, apex of tubercle almost reaching anterior margin of mesosternum; pronotum saddle-shaped, pronotum longer than head, slightly narrower than head, prozona significantly longer than metazona, pronotum with slightly expanded metazona dorsally and slightly constricted on the metazoan, median carina barely discernible and flat dorsally, straight and present as very low ridge in profile, crossed by three sulci,

shallow incision by principal sulcus and minor transverse carinae, lacking lateral carinae, median posterior margin of metazona broadly angular and not concave, pronotal disc irregularly and thinly carinulated and punctured, dorsum of prozona irregularly thinly punctured with irregular, big and shallow depression dorso-laterally, lateral lobe of prozona distinctly punctured, dorsum of metazona with ridges forming numerous small and shallow pits, posteroventral margin of lateral lobe angular with an angle of more or equal to 90 degrees and not concave; sternum long, anterior border of mesosternum slightly arched, mesosternal lobe vertically longer than lateral width, mesosternal interspace sub-quadrangular, elongate with vertical length longer than basal width, anterior margin of interspace weakly convex, obtusely angular, inner posterior corners of lobe obtusely round, metasternal lobe contiguous. *Legs*: Upper and lower carinae of hind femur smooth, basal lobe dorsally longer than ventral lobe, dorsal genicular lobe rounded distally, ventral genicular lobe with acutely pointed spine, distal end of dorsal carina with acutely pointed spine; hind tibia with outer apical spine, number of spines on outer margin 8 to 9, distance between first and second spines on inner margin as long as any other inter-spine distance, distal half of hind tibia obviously broadened towards apex with distinct outer and inner edges running through the spines. *Wings*: Tegmen macropterous, male wings developed in contact with each other above abdomen; distal margin round, cell of distal part sub-rectangular. Genitalia: Cerci narrowing towards apex, slightly compressed laterally, highly elongated and straight in profile, apex of cerci bifurcated; supra-anal plate scutatiform, lateral side slightly expanded, apex not divided, lacking furcula and smooth without tubercles near lateral margins, lateral groove deeply impressed on the middle field not reaching the medial area of the plate and on sides of middle field, lacking transverse groove on middle and apical field, lacking tubercles on sides of middle and apical field; subgenital plate sub-triangular ventrally

with apex blunted and not divided, short with vertical length equal to or less than basal width, not tapering or slightly tapering with apex truncated, lacking tubercle at end of apex.

Female: Larger than male, total length 23.29 mm – 31.27 mm. Colouration, vestiture and texture as in male. **Structure:** Mostly resemble male specimens, body robust. Genitalia: Ovipositor long and curved apically in profile, dorsal and ventral valves with equal length; dorsal valves slightly convergent dorsally, with one apical tooth, prominent teeth all over the margin, non-bidentate and lacking notch on apex; ventral valves very narrow and long, with prominent teeth all over the margin, deeply constricted laterally in the middle field; subgenital plate concavely broadly rounded posteriorly in the middle, two pair of lateral teeth on posterior margin, first pair from the middle acutely pointed, second pair with obtusely angular spine.

Food plant. Apple, broccoli, cabbage, cacao, cauliflower, Chinese cabbage, citrus, coconut, cotton, *Cyperus* sp., lettuce, maize, mustard, orange, paddy leaf, peach, pineapple, pulse, radish, sorghum, sugar cane, sweet potato, and tobacco (Roffey, 1979; COPR, 1982; Willemse, 2001; Tan & Kamaruddin, 2014; Tajamul & Ahmad, 2016).

Ecology. Forest, low-lying grassland, open grassland, shallow pools in paddy fields, swampy areas (Roffey, 1979; COPR, 1982; Willemse, 2001; Tajamul & Ahmad, 2016; Tan & Kamaruddin, 2016) and montane forest with 310 m – 950 m elevation.

Distribution. Andaman Islands, Bangladesh, China, Hawaiian Islands (introduced), India, Indonesia, Japan, Malaysia, Myanmar, Palau Islands, the Philippines, Singapore, Taiwan, Thailand, Vietnam (Hollis, 1971; COPR, 1982; Willemse, 2001; Mahmood et al., 2007; Tan, 2010a, 2010b, 2012; Tan & Kamaruddin, 2014, 2016; Tajamul & Ahmad, 2016; Cigliano et al., 2021).

Remarks. *Oxya japonica japonica* shares some resemblance with *O. hyla intricata* where both species have fully developed wings in comparison with their sister group, *Pseudoxya*. However, *O. japonica japonica* can be distinguished from *O. hyla intricata* by the structure of female subgenital plate, where *O. japonica japonica* possessed two pair of lateral teeth on the posterior margin of the plate. Furthermore, both species can be differentiated by the colour of their hind tibia. Hind tibia of *O. japonica japonica* is bluish green, whereas *O. hyla intricata* possessed brownish to dark brown similar to the colour of its hind femur.

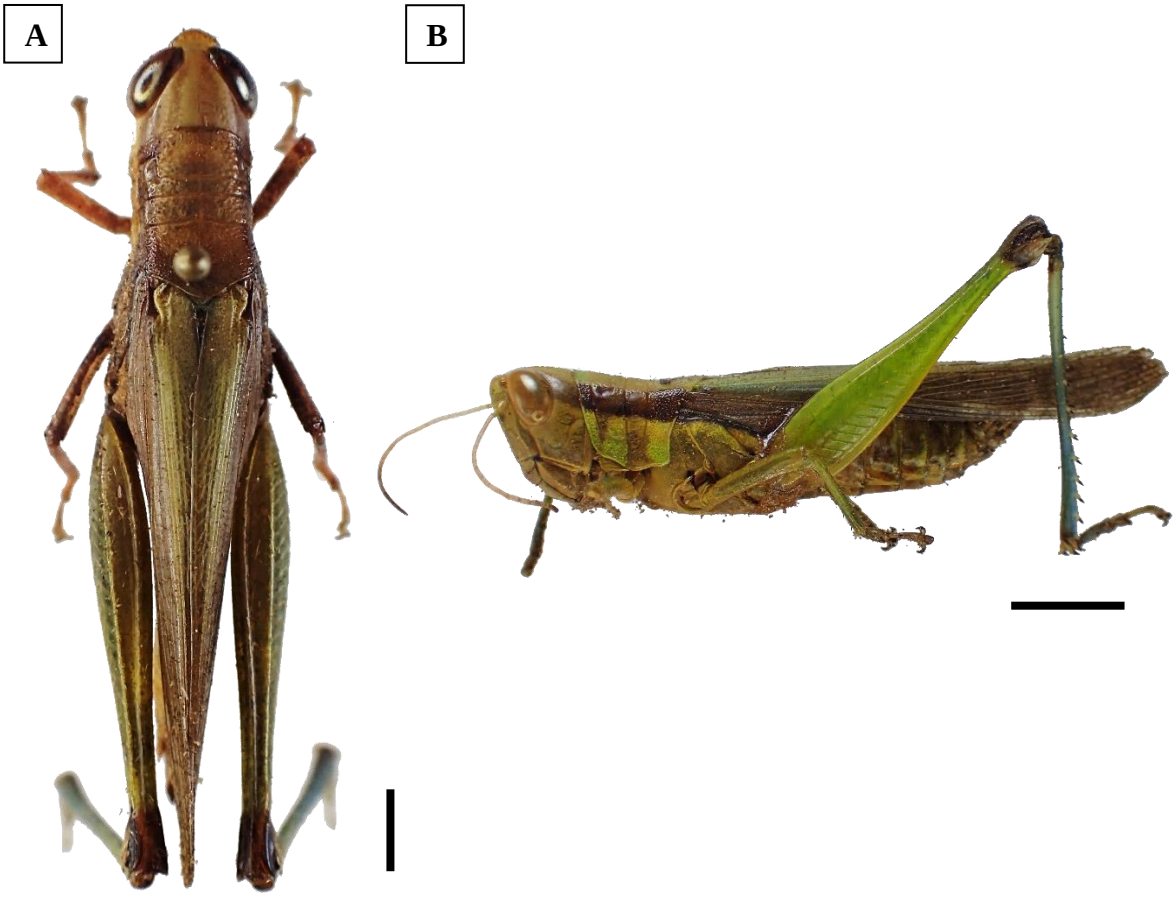


Figure 3.37: *Oxya japonica japonica*, ♂. **A.** Dorsal view of type; **B.** Lateral view of type. Scale = 5 mm.

Genus *Pseudoxya* Yin & Liu, 1987

Pseudoxya diminuta (Walker, 1871)

Figure 3.38, Figure 3.39

Oxya diminuta Walker, 1871: 64; Willemse, 1930: 121; Willemse, 1956: 146

Oxya rufipes Wattenwyl & Fea, 1893: 153; Bolivar, 1918b: 16

Traulia diminuta Kirby, 1910: 476

Caryanda diminuta Hollis, 1975: 217

Materials examined. 95 specimens (♂: 27, ♀: 68). **BORNEO: EAST MALAYSIA: SARAWAK: Betong:** Skuyat Baru, 16.III.2019, Felycia Rinta, 1♀ (UIRC). **Bintulu:** Sg. Sibiyu Nursery, 21.III.1997, Ento Team, 1♀ (RDID). Similajau National Park, 13.IX.2000, Ento Team, 1♀ (FN.00-1106), 1♂ (FN.00-1107) (RDID). **Kuching:** Bau, Adis Buan, 03.IV.2018, Syahida, 1♀ (UIRC); 04.IV.2018, Nurul Syafira, 1♀ (UIRC). Bau, Skibang, 29.IV.2017, Damianne Joem, 1♂ (UIRC). J. Bukitan, 21.II.1997, Serdi, 1♀ (UIRC). Kuching, 11.I.2004, Emylda Dino, 1♀ (UIRC); 18.I.2004, Lizawati R., 1♀ (UIRC). Landeh, Kg. Paya Mebi, 26.XI.1999, Fariza, 1♀ (RDID). Matang, Gunung Serapi, 05.IX.1983, Lippa Akeng, 2♀ (FN.83-0691, FN.83-0693) (RDID). Matang Jaya, 22.III.2016, Hafis Dillah, 1♀ (UIRC). Padawan, Annah Rais, 14.IV.2016, Woo Chee Yoong, 1♀ (UIRC); 15.IV.2016, W.T. Ng, 1♀ (UIRC). Padawan, Borneo Highlands, 14.V.2016, Ammelia, 1♀ (UIRC). Padawan, Gunung Regu, 19.VIII.2009, Insect Group, 1♀ (UIRC). Padawan, Kg. Payang, 15.IV.2016, Delianistie Jackeria, 1♂ (UIRC). Pending, Pending Recreational Park, 21.XI.2003, Sandra James, 1♀ (UIRC). Petra Jaya, Lorong Haji Gobil 1A, 25.IV.2018,

Nabila Nurshuhadah, 2♀ (UIRC). Samariang, 11.V.2018, Syameera, 1♀ (UIRC). Semenggoh, 26.III.1979, A.A. Hamid, 1♀ (FN.01373) (RDID). Siburan, 30.XI.2003, Fong, 1♂ (UIRC); 14.V.2016, Delianistie Jackeria, 1♀ (UIRC). Tabuan Laru, 24.IV.2016, Veronica Martin, 1♀ (UIRC). **Lundu:** Kg. Stuom Muda, 26.XI.1999, Jinal J., 6♀ 1♂ (RDID). **Miri:** Bario, Kelabit Uplands, 12.IV.1995, S.H., F.A., Lim, W.M., 1♀ (O1173) (UIRC). Niah, 24.II.1979, A.A. Hamid & Yeo, 1♀ (FN.79-0064), A.A. Hamid, 4♀ (FN.01419 – FN.01421, FN.01424) (RDID). **Samarahan:** Kota Samarahan, 12.VII.2002, Ang Swee Kim, 1♀ (UIRC); 11.XII.2003, Wahap M., 1♀ (UIRC). 28.XII.2003, Phyllis Lahang, 1♀ (UIRC). Sadong Jaya, 20.VII.2019, Ento Team, 1♀ (UIRC). Samarahan, 18.VII.2002, Besar K., 1♀ (UIRC). Taman Desa Ilmu, 26.III.2016, Amirah Damian, 2♂ (UIRC). Unijaya, 16.IV.2016, Clementine M. & Nickitta D., 1♂ (UIRC). UNIMAS, 12.III.1997, Rahman, 1♀ (UIRC); 16.II.2000, Dayang Sa'emah, 1♀ (UIRC); 09.VII.2002, Sandra James, 1♀ (UIRC); 23.VII.2002, Siti Nurlydia, 1♀ (UIRC); 25.VII.2002, Tan Siew Khim, 1♀ (UIRC); 26.VII.2002, Wei Sze, 1♂ (UIRC); 10.VIII.2002, Sweeney Edward, 1♀ (UIRC); 15.III.2016, Nur Najihah Isahak, 1♀ (UIRC); 17.III.2016, Marina Maliyana, 1♂ (UIRC); 19.IV.2016, Marina Maliyana, 1♀ (UIRC); 15.III.2017, F. Ustar, F. Bakri & I. Ismail, 1♀ (UIRC); 17.III.2017, F. Ustar, F. Bakri & I. Ismail, 1♂ (UIRC); 09.IV.2017, Nurnatasha Amira, 1♀ (UIRC); 13.IV.2017, Mawaddah, 1♀ (UIRC). UNIMAS, Basketball Court, 03.XII.2003, Sandra James, 1♂ (UIRC); 08.XII.2003, Sandra leg., 1♂ (UIRC). UNIMAS, East Campus, 01.IV.2016, Noor Najilah Anifah, 1♀ (UIRC). UNIMAS, Kolej Rafflesia, 02.V.2016, Nurhanis Hafizah, 2♀ (UIRC). UNIMAS, Lake B, 25.VII.2002, Insect Group, 1♂ (UIRC). UNIMAS, PITAS, 10.X.2015, Siti Nur Zulaikha Halimi, 1♀ (UIRC); 14.III.2016, Faridah & Hazwani, 1♂ (UIRC); 13.V.2016, Aina & Syafinaz, 1♂ (UIRC); 18.III.2017, Nurhanis Hafizah, 1♀ (UIRC); 14.III.2019, Nurul 'Arifah 1♀ (UIRC). **Serian:**

Ranchan Recreation Park, 14.IV.2018, Lim Zhi Han, 1♂ (UIRC). **Sibu:** Oya, 09.XII.1976, A.A. Hamid, 1♀ (FN.00316), 1♂ (FN.00315) (RDID). Panasu Camp, 30.X.1997, Ento Team, 1♀ (FN.97-0147) (RDID). **Sri Aman:** Kg. Sabu, 24.III.2018, Ivy, 1♀ (UIRC); 15.IV.2018, Ivy, 1♂ (UIRC). Taman Harmoni, 22.IV.2018, Ivy, 1♀ (UIRC). **SABAH: Keningau:** Taman Banjaran Crocker, Ulu Membakut, 24.II.2006, Yusilie K., 1♀ (SP/EOR/01198) (SPM). **Kota Belud:** Kg. Kiau Teburi, 17.III.2002, Mudi M., 1♂ (OR/02/00783) (SPM). **Kota Kinabalu:** UMS, 17.VIII.2015, caught by sweep net, Kiyotaka Orita, 1♂ (UMS). UMS Hill, 20.V.2014, caught by sweep net, Tan Kok Kiat, 1♀ (UMS). UMS, Bukit Kolej Tun Mustapha, 29.V.2017, caught by aerial net, Hayati, 2♂ (UMS). UMS, ITBC, 20.V.2017, caught in grass by hand, Azila N., 1♀ (UMS). **Ranau:** Kinabalu Park, Poring, 11.III.2000, Alt: 650 m, Ito Gen, 1♂ (OR/01/00652) (SPM). Kinabalu Park HQ, 20.VIII.2002, Alt: 1,600 m, Yusilie & Nancy, 2♀ (OR/02/00775, OR/02/00776), 1♂ (OR/02/00771), Ito Gen, 1♀ (OR/02/00807) (SPM). **Tawau:** Balung, 13.V.2006, Yusilie K., 1♂ (SP/EOR/01197) (SPM). Tawau Hill Park, 08.VII.1997, Johny L., 1♂ (OR/97/00174) (SPM); 13.V.2001, Yusilie K., 1♀ (OR/01/00656) (SPM).

Diagnosis. *Pseudoxya diminuta* is recognised by the following characters: wings short, not reaching the tip of abdomen; hind tibia red; inner margin of hind tibia with 10 spines; male cerci with acutely pointed tip; female subgenital plate obtusely triangular.

Description. Male: Body very small, total length 14.48 mm – 18.81 mm. **Colouration:** Body yellowish green and pale brown. Head: Dorsum of head brown with two very faint brown longitudinal stripes dorso-laterally, greenish yellow laterally. *Antennae*: Pale yellow to brown. Thorax: Pronotum dorsum of pronotal disc pale brown with two dark brown longitudinal stripes dorso-laterally, yellowish green laterally. *Legs*: Hind femur

unicolourous yellowish green or pale brown; hind tibia red; tarsi reddish to brown. *Wings*: Dorsum of tegmen with faint green bands. **Structure:** Body robust and very small. Head: Sub-rectangular in frontal view, frons oblique, sub-triangularly to vertex of head with an angle of over 40 degrees in profile; eyes long oval, vertical diameter longer than horizontal diameter of eye laterally, exceeding the outline of head dorsally, eyes slightly higher than vertex of head in profile, inter-ocular distance same as the width of anterior margin of frontal ridge, lacking foveolae, lateral carina very faintly projected adjacent to compound eyes dorsally, not cutting through anterior margin of fastigium, distance from anterior margin of eyes to apex of fastigium much shorter than the horizontal diameter of eye in profile, anterior apex of head obliquely, sub-triangularly projecting forward away from eyes, lacking transverse groove at base of fastigium, fastigium not excavated; frontal costa above frontal ocellus distinctly punctured with small and deep depressions, with weak groove laterally projecting slightly thick frontal ridge that elongate weakly towards clypeus; frontal costa between antennae not obviously projected forward, not forming discernible arch above frontal ocellus in profile; frons thinly ridged and slightly punctured. *Antennae*: As long as the combined length of pronotum and head; filiform-like shaped. Thorax: Prosternal process cylindrical, slightly compressed, short and straight; pronotum saddle-shaped; pronotum longer than head, width of pronotum as wide as head; prozona significantly longer than metazona, slightly expanding caudally dorsally and not constricted in the middle; median carina barely discernible and flat dorsally, straight and with no trace in profile, crossed by three sulci, very shallow incision by principal and minor transverse sulci, lacking lateral carinae; median posterior margin of metazona broadly angular and not concave; surface of pronotum coarsely punctured; dorsum of prozona and lateral lobe punctured and thinly carinulated laterally; dorsum of metazona with thinly projected ridges forming honeycomb-

like texture; posteroventral margin of lateral lobe roundly angular with an angle of slightly more than 90 degrees and slightly arched; anterior border of mesosternum broadly projected in the middle, mesosternal lobe laterally wider than vertical width, mesosternal interspace elongate with vertical length longer than its narrowest width, anterior margin of interspace straight, inner posterior corners of lobe obtusely round; metasternal lobe contiguous. *Legs*: Upper and lower carinae of hind femur smooth, basal lobe slightly dorsally longer than ventral lobe, dorsal genicular lobe rounded distally, ventral genicular lobe with acutely pointed spine, distal end of dorsal carina with narrowly obtuse-angular spine; hind tibia with outer apical spine, number of spines on outer margin 8, distance between first and second spines on inner margin as long as any other inter-spine distance, distal half of hind tibia obviously broadened towards apex with distinct outer and inner edges running through the spines. *Wings*: Tegmen macropterous, male wings developed in contact with each other above abdomen; distal margin round, cell of distal part sub-rectangular. Genitalia: Cerci narrowing towards apex, short triangular, compressed laterally, straight in profile, apex acutely pointed; supra-anal plate short, scutatiform, apex not divided, furcula very small and obtuse-angularly pointed, lacking tubercles near lateral margins, thick lateral ridge basally extending to the middle field and forming slightly deep groove; subgenital plate triangular ventrally with apex rounded and not divided, very short with basal width longer than vertical length, not tapering and lacking tubercle at end of apex.

Female: Slightly larger than male, total length 19.39 mm – 24.62 mm. Colouration, vestiture and texture as in male. **Structure:** Mostly resemble male specimens, body robust. Genitalia: Ovipositor long and curved apically in profile, dorsal and ventral valves with equal length; dorsal valves converging dorsally, with one apical tooth, prominently serrated all over the margin, non-bidentate and lacking notch on apex; ventral valves very narrow and long, with

prominently acute teeth all over the margin, faintly constricted laterally in the middle field; subgenital plate triangular, posterior margin broadly rounded, lacking lateral teeth on posterior margin of the plate.

Food plant. Bamboo, bamboo grass, cacao, and rice (Roffey, 1979; COPR, 1982; Willemse, 2001).

Ecology. Gardens, grasslands, herby areas, low-lying areas, outskirts of forests, paddy fields, shrubby areas, tall grassy areas (Roffey, 1979; COPR, 1982; Willemse, 2001; Tan & Kamaruddin, 2014, 2016) and montane forests with 650 m – 1,600 m elevation.

Distribution. Andaman Islands, Bangladesh, Cambodia, southern China, eastern India, Indonesia, Laos, Malaysia, Myanmar, Singapore, Thailand, Vietnam (COPR, 1982; Willemse, 2001; Mahmood et al., 2007; Tan, 2010a, 2010b, 2012; Tan & Kamaruddin, 2014, 2016; Khan et al., 2016; Cigliano et al., 2021).

Remarks. *Pseudoxya diminuta* shares certain resemblances with genus *Oxya* with the exceptions of the size of its tegmina. *Pseudoxya diminuta* has abbreviated wings, reaching half of the length of its abdomen whereas members of genus *Oxya* have fully developed wings. Plus, the adult of *P. diminuta* is much smaller than *Oxya* in size resembling juvenile *Oxya*, thus making the abdominal area looking much stouter than members of *Oxya*. In addition, hind tibiae of *P. diminuta* is completely red as opposed to the bluish to black hind tibiae of *O. japonica japonica* and yellowish brown to greenish brown hind tibiae of *O. hyla intricata*.

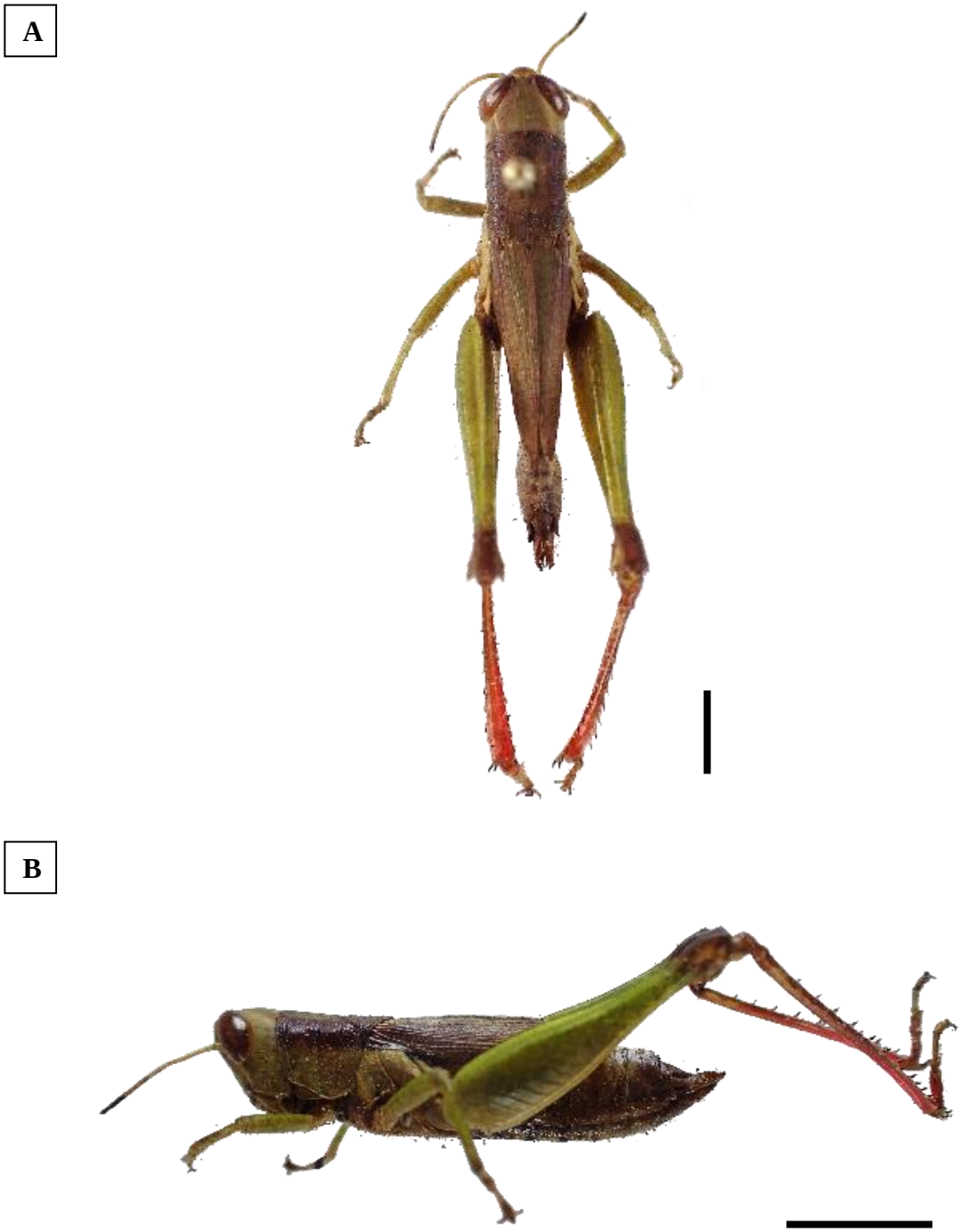


Figure 3.38: *Pseudoxya diminuta*, ♂. **A.** Dorsal view of type; **B.** Lateral view of type. Scale = 5 mm.

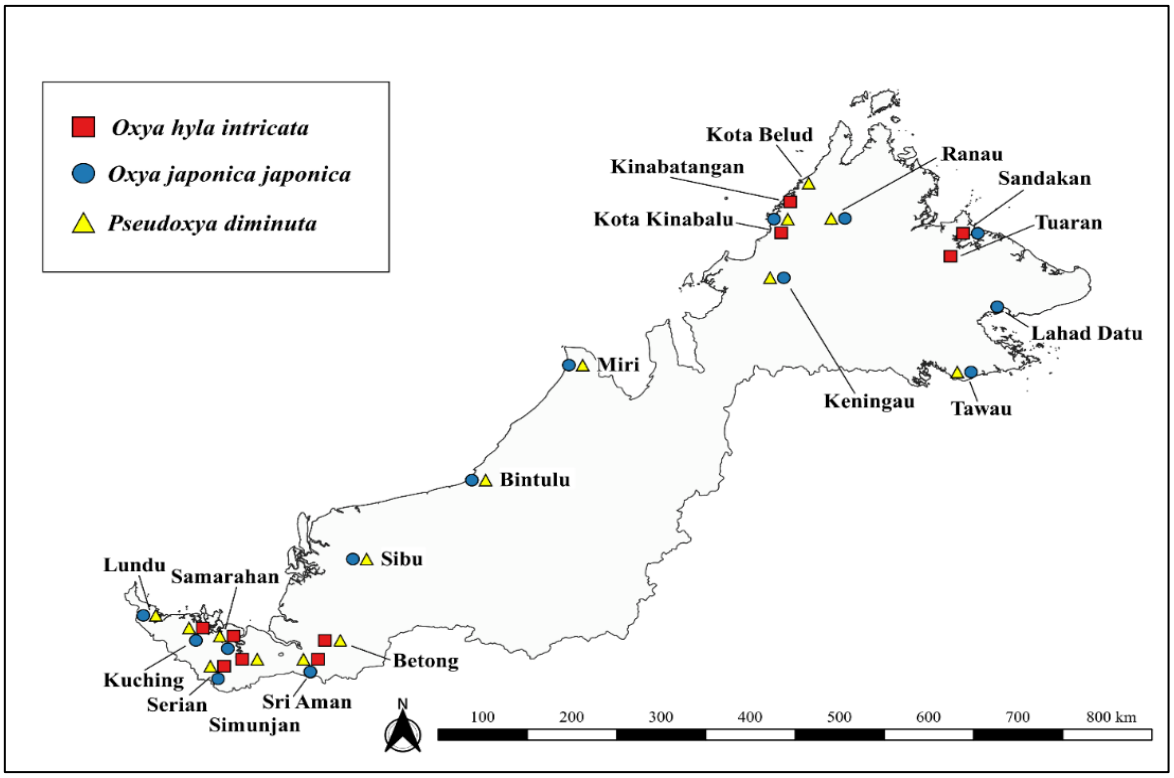


Figure 3.39: Distribution map of subfamily Oxyinae from Malaysian Borneo.

3.4 Conclusion

Based on the systematic study from the examination of specimens by using comparative morphological structures method, a key to five subfamilies of Acrididae from Malaysian Borneo was successfully produced. Diagnosis and redescriptions of selected genera within Acrididae, namely *Phlaeoba*, *Coloracris*, *Traulia*, *Patanga* and *Oxya*, and all 28 species of acridids were presented, with no new species recorded. From the study, only 0.46% of species documented worldwide were recovered in Malaysian Borneo. Consequently, 53.3% of species documented in Malaysia were recovered in Malaysian Borneo from this study. Geological distribution maps for each species were generated using Quantum Geographic Information System (QGIS).

CHAPTER 4

PHYLOGENY OF FAMILY ACRIDIDAE MACLEAY, 1821 IN MALAYSIAN BORNEO BASED ON MORPHOLOGICAL DATA

4.1 Introduction

Family Acrididae is recognised as the largest family in suborder Caelifera, comprising of approximately 28 subfamilies including, Acridinae, Cyrtacanthacridinae, Gomphocerinae, Hemiacridinae, Melanoplinae, Oedipodinae and Oxyinae, to name a few (Cigliano et al., 2021), with diverse biogeographical distribution pattern ranging from the tropical forests to the urbanised area (Bragg, 1939; Almeida & Câmara, 2008; Sergeev, 2011, 2021; Song et al., 2018). The family name was first coined by MacLeay (1821) and studies on these short-horned grasshoppers and locusts have uncovered a total of 28 valid subfamilies, 1,410 valid genera and 6,767 valid species to date (Cigliano et al., 2021) distributed across the world.

Presently, the phylogenetic relationship within members of the family is still unclear, even though established as part of the largest family in Caelifera and several well-founded studies had been conducted focusing on the phylogenetic relationships at family and subfamily level using morphological or molecular data. Subfamilies in Acrididae were known to have dubious relationships, especially Catantopinae that is notoriously known to be the dumping ground of aberrant species (Liu et al., 2008; Chapco, 2013; Song et al., 2018; Li et al., 2019). First attempt to visualise the relationship within families in Caelifera had been made by Flook and Rowell (1997) using mitochondrial ribosomal RNA gene sequences 12S and 16S revealing a monophyletic Caelifera although Acrididae, represented by Gomphocerinae, Oedipodinae, Ommatolampinae and Proctolabinae, was deduced to be

paraphyletic since Pamphagidae was nested within Acrididae. Subsequent study conducted by the authors in order to elucidate the relationship in higher systematics of Caelifera using combined 12S and 16S mitochondrial RNA sequences presented monophyletic grouping of Oedipodinae and Oxyinae respectively, while supporting the monophyletic clade consisting of Calliptaminae, Catantopinae, Cyrtacanthacridinae and Eyprepocnemidinae (Rowell & Flook, 1998). However, Rowell and Flook (1998) suspected some subfamilies of Acrididae from the analysis showing polyphyletic relationships, forming clades of unnatural grouping as shown by Acridinae, Catantopinae, Copiocerinae, Gomphocerinae, Hemiacridinae and Ommatolampinae.

Even though some scientists believe in the accuracy of molecular data, the use of morphological data in constructing phylogenetic analyses to establish relationships within organisms is still applicable and utilised by others. According to a study that centralised on resolving the relationship of Chinese catantopines (family Catantopidae) with the use of both external morphology and male genitalia, the relationship among sampled genera was proven to be well resolved and supported with Bremer values of 3 to 8 (Li et al., 2011). Taxa sampled included Chinese members of Calliptaminae, Catantopinae, Coptacridinae, Cyrtacanthacridinae, Habrocneminae, Oxyinae and Podisminae, where 88 characters were coded (71 external morphological characters, 17 male genitalic characters), and resulted in monophyletic clades of Calliptaminae, Catantopinae, Cyrtacanthacridinae and Habrocneminae, whereas members of Coptacridinae and Oxyinae were revealed having highly unresolved relationship within their clades although displaying well supported monophyletic clades to the rest of the subfamilies. On the other hand, the monophyletic grouping of Podisminae recovered five monophyletic clades within the subfamily that were treated as tribes according to Li et al. (2011), specifically Dericorythini, Fruhstorferiolini,

Podismini, Promeosternini and Traulini, as well as the rest of the genera that were dumped under tribe ‘Melanoplini’.

Most studies on phylogeny of Caelifera based on morphological data were focused on the lower-level relationships, either within subfamilies, genus or species, in addition to their association and interaction with the behaviour, biogeography, evolution or ecology of the community (Li et al., 2011). Song and Wenzel (2007) being one of the examples, presented their study on the phylogeny of bird-grasshopper from subfamily Cyrtacanthacridinae, although the primary goal of the study was to investigate the evolution of locust phase polyphenism on cyrtacanthacridines. The study focused on using morphological data based on 71 characters of both external body structures and internal structures of male genitalia and yielded a well-resolved phylogenetic tree and proving that locust phase polyphenism had evolved numerous times within members of the subfamily.

Although grasshoppers in general are known insects famous for their ubiquity and propensity to destruct crops in higher density population, as well as fertilising soil in lower density population, some are still unclear on the line that separates acridids from other variety of orthopterans such as the lentulids (Lentulidae), milkweed grasshoppers (Pyrgomorphidae), monkey grasshoppers (Eumastacidae), lubber grasshoppers (Romaleidae) and toad grasshoppers (Pamphagidae) of the same suborder. This is especially true in Malaysian Borneo, where knowledge on the family is still scarce as little to no studies has been done in the region due to the scantiness of experts in the field.

In addition to the instability of the family’s position in phylogeny due to the ambiguity in taxonomic hypotheses on different morphological sets (as mentioned in 1.2 Problem Statement), some subfamily such as Catantopinae were expected to be paraphyletic.

Paraphyly of Catantopinae were anticipated as members of the subfamily were mostly grouped without any distinct morphological structures. This was observed in Song et al. (2018), where paraphyletic catantopids were recovered even though taxon sampling of Australian taxa were scant. Song et al. (2018) further strengthen their arguments by disclosing prosternal process as the main feature to group a species in Catantopinae, although now it was reduced to species exhibiting prosternal process without other distinct features to be categorised differently. By using these studies as the basis of foundation for the relationship of members in the family from Malaysian Borneo, this chapter seek to construct the phylogeny of family Acrididae represented by Malaysian Bornean specimens based on qualitative and quantitative data of external morphological characters of 28 ingroups acridid species and two outgroup species represented by *Atractomorpha psittacina psittacina* and *A. sinensis* from family Pyrgomorphidae.

4.2 Methodology

4.2.1 Taxa Sampling

This study involved an examination of 1,216 acridoid specimens representing 28 species of 20 genera from five subfamilies, assessed from museum and institutions collections in Sarawak and Sabah, as well as new collections. The institutions providing specimens for this study were Insect Reference Collection (UIRC) of Universiti Malaysia Sarawak, Research, Development and Innovation Division (RDID) of Forest Department Sarawak, Institute of Tropical Biology and Conservation (ITBC) of Universiti Malaysia Sabah, Sabah Parks Natural History Museum (SPM) and Sabah Museum (SM). Data such as date of collection, locality, collector's name, sex, and host plant were recorded from each specimen.

Apart from examining the collections from said institutions, field collections were also conducted at four sampling sites in Sarawak, namely: (i) Adis Buan Resort, Bau (1°32'32.3"N, 110°09'05.6"E) for seven days from 2nd to 9th March 2018; (ii) Libiki Bamboo Resort, Bau (1°19'57.9"N, 110°06'22.0"E) for five days from 25th to 30th March 2019; (iii) Sadong Jaya, Samarahan (1°24'47.6"N, 110°31'38.9"E) for five days from 17th to 22nd July 2019; and (iv) Kubah National Park, Kuching (1°36'46.0"N, 110°11'49.0"E) for four days from 4th to 8th December 2019. Fresh specimens collected from field samplings were deposited to UIRC, Sarawak.

Three types of methods were used in collecting the species, which were aerial netting, beating, and handpicking. Grasshoppers are very mobile with the capability to jump far due to their enlarged hind legs, thus the aerial-netting method is more suitable to be used in collecting them. Handpicking method requires the collector to be quick and swift when the grasshoppers are in sight. Collectors need to be in high alert as these grasshoppers are very agile and exhibited cryptic colouration as their defence mechanism that were used to mask their locations. Beating method is a technique to locate insects, where the bushes were beaten using a stick which caused the grasshoppers and other insects to move and reveal their position. Table 4.1 showed the list of grasshoppers and locust species from family Acrididae collected and documented throughout Malaysian Borneo in this study.

Table 4.1: List of species from family Acrididae documented from Malaysian Borneo.

Subfamily	Species
Acridinae MacLeay, 1821	*Phlaeoba antennata* Brunner von Wattenwyl, 1893
	Phlaeoba infumata Brunner von Wattenwyl, 1893
Catantopinae Brunner von Wattenwyl, 1893	*Apalacris varicornis* Walker, 1870
	Coloracris azureus Willemse, 1938
	Coloracris coerulescens Willemse, 1938
	Coloracris sp.
	Craneopsis olivacea Ramme, 1941

Table 4.1 continued.

Subfamily	Species
	Meltripata sp. 1
	Meltripata sp. 2
	Perakia borneensis Willemse, 1936
	Phalaca waterstradti Ramme, 1941
	Stenocatantops splendens (Thunberg, 1815)
	Traulacris grandis (Miller, 1932)
	Traulia azureipennis (Serville, 1838)
	Traulia borneensis Willemse, 1921
	Traulia sanguinipes sanguinipes Stål, 1878
	Xenocatantops humilis (Serville, 1838)
Cyrtacanthacridinae Kirby, 1910	*Patanga luteicornis* (Serville, 1838)
	Patanga succincta (Johannson, 1763)
	Valanga nigricornis (Burmeister, 1838)
Oedipodinae Walker, 1871	*Aiolopus thalassinus tamulus* (Fabricius, 1798)
	Gastrimargus marmoratus (Thunberg, 1815)
	Heteropternis obscurella (Blanchard, 1853)
	Locusta migratoria manilensis (Meyen, 1835)
	Trilophidia annulata (Thunberg, 1815)
Oxyinae Brunner von Wattenwyl, 1893	*Oxya hyla intricata* (Stål, 1861)
	Oxya japonica japonica (Thunberg, 1824)
	Pseudoxya diminuta (Walker, 1871)

4.2.2 Character Sampling

All specimens were distinguished by comparing the external morphological characters following methods by Cigliano et al. (1996), Song and Wenzel (2007), and Li et al. (2011), while examination of genitalic structures followed methods and terminology by Roberts (1941). A morphological matrix with a total of 100 characters and 321 character states were compiled from the assessments. These include 82 qualitative characters such as the head, pronotum, mesosternum, metasternum, legs and external genitalic characters, as well as 18 quantitative characters for male and female. Irrelevant characters were coded as "-", while characters that provide missing information to the specimens were coded as "?". Complete list of characters and character states used in the phylogeny analyses were presented in Table 4.2 and the data matrix was listed in Table 4.3.

Table 4.2: List of morphological characters and character states used in the phylogeny analysis.

No.	Character and character states
Head	
1	*Overall head shape laterally*: (0) slanted; (1) straight.
2	*Eye in dorsal view*: (0) prominent; (1) not prominent.
3	*Shape of eyes*: (0) subcircular or long oval; (1) rounded or oval.
4	*Interocular distance*: (0) same as the width of frontal ridge; (1) distinctly wider than the width of frontal ridge; (2) narrower than the width of frontal ridge.
5	*Shape of anterior apex of head from dorsal view*: (0) distinctly projecting forward away from eyes; (1) linear and close to eyes.
6	*Shape of fastigium ridge of head (from 5:1)*: (0) ridge absent; (1) horizontally elongated isosceles trapezoid; (2) vertically elongated isosceles trapezoid; (3) lateral ridges round with longitudinal depression in the middle.
7	*Fastigium excavated*: (0) absent; (1) present.
8	*Presence of lateral carinae on fastigium*: (0) absent; (1) present.
9	*Shape of fastigium in dorsal view*: (0) normal, not strongly projected anteriorly; (1) strongly projected anteriorly.
10	*Transverse groove at base of fastigium*: (0) absent; (1) present and fine; (2) present and distinct.
11	*Obliquity of frons in profile*: (0) not oblique; (1) oblique; (2) strongly oblique.
12	*Vertex from lateral view*: (0) lower than eyes; (1) as high as eyes.
13	*Frontal costa between antennae*: (0) not obviously projected; (1) obviously projected forward.
14	*Frontal ridge of head*: (0) obliterate below ocellus; (1) ridge elongate below ocellus.
15	*Integument of frontal ridge of head above frontal ocellus*: (0) smooth without any pattern; (1) punctured; (2) granulose.
16	*Sculpting pattern on frontal ridge of head above frontal ocellus (from 15:1)*: (0) lightly punctured; (1) small and deep punctures present; (2) wide punctures proportionally like the surface of a golf ball.
17	*Sculpting pattern on integument between preocular ridge and frontal ridge of head*: (0) smooth without any sculpture; (1) punctured; (2) ridged; (3) pebbled surface.
18	*Antennae shape*: (0) filiform; (1) sword-shaped.
19	*Antennae length*: (0) shorter than the combined length of head and pronotum; (1) as long as the combined length of head and pronotum; (2) longer than the combined length of head and pronotum; (3) extending much beyond pronotum.
20	*Relation of head to pronotum*: (0) not wider than; (1) as wide as; (2) wider.
Prosternal process	
21	*Presence of prosternal process*: (0) absent; (1) present.
22	*Shape of prosternal process*: (0) conical; (1) cylindrical; (2) transverse and lobular; (3) mushroom-shaped.
23	*(22:0) Apical part of cone-shaped prosternal process*: (0) straight; (1) strongly bent posteriorly
24	*(22:1) Apical part of cylindrical prosternal process*: (0) straight or slightly bent posteriorly; (1) strongly bent posteriorly; (2) compressed laterally and flat apically.
25	*(22:2) Ventral margin of lobular prosternal process*: (0) truncate or slightly serrated; (1) with 2-3 apically rounded, triangular processes; (2) medially projected into a large triangle; (3) triangular as state 2 and turned anteriorly.
Mesosoma (Thorax)	
26	*Surface of pronotum*: (0) smooth to finely sculptured; (1) coarsely and distinctly sculptured.

Table 4.2 continued.

No.	Character and character states
27	*Sculpting pattern on dorsum of prozona*: (0) no pattern; (1) punctured; (2) tuberculose; (3) irregularly wrinkled ridges.
28	*Sculpting pattern on lateral lobe of prozona*: (0) smooth; (1) distinctly punctured; (2) distinctly wrinkled.
29	*Sculpting pattern on dorsum of metazona*: (0) no basic sculpting pattern; (1) ridged; (2) elongated pit; (3) large irregular punctures.
30	*Sculpting pattern on dorsum of metazona (from 29:1)*: (0) ridges forming numerous small pits; (1) ridges distinctly thickened; (2) honeycombed.
31	*Pronotum from dorsal view*: (0) expanding caudally; (1) subcylindrical; (2) with expanded metazona.
32	*Transverse sulci of pronotal disk*: (0) deeply impressed; (1) shallowly impressed.
33	*Convexity of median posterior margin of pronotum*: (0) nearly linear; (1) smoothly round or broadly angular; (2) projected into a right or acute angle.
34	*Median carina on prozona of pronotum*: (0) flat; (1) distinctly elevated.
35	*Distinctness of median carina on pronotum*: (0) distinct; (1) barely discernible to absent.
36	*Median carina on pronotum in lateral view*: (0) straight; (1) strongly elevated medially.
37	*Incision on median carina of pronotum by principal sulcus*: (0) shallow to indistinct; (1) deep.
38	*Presence of additional incisions on median carina of pronotum by minor transverse carina*: (0) absent; (1) present.
39	*Lateral carinae on pronotum*: (0) absent or slightly elevated, distinctly not reaching to posterior margin of pronotum; (1) distinctly elevated, completely or nearly so.
40	*Median carina of pronotum (from 39:0)*: (0) no trace; (1) present as a low ridge; (2) present as a narrow and sharp ridge; (3) present as a thick ridge; (4) highly raised.
41	*Median carina of pronotum*: (0) crossed by one sulcus; (1) crossed by three sulci.
42	*Ventral posterior angle of lateral lob of pronotum*: (0) broadly round; (1) roundly angular to angular.
43	*Posterior margin of lateral lob of pronotum*: (0) not concave to slightly arched; (1) strongly concave.
44	*Anterior border of mesosternum*: (0) straight or slightly arched; (1) broadly projected in the middle.
45	*Mesosternal lobe*: (0) laterally wider than vertical length; (1) vertically longer than lateral width.
46	*Shape of mesosternal interspace*: (0) wide; (1) elongate; (2) very reduced.
47	*Inner posterior corners of lateral lobes of mesosternum*: (0) obtusely round or angularly round; (1) right angular to acutely angular.
48	*Contact of lateral lobes of metasternum medially*: (0) separated; (1) contiguous.
Legs	
49	*Upper carina*: (0) smooth; (1) serrate.
50	*Lower carina*: (0) smooth; (1) serrate.
51	*Relative length of dorsal and ventral basal lobe of hind femur*: (0) dorsal lobe as long as ventral lobe; (1) dorsal lobe longer than ventral lobe.
52	*Shape of ventral genicular lobe of hind femur*: (0) round or roundly angular distally; (1) spined distally.
53	*Shape of dorsal genicular lobe of hind femur*: (0) round distally; (1) spined distally.
54	*Shape of distal end of dorsal carina of hind femur*: (0) round or slightly broadly angular; (1) spined, acutely pointed, or narrowly obtuse-angular.
55	*Outer apical spine on hind tibia*: (0) absent; (1) present.
56	*Number of spines on outer margin of hind tibia*: (0) 5–6; (1) 8–10; (2) over 12.

Table 4.2 continued.

No.	Character and character states
57	*Distance between 1st and 2nd spines of inner spine series on hind tibia*: (0) as long as any other inter-spine distance; (1) longer than any other inter-spine distance.
58	*Distal half of hind tibia*: (0) not obviously broaden toward apex; (1) broadened toward apex; (2) strongly broadened toward apex.
Wings	
59	*Tegmina development*: (0) macropterous; (1) brachypterous.
Male genitalia	
60	*Presence of hair tufts on last sternum of abdomen*: (0) absent; (1) present.
61	*Overall profile of male cerci*: (0) simple rod; (1) narrowing toward apex; (2) expanding and round; (3) quadrate.
62	*Shape of male cerci (from 61:1)*: (0) short triangular; (1) elongated conical; (2) highly elongated and strongly curved inward; (3) elongated and apex strongly curved downward.
63	*Apex of cerci in males*: (0) pointed; (1) round; (2) truncated; (3) bifurcated; (4) dentate.
64	*Curvature of male cerci*: (0) straight; (1) curved inward posteriorly; (2) curved upward posteriorly; (3) curved downward posteriorly.
65	*Shape of male supra-anal plate*: (0) triangular; (1) rectangular or trapezoid; (2) scutate.
66	*Basal field of male supra-anal plate*: (0) smooth without tubercles near lateral margins; (1) with two digitiform tubercles near lateral margins.
67	*Presence and size of furcula*: (0) absent; (1) present and small; (2) present, and large and long.
68	*Overall shape of male subgenital plate*: (0) apex divided into two lobes; (1) apex not divided.
69	*Male subgenital plate apex (from 68:1)*: (0) apex blunt; (1) overall simple conical structure; (2) lateral side expanded.
70	*Shape of male subgenital plate in ventral view*: (0) very short; (1) long; (2) strongly elongated.
71	*Shape of male subgenital plate in dorsal view*: (0) strongly tapering toward apex; (1) gradually tapering toward apex; (2) not tapering.
72	*Presence of tubercle at apex of male subgenital plate*: (0) absent; (1) present and short; (2) present and much prolonged.
Female genitalia	
73	*Shape of ovipositor valves from lateral view*: (0) curve; (1) straight.
74	*Relation of dorsal/ventral ovipositor valves*: (0) as long as ventral; (1) twice as long as ventral.
75	*Shape of dorsal valves from dorsal view*: (0) convergent; (1) divergent.
76	*Presence of apical tooth on dorsal ovipositor valves*: (0) with one apical tooth; (1) with two apical teeth.
77	*Shape of dorsal ovipositor valves on the superior margin*: (0) low serrulate; (1) serrate; (2) prominently serrate; (3) prominent teeth on distal portion; (4) prominent teeth all over the margin
78	*Presence of a notch on apex of dorsal external margin of dorsal valves of ovipositor*: (0) absent; (1) distinctly present.
79	*Presence of external apical tooth on the ventral ovipositor valves*: (0) very prominent; (1) not prominent.
80	*Width of ventral ovipositor valves*: (0) very narrow; (1) very wide; (2) wide.
81	*Posterior margin of female subgenital plate in ventral view*: (0) triangularly projected posteriorly in the middle; (1) straight or broadly rounded.
82	*Presence of lateral teeth on posterior margin of female subgenital plate in ventral view*: (0) absent; (1) present.
Quantitative characters (Male)	
83	*Body length (BL)*: (0) less than 14 mm; (1) 14 mm – 20.99 mm; (2) 21 mm – 27.99 mm; (3) 28 mm – 34.99 mm; (4) 35 mm – 41.99 mm; (5) more than 42 mm.

Table 4.2 continued.

No.	Character and character states
84	*Front head length (FHL)*: (0) less than 3 mm; (1) 3 mm – 4.99 mm; (2) 5 mm – 6.99 mm; (3) 7 mm – 8.99 mm; (4) 9 mm – 10.99 mm; (5) more than 11 mm.
85	*Head width (HW)*: (0) less than 3 mm; (1) 3 mm – 3.99 mm; (2) 4 mm – 4.99 mm; (3) 5 mm – 5.99 mm; (4) 6 mm – 6.99 mm; (5) more than 7 mm.
86	*Pronotum length (PL)*: (0) less than 4 mm; (1) 4 mm – 5.99 mm; (2) 6 mm – 7.99 mm; (3) 8 mm – 9.99 mm; (4) 10 mm – 11.99 mm; (5) more than 12 mm.
87	*Pronotum width (PW)*: (0) less than 3 mm; (1) 3 mm – 3.99 mm; (2) 4 mm – 4.99 mm; (3) 5 mm – 5.99 mm; (4) 6 mm – 6.99 mm; (5) more than 7 mm.
88	*Tegmen length (TL)*: (0) less than 7 mm; (1) 7 mm – 14.99 mm; (2) 15 mm – 22.99 mm; (3) 23 mm – 30.99 mm; (4) 31 mm – 38.99 mm; (5) more than 39 mm.
89	*Hind femora length (HFL)*: (0) less than 9 mm; (1) 9 mm – 12.99 mm; (2) 13 mm – 16.99 mm; (3) 17 mm – 20.99 mm; (4) 21 mm – 24.99 mm; (5) more than 25 mm.
90	*Hind tibia length (HTL)*: (0) less than 8 mm; (1) 8 mm – 11.99 mm; (2) 12 mm – 15.99 mm; (3) 16 mm – 19.99 mm; (4) 20 mm – 23.99 mm; (5) more than 24 mm.
91	*Hind tarsi length (HSL)*: (0) less than 2 mm; (1) 2 mm – 3.99 mm; (2) 4 mm – 5.99 mm; (3) 6 mm – 7.99 mm; (4) 8 mm – 9.99 mm; (5) more than 10 mm.
Quantitative characters (Female)	
92	*Body length (BL)*: (0) less than 24 mm; (1) 24 mm – 33.99 mm; (2) 34 mm – 43.99 mm; (3) 44 mm – 53.99 mm; (4) 54 mm – 63.99 mm; (5) more than 64 mm.
93	*Front head length (FHL)*: (0) less than 6 mm; (1) 6 mm – 7.99 mm; (2) 8 mm – 9.99 mm; (3) 10 mm – 11.99 mm; (4) 12 mm – 13.99 mm; (5) more than 14 mm.
94	*Head width (HW)*: (0) less than 3 mm; (1) 3 mm – 4.99 mm; (2) 5 mm – 6.99 mm; (3) 7 mm – 8.99 mm; (4) more than 9 mm.
95	*Pronotum length (PL)*: (0) less than 4 mm; (1) 4 mm – 5.99 mm; (2) 6 mm – 7.99 mm; (3) 8 mm – 9.99 mm; (4) 10 mm – 11.99 mm; (5) more than 12 mm.
96	*Pronotum width (PW)*: (0) less than 3 mm; (1) 3 mm – 3.99 mm; (2) 4 mm – 4.99 mm; (3) 5 mm – 5.99 mm; (4) 6 mm – 6.99 mm; (5) more than 7 mm.
97	*Tegmen length (TL)*: (0) less than 9 mm; (1) 9 mm – 19.99 mm; (2) 20 mm – 30.99 mm; (3) 31 mm – 41.99 mm; (4) 42 mm – 52.99 mm; (5) more than 53 mm.
98	*Hind femora length (HFL)*: (0) less than 13 mm; (1) 13 mm – 17.99 mm; (2) 18 mm – 22.99 mm; (3) 23 mm – 27.99 mm; (4) 28 mm – 32.99 mm; (5) more than 33 mm.
99	*Hind tibia length (HTL)*: (0) less than 12 mm; (1) 12 mm – 16.99 mm; (2) 17 mm – 21.99 mm; (3) 22 mm – 26.99 mm; (4) 27 mm – 31.99 mm; (5) more than 32 mm.
100	*Hind tarsi length (HSL)*: (0) less than 5 mm; (1) 5 mm – 7.99 mm; (2) 8 mm – 10.99 mm; (3) 11 mm – 13.99 mm; (4) 14 mm – 16.99 mm; (5) more than 17 mm.

Table 4.3: Data matrix for family Acrididae.

Taxa	Characters																								
	01	**02**	**03**	**04**	**05**	**06**	**07**	**08**	**09**	**10**	**11**	**12**	**13**	**14**	**15**	**16**	**17**	**18**	**19**	**20**	**21**	**22**	**23**	**24**	**25**
Outgroup																									
Atractomorpha psittacina psittacina	0	1	1	0	0	-	0	1	1	0	2	1	1	0	2	-	3	0	0	0	1	1	-	2	-
Atractomorpha sinensis	0	1	1	0	0	-	0	1	1	0	2	1	1	0	2	-	3	0	0	0	1	1	-	2	-
Acridinae																									
Phlaeoba antennata	0	0	0	1	0	-	1	1	0	1	1	1	1	1	1	0	3	1	2	0	0	-	-	-	-
Phlaeoba infumata	0	0	0	1	0	-	1	1	0	0	1	1	1	1	1	0	2	1	1	1	0	-	-	-	-
Catantopinae																									
Apalacris varicornis	1	0	0	2	1	1	1	1	0	2	0	1	1	0	1	1	1	0	2	2	1	0	0	-	-
Coloracris azureus	0	0	1	0	0	-	0	0	0	0	1	1	1	0	1	0	2	0	3	1	1	0	0	-	-
Coloracris coerulescens	1	1	0	0	0	-	0	0	0	0	0	1	1	0	1	0	2	-	-	2	1	0	0	-	-
Coloracris sp.	0	0	0	0	0	-	0	0	0	0	1	1	1	0	1	2	1	0	3	2	1	0	0	-	-
Craneopsis olivacea	1	1	1	1	0	-	0	0	0	0	0	1	0	0	1	0	2	0	2	1	1	1	-	2	-
Meltripata sp. 1	0	0	1	1	0	-	0	0	0	0	1	1	0	0	1	2	2	0	3	1	1	1	-	2	-
Meltripata sp. 2	1	1	0	0	0	-	0	0	0	0	0	1	1	0	1	0	0	0	3	1	1	0	0	-	-
Perakia borneensis	1	0	0	2	1	1	0	0	0	0	0	1	0	0	1	2	2	0	2	1	1	1	-	2	-
Phalaca waterstradti	0	0	1	0	0	-	0	0	0	0	1	1	0	0	0	-	1	0	3	1	1	1	-	2	-
Stenocatantops splendens	0	0	0	2	1	2	0	1	0	1	1	1	1	1	1	1	2	0	1	1	1	1	-	0	-
Traulacris grandis	0	0	1	1	0	-	0	0	0	0	1	1	1	0	1	2	1	0	3	1	1	0	0	-	-
Traulia azureipennis	0	0	0	1	0	-	1	1	0	1	1	0	1	1	1	1	1	0	2	1	1	0	0	-	-
Traulia borneensis	0	0	0	1	0	-	1	0	0	0	1	0	1	1	1	1	1	0	2	1	1	0	0	-	-
Traulis sanguinipes sanguinipes	1	0	0	1	0	-	0	1	0	0	1	1	1	1	1	1	2	0	2	1	1	0	0	-	-
Xenocatantops humilis	0	0	0	2	1	0	0	1	0	0	1	1	1	1	1	1	1	0	2	0	1	1	-	0	-
Cyrtacanthacridinae																									
Patanga luteicornis	0	1	0	0	1	2	0	1	0	0	1	1	0	1	1	2	1	0	2	2	1	1	-	0	-
Patanga succincta	0	1	0	0	1	2	1	1	0	1	0	1	0	1	1	1	1	0	2	2	1	1	-	0	-
Valanga nigricornis	0	1	0	0	1	0	0	1	0	0	1	1	0	1	1	1	2	0	2	1	1	1	-	0	-
Oedipodinae																									
Aiolopus thalassinus tamulus	1	0	0	1	0	-	1	1	0	0	1	1	0	0	1	0	2	0	1	1	0	-	-	-	-

Table 4.3 continued.

Taxa	Characters																								
	01	**02**	**03**	**04**	**05**	**06**	**07**	**08**	**09**	**10**	**11**	**12**	**13**	**14**	**15**	**16**	**17**	**18**	**19**	**20**	**21**	**22**	**23**	**24**	**25**
Gastrimargus marmoratus	1	1	1	1	1	2	1	1	0	1	0	1	0	1	1	0	1	0	2	1	0	-	-	-	-
Heteropternis obscurella	0	1	0	1	0	-	1	1	0	1	0	0	0	0	0	-	0	0	2	1	0	-	-	-	-
Locusta migratoria manilensis	1	1	0	1	1	0	0	1	0	0	0	1	0	1	1	0	1	0	1	1	0	-	-	-	-
Trilophidia annulata	1	1	1	1	1	3	1	1	0	0	0	1	1	1	1	2	3	0	1	1	0	-	-	-	-
Oxyinae																									
Oxya hyla intricata	0	0	0	0	0	-	0	0	0	0	1	1	1	1	0	-	3	0	1	0	1	1	-	0	-
Oxya japonica japonica	0	1	0	1	0	-	1	0	0	0	1	1	1	1	0	-	2	0	1	2	1	1	-	0	-
Pseudoxya diminuta	0	0	0	0	0	-	0	1	0	0	1	1	0	1	1	1	1	0	1	1	1	1	-	0	-

Taxa	Characters																								
	26	**27**	**28**	**29**	**30**	**31**	**32**	**33**	**34**	**35**	**36**	**37**	**38**	**39**	**40**	**41**	**42**	**43**	**44**	**45**	**46**	**47**	**48**	**49**	**50**
Outgroup																									
Atractomorpha psittacina psittacina	1	2	-	-	-	0	1	2	0	1	0	0	1	0	0	-	1	0	0	0	1	0	1	0	0
Atractomorpha sinensis	1	2	-	-	-	0	1	2	0	1	0	0	1	0	0	-	1	0	0	-	1	0	1	0	0
Acridinae																									
Phlaeoba antennata	1	3	2	1	1	1	1	1	0	0	0	0	0	1	-	0	1	0	1	0	0	0	0	1	0
Phlaeoba infumata	1	3	2	1	1	1	1	1	0	0	0	0	0	1	-	0	1	0	0	0	0	0	0	1	0
Catantopinae																									
Apalacris varicornis	1	2	1	1	0	0	1	2	1	0	1	0	1	0	1	1	1	0	0	0	1	0	0	1	0
Coloracris azureus	1	3	2	1	1	0	0	1	-	1	-	-	-	0	0	-	0	0	1	1	1	0	1	1	0
Coloracris coerulescens	1	3	2	1	1	1	1	1	-	1	-	-	-	0	0	-	0	0	1	0	0	0	0	1	0
Coloracris sp.	1	3	2	1	1	1	1	1	-	1	-	-	-	0	0	-	1	0	1	1	0	0	1	1	0
Craneopsis olivacea	1	1	1	1	1	0	0	1	0	1	0	1	1	0	1	1	1	0	0	1	1	0	1	1	1
Meltripata sp. 1	1	3	2	1	1	1	0	1	-	1	-	-	-	0	0	-	1	0	0	1	0	0	1	1	0
Meltripata sp. 2	0	0	0	1	0	0	0	1	-	1	-	-	-	0	0	-	1	0	1	1	0	0	1	1	0
Perakia borneensis	1	3	2	1	1	1	0	1	-	1	-	-	-	0	0	-	0	0	1	1	2	0	1	0	0
Phalaca waterstradti	1	3	2	1	0	0	0	1	0	1	0	1	1	0	1	1	1	0	0	0	1	0	1	1	1
Stenocatantops splendens	1	1	1	1	2	0	1	2	0	0	0	0	1	0	1	1	1	0	0	1	2	0	1	1	0

Table 4.3 continued.

Taxa	Characters																								
	26	**27**	**28**	**29**	**30**	**31**	**32**	**33**	**34**	**35**	**36**	**37**	**38**	**39**	**40**	**41**	**42**	**43**	**44**	**45**	**46**	**47**	**48**	**49**	**50**
Traulacris grandis	1	1	2	1	1	1	0	1	0	1	0	1	1	0	0	1	1	0	1	1	1	0	1	1	0
Traulia azureipennis	1	3	2	1	1	0	1	1	1	0	1	1	1	0	3	1	1	0	0	0	1	0	0	1	0
Traulia borneensis	1	1	1	1	0	0	1	1	0	1	0	0	1	0	0	1	1	0	0	0	0	0	0	1	0
Traulis sanguinipes sanguinipes	1	1	2	1	1	0	1	1	0	1	0	0	1	0	1	1	1	0	0	0	1	0	0	1	0
Xenocatantops humilis	1	1	1	1	0	0	1	1	0	1	0	0	1	0	1	1	1	0	0	0	0	0	1	1	0
Cyrtacanthacridinae																									
Patanga luteicornis	1	3	2	1	0	0	1	1	0	0	0	0	1	0	1	1	1	0	0	1	1	1	1	1	0
Patanga succincta	1	3	1	1	2	0	1	1	0	0	0	0	1	0	1	1	1	0	0	1	1	1	1	1	1
Valanga nigricornis	1	3	2	1	0	0	0	1	1	0	1	0	1	0	2	1	1	0	0	1	1	1	1	1	1
Oedipodinae																									
Aiolopus thalassinus tamulus	1	1	1	0	-	0	1	1	0	0	0	0	0	0	1	0	1	0	0	0	0	0	0	0	0
Gastrimargus marmoratus	1	2	2	-	-	0	1	2	1	0	1	0	0	0	4	0	1	0	0	0	0	0	0	1	0
Heteropternis obscurella	0	3	2	0	-	0	1	1	0	0	0	0	0	0	1	0	1	0	0	0	1	0	0	0	0
Locusta migratoria manilensis	1	2	2	1	1	0	1	2	1	0	0	0	0	0	2	0	0	0	0	0	1	0	0	1	0
Trilophidia annulata	1	2	2	0	-	0	0	2	1	0	1	1	1	0	3	-	1	0	0	0	1	0	0	0	0
Oxyinae																									
Oxya hyla intricata	1	1	1	1	0	2	1	1	0	1	0	0	1	0	1	1	1	0	1	1	1	0	1	0	0
Oxya japonica japonica	1	1	1	1	0	2	1	1	0	1	0	0	1	0	1	1	1	0	0	1	1	0	1	0	0
Pseudoxya diminuta	1	1	1	1	2	0	1	1	0	1	0	0	1	0	0	1	1	0	1	0	1	0	1	0	0

Taxa	Characters																								
	51	**52**	**53**	**54**	**55**	**56**	**57**	**58**	**59**	**60**	**61**	**62**	**63**	**64**	**65**	**66**	**67**	**68**	**69**	**70**	**71**	**72**	**73**	**74**	**75**
Outgroup																									
Atractomorpha psittacina psittacina	1	1	0	0	1	2	1	1	0	1	1	-	1	0	0	0	0	1	1	0	1	0	0	0	0
Atractomorpha sinensis	1	1	0	0	0	1	0	0	0	1	1	-	1	0	0	1	0	-	-	0	1	0	0	0	0
Acridinae																									
Phlaeoba antennata	1	0	0	1	0	1	0	0	0	1	1	1	1	0	2	0	0	1	1	0	1	0	0	0	0
Phlaeoba infumata	1	0	0	1	0	1	0	0	0	1	1	0	0	0	2	0	0	1	1	0	1	0	0	0	0

Table 4.3 continued.

Taxa	Characters																								
	51	**52**	**53**	**54**	**55**	**56**	**57**	**58**	**59**	**60**	**61**	**62**	**63**	**64**	**65**	**66**	**67**	**68**	**69**	**70**	**71**	**72**	**73**	**74**	**75**
Catantopinae																									
Apalacris varicornis	1	0	0	1	0	1	0	0	0	1	1	0	0	0	0	0	0	1	1	0	1	0	0	0	0
Coloracris azureus	1	0	0	1	0	0	0	0	0	1	0	-	3	2	2	0	2	1	0	0	2	0	-	-	-
Coloracris coerulescens	0	0	0	1	0	0	0	0	0	-	-	-	-	-	-	-	-	-	-	-	-	-	0	0	0
Coloracris sp.	1	0	0	1	0	0	0	0	0	1	1	1	1	0	2	0	2	1	0	0	2	0	-	-	-
Craneopsis olivacea	1	1	0	0	1	1	0	0	1	1	1	1	0	0	2	1	0	1	1	0	2	0	-	-	-
Meltripata sp. 1	1	0	0	0	1	0	0	0	1	1	1	1	0	0	0	1	0	1	1	0	1	1	-	-	-
Meltripata sp. 2	1	0	0	1	0	0	1	0	1	-	-	-	-	-	-	-	-	-	-	-	-	-	0	0	0
Perakia borneensis	1	0	0	0	1	1	0	1	1	1	1	1	0	0	2	0	0	1	1	1	0	0	-	-	-
Phalaca waterstradti	1	1	0	0	1	0	0	1	0	1	1	1	0	0	2	0	1	1	0	0	1	0	-	-	-
Stenocatantops splendens	1	0	0	0	0	1	0	1	0	1	1	2	0	1	2	0	0	1	1	1	0	0	0	0	0
Traulacris grandis	0	0	0	1	1	0	0	0	1	1	1	0	1	0	2	0	1	1	0	0	2	0	0	0	0
Traulia azureipennis	0	0	0	1	0	0	0	1	0	1	2	-	1	3	2	1	1	1	0	0	2	0	0	0	0
Traulia borneensis	1	0	0	1	0	0	0	0	1	1	3	-	2	1	2	1	1	1	0	0	2	0	0	0	0
Traulis sanguinipes sanguinipes	1	0	0	1	0	0	0	0	0	1	2	-	1	3	2	0	1	1	0	0	1	1	0	0	0
Xenocatantops humilis	1	0	0	1	0	1	0	0	0	1	1	2	3	1	0	0	1	1	1	0	1	1	0	0	0
Cyrtacanthacridinae																									
Patanga luteicornis	0	0	0	0	0	-	0	0	0	1	1	3	1	3	2	1	0	1	1	1	0	0	0	0	0
Patanga succincta	1	0	0	1	0	0	0	0	0	1	1	3	1	3	2	1	0	1	1	1	0	0	0	0	0
Valanga nigricornis	0	0	0	1	0	-	0	0	0	1	1	3	0	3	2	0	1	1	1	1	0	0	0	0	0
Oedipodinae																									
Aiolopus thalassinus tamulus	1	0	0	0	0	1	0	1	0	1	1	0	0	0	2	0	0	1	1	0	1	1	0	0	0
Gastrimargus marmoratus	1	0	0	1	0	2	0	0	0	1	1	0	0	0	0	0	0	1	1	0	1	1	0	0	0
Heteropternis obscurella	1	0	0	1	0	1	0	0	0	1	1	0	1	0	2	0	0	1	1	1	0	0	0	0	0
Locusta migratoria manilensis	1	0	0	1	0	1	0	1	0	1	1	0	0	0	0	0	0	1	1	1	1	1	0	0	0
Trilophidia annulata	1	0	0	1	0	0	0	0	0	0	1	0	0	0	2	0	0	1	1	0	1	1	0	0	0
Oxyinae																									
Oxya hyla intricata	1	1	0	1	1	0	0	1	0	1	1	1	2	0	2	0	0	1	2	0	2	0	0	0	0

Table 4.3 continued.

Taxa	Characters																								
	51	**52**	**53**	**54**	**55**	**56**	**57**	**58**	**59**	**60**	**61**	**62**	**63**	**64**	**65**	**66**	**67**	**68**	**69**	**70**	**71**	**72**	**73**	**74**	**75**
Oxya japonica japonica	1	1	0	1	1	-	0	1	0	1	1	-	3	0	2	0	0	1	2	0	2	0	0	0	0
Pseudoxya diminuta	1	1	0	1	1	0	0	1	1	1	1	0	0	0	2	0	1	1	1	0	2	0	0	0	0

Taxa	Characters																								
	76	**77**	**78**	**79**	**80**	**81**	**82**	**83**	**84**	**85**	**86**	**87**	**88**	**89**	**90**	**91**	**92**	**93**	**94**	**95**	**96**	**97**	**98**	**99**	**100**
Outgroup																									
Atractomorpha psittacina psittacina	0	2	0	1	0	0	0	2	3	0	1	0	2	1	1	1	1	2	0	2	1	2	1	0	0
Atractomorpha sinensis	0	2	0	1	0	0	0	1	2	0	1	0	2	1	1	1	1	2	0	2	1	2	1	0	0
Acridinae																									
Phlaeoba antennata	0	0	0	1	0	0	0	1	2	1	0	0	1	1	1	1	1	2	1	1	1	1	1	1	0
Phlaeoba infumata	0	0	0	0	0	0	0	1	2	0	0	0	1	1	1	1	1	2	1	1	1	1	1	1	0
Catantopinae																									
Apalacris varicornis	0	0	0	1	0	0	0	1	1	1	1	0	2	1	1	2	1	1	1	2	2	2	1	1	1
Coloracris azureus	-	-	-	-	-	-	-	2	2	2	0	1	1	2	1	2	-	-	-	-	-	-	-	-	-
Coloracris coerulescens	0	0	0	0	0	0	0	-	-	-	-	-	-	-	-	-	1	2	2	1	2	1	1	1	1
Coloracris sp.	-	-	-	-	-	-	-	2	2	2	1	1	1	2	1	2	-	-	-	-	-	-	-	-	-
Craneopsis olivacea	-	-	-	-	-	-	-	2	3	4	2	3	2	2	1	3	-	-	-	-	-	-	-	-	-
Meltripata sp. 1	-	-	-	-	-	-	-	2	2	2	1	1	1	1	1	3	-	-	-	-	-	-	-	-	-
Meltripata sp. 2	0	0	0	0	2	0	0	-	-	-	-	-	-	-	-	-	0	1	1	0	1	1	1	0	0
Perakia borneensis	-	-	-	-	-	-	-	3	2	4	2	3	1	2	2	3	-	-	-	-	-	-	-	-	-
Phalaca waterstradti	-	-	-	-	-	-	-	2	2	3	1	2	1	1	1	3	-	-	-	-	-	-	-	-	-
Stenocatantops splendens	0	0	0	0	0	0	0	3	2	2	2	1	3	2	2	2	2	2	1	2	2	3	2	2	1
Traulacris grandis	0	0	0	1	0	0	0	1	2	2	1	1	1	2	2	2	1	1	1	1	2	1	1	1	1
Traulia azureipennis	0	0	0	1	2	0	0	2	2	2	1	1	2	1	1	2	1	1	2	2	2	2	1	1	1
Traulia borneensis	0	0	0	0	2	0	0	2	2	2	1	1	1	1	1	2	1	1	2	2	3	1	1	1	1
Traulis sanguinipes sanguinipes	0	0	0	1	0	0	0	2	2	2	1	1	2	2	1	2	1	1	2	2	2	2	1	1	1
Xenocatantops humilis	0	0	0	0	0	0	0	2	2	2	1	1	2	1	1	2	1	1	1	2	2	2	1	1	1

Table 4.3 continued.

Taxa	Characters																								
	76	**77**	**78**	**79**	**80**	**81**	**82**	**83**	**84**	**85**	**86**	**87**	**88**	**89**	**90**	**91**	**92**	**93**	**94**	**95**	**96**	**97**	**98**	**99**	**100**
Cyrtacanthacridinae																									
Patanga luteicornis	0	0	0	1	0	0	0	5	4	4	3	3	5	5	4	4	4	4	3	5	5	5	5	4	3
Patanga succincta	0	0	0	1	0	0	0	5	4	4	3	3	5	5	4	4	4	4	3	5	5	5	5	4	2
Valanga nigricornis	0	0	0	0	0	0	0	5	4	4	4	4	5	5	4	4	4	4	3	5	5	5	4	4	2
Oedipodinae																									
Aiolopus thalassinus tamulus	0	0	0	0	0	0	1	1	2	1	0	0	2	1	1	1	1	1	1	1	1	2	1	1	0
Gastrimargus marmoratus	0	0	0	1	2	1	0	3	3	3	2	3	4	3	3	2	2	3	2	4	4	3	3	3	1
Heteropternis obscurella	0	0	0	0	1	1	0	1	2	1	0	1	2	1	1	1	0	1	1	1	1	2	1	1	0
Locusta migratoria manilensis	0	0	0	1	2	0	0	3	3	3	2	3	5	3	3	3	3	3	3	3	5	4	3	3	1
Trilophidia annulata	0	0	0	1	0	1	0	1	1	1	0	0	2	1	1	1	0	0	1	1	1	2	0	0	0
Oxyinae																									
Oxya hyla intricata	0	4	0	0	0	1	1	1	2	0	0	0	2	1	1	1	1	1	1	1	1	2	1	0	0
Oxya japonica japonica	0	4	0	0	0	1	1	1	2	1	1	0	2	1	1	2	1	1	1	1	1	2	1	1	0
Pseudoxya diminuta	0	2	0	0	0	1	0	1	1	1	0	0	1	1	1	1	0	0	1	1	1	1	0	0	0

4.2.3 Morphometric Measurement

Measurements of external morphological characters were taken by using Mitutoyo CD-6”CSX digital calliper that was calibrated to 0.01 mm and recorded to two decimal points. A total of 18 external morphological characters were included in the examination, following Ronderos and Cigliano (1991), Cigliano et al. (1996), Song and Wenzel (2007) and Li et al. (2011) with some modifications to suit the specimens available in collections.

The quantitative characters involved in the examination include total body length (BL), length of front head (FHL), width of head (HW), length of pronotum (PL), length from fastigium to post-occiput (FPL), length from head to pronotum (PHL), width of pronotum (PW), length of antennae (AL), inter-ocular distance or width between eyes (WBE), size of eye (height) (ES (H)), size of eye (width) (ES (W)), length of tegmen (TL), width of tegmen at apex (TW (1)), maximum width of tegmen (TW (2)), width of tegmen basally (TW (3)), length of hind femora (HFL), length of hind tibia (HTL) and length of hind tarsi (HSL). Missing characters were denoted by “-” (Appendix 1). The data obtained from the measurements of external characters was later converted into informative characters to be included as part of the data matrices (Table 4.2: Character states 83–100).

4.2.4 Phylogenetic Analyses

The phylogeny analyses for the subfamilies of Acrididae in Malaysian Borneo were constructed by using Phylogenetic Analysis Using Parsimony (*and Other Methods) (PAUP*) software version 4.0a169 developed by Swofford (2003) and Tree Analysis Using New Technology (TNT) software version 1.5 developed by Goloboff and Catalano (2016). A total of 28 species of Acrididae from 20 genera and five subfamilies were included in the analysis, with the inclusion of two species from family Pyrgomorphidae, genus

Atractomorpha as the outgroup. The species *Atractomorpha psittacina psittacina* and *A. sinensis* were used to root the trees based on their close affinities within suborder Caelifera, and prior grouping of family Pyrgomorphidae that was nestled as one the subfamilies in family Acridoidea (Kirby, 1914; Liu et al., 2008; Chapco & Contreras, 2011).

From the examination of the specimens, a data matrix was created in Excel software by coding the specimens according to the character best suited them. The taxa block was then exported into Mesquite version 3.61 to create a nexus (.nex) formatted file to be analysed using Phylogenetic Analysis Using Parsimony (*and Other Methods) (PAUP*), while another copy of the nexus formatted file was exported to a TNT formatted file to allow data analysation by Tree Analysis Using New Technology (TNT) software.

The analysis conducted using TNT software uses the traditional searching method adopted from Goloboff et al. (2008). Parameters used in the analysis includes setting the memory to allow a maximum of 10,000 trees to be saved. Next, Wagner trees was set to 1 random seed executed with 1,000 number of replicates. Tree-bisection-reconnection (TBR) was chosen as the swapping algorithm with 10 trees to be save per replication with replacement of existing trees. Branch support was calculated using bootstrap values, jackknife and symmetric resampling values with 1,000 random addition replicates performed for each measure.

4.3 Results and Discussion

4.3.1 Character Homology and Terminology

A total of 100 morphological characters with 321 character states, which comprised of 82 qualitative characters: 59 characters from the external morphology (characters 1–59), 13 characters from the male genitalia (characters 60–72) and 10 characters from the female

genitalia (characters 73–82), and 18 quantitative characters were included in the analysis. The characters were adapted and compiled from Ronderos and Cigliano (1991), Cigliano et al. (1996), Song and Wenzel (2007) and Li et al. (2011), as well as some novel characters discovered throughout the course of the study. The terminology of the genitalic characters follows that of Roberts (1941).

Head

Members of family Acrididae can be distinguished by the shape of their head in lateral view, either slanted (1-0) or straight (1-1). Majority of the subfamilies possessed slightly slanted head laterally, while certain species from subfamily Catantopinae possessed straight head shape, specifically *Apalacris varicornis*, *Craneopsis olivacea*, and *Perakia borneensis*, as well as members of subfamily Oedipodinae with the exceptions of *Heteropternis obscurella*. In terms of eye shape, almost all species of the family have prominent eyes, exceeding the outline of their head (2-0) (Figure 4.1A), except for *C. olivacea*, *Coloracris azureus*, *Meltripata* sp. 2, *Oxya japonica japonica*, all members of the subfamilies Cyrtacanthacridinae (Figure 4.1B) and Oedipodinae, with the exclusion of *Aiolopus thalassinus tamulus* from the latter. Shape of the eyes was defined as subcircular or long oval, with the vertical diameter of eye greater than the horizontal diameter (3-0) or, oval or rounded, with the vertical diameter of eye equal to or less than the horizontal diameter (3-1). Distance between eyes or the interocular distance was either the same as the width of frontal ridge (4-0) (Figure 4.1A) as portrayed by most species from the family, distinctly wider than the width of frontal ridge (4-1) (Figure 4.1C) which can be seen in Acridinae, Oedipodinae and a few members of Catantopinae or narrower than the width of frontal ridge (4-2) (Figure 4.1D) that was exhibited by *A. varicornis*, *P. borneensis*, *Stenocatantops*

splendens and *Xenocatantops humilis*. Similarly, most members of the family exhibited the same shape of anterior apex of head dorsally which was distinctly projecting forward away from the compound eyes (5-0) (Figure 4.1C), while members of subfamily Cyrtacanthacridinae, and a few species from subfamilies Catantopinae and Oedipodinae exhibited the opposite character where the anterior apex of head was linear and close to eyes from dorsal view (5-1) (Figure 4.1D). However, 18 species did not exhibit any presence of ridge on the fastigium of head (6-0), while two species, *A. varicornis* and *S. splendens* from subfamily Catantopinae portrayed horizontally elongated isosceles trapezoid ridge on the fastigium (6-1), four species from subfamilies Catantopinae, Cyrtacanthacridinae and Oedipodinae portrayed vertically elongated isosceles trapezoid ridge of the fastigium (6-2), and only one species from subfamily Oedipodinae, *Trilophidia annulata*, was defined with rounded lateral ridges with longitudinal depression in the middle (6-3). Most members of the family do not exhibit fastigium that were deeply burrowed (7-0), while species from subfamily Acridinae, all members of subfamily Oedipodinae with the exceptions of *Locusta migratoria manilensis*, and a few other species have excavated fastigium (7-1). The lateral carinae on fastigium (8-1) can be seen on subfamilies Acridinae, Cyrtacanthacridinae, Oedipodinae and other species, while it was absent on the rest (8-0). All members of the family Acrididae possessed fastigium that was not strongly projected anteriorly, with the distance from anterior margin of eyes to the apex of fastigium was equal or less than the horizontal diameter of eye (9-0), while only the outgroup from genus *Atractomorpha* exhibited strongly projected fastigium anteriorly, with the distance from anterior margin of eyes to the apex of fastigium was obviously greater than the horizontal diameter of eye (9-1). Majority of the species do not possess any transverse groove at the base of fastigium (10-0), while several species portrayed fine transverse groove that was not interrupting the lateral

carinae of the vertex of head (10-1), and one species, *A. varicornis*, exhibited very distinct transverse groove that was cutting through the lateral carinae of the vertex of head (10-2). With regard to the obliquity of frons, less than half of the species observed were not oblique, forming a right angle with the vertex in lateral view (11-0) (Figure 4.1E), while the rest of the species were oblique, forming an acute angle of over 40 degree with the vertex laterally (11-1) (Figure 4.1F), and species from the outgroup family formed very acute angle that was less than 40 degree with the vertex laterally (11-2). All members of the family were revealed to possess vertex of head as high as the eyes in lateral view (12-1) (Figure 4.1F), with only three species, namely *Traulia azureipennis*, *T. borneensis* and *H. obscurella* with the vertex of head lower than the eyes (12-0). Almost half of the species from the family exhibited frontal costa that were not obviously projected between the antennae (13-0) (Figure 4.1E), while the other half portrayed frontal costa that were projecting forward between the antennae (13-1). In relation to the frontal ridge of the head, some of the species from subfamily Catantopinae and two species from Oedipodinae possessed frontal ridge that was obliterated below frontal ocelli (14-0) (Figure 4.1G), while majority of the subfamilies were born with frontal ridge that were elongated below the frontal ocelli (14-1). Other morphological structures utilised as characters to define the inter-relationship of the family was the sculpting patterns and integuments on the skin. Almost all species had punctured outer layer (15-1), with the exceptions of *Phalaca waterstradti*, *H. obscurella*, *Oxya hyla intricata* and *O. japonica japonica* which exhibited smooth integument without any pattern (15-0), while two species from the outgroup, *At. psittacina psittacina* and *At. sinensis* possessed granulose integument (15-2). As for the sculpting pattern on the frontal ridge of head above the frontal ocellus, three different character states can be seen from the family, which were lightly punctured (16-0), small and deep punctures (16-1), and wide punctures

mimicking the surface of a golf ball (16-2). Patterns on the integument between preocular ridge and frontal ridge of head can be discriminated by four different states which were smooth without any sculpture (17-0) (Figure 4.1G), punctured (17-1) (Figure 4.1H), ridged (17-2) (Figure 4.1I) and with pebbled surface (17-3). The antennae of these short-horned grasshoppers came in two different forms; filiform, where the width of basal segments is equal to the apical segments (18-0) (Figure 4.1G, J) or sword-shaped, where the width of basal segments is greater than the length (18-1) (Figure 4.1K). Length of the antennae could be distinguished into four different types, either shorter than the combined length of head and pronotum (19-0), as long as the combined length of head and pronotum (19-1), longer than the combined length of head and pronotum (19-2) or extending much beyond the pronotum (19-3). With reference to the width of head in comparison to the width of pronotum, the head were either wider than the pronotum (20-0), as wide as the pronotum (20-1) (Figure 4.1D) as seen in *P. borneensis*, or wider than the width of pronotum (20-2) (Figure 4.1B) as portrayed by members of genus *Patanga*.

Prosternal process

Prosternal process is an extended tubercle found ventrally on the first segment of the thorax, named prosternum, located between the first pair of legs, also known as the prosternal spine. This character is useful to identify species at subfamily level as not all members of the family possessed prosternal process, such as subfamilies Acridinae and Oedipodinae. Four different forms of prosternal process can be identified from each subfamily namely conical (22-0) (Figure 4.2A), cylindrical (22-1) (Figure 4.2B, C), transverse and lobular (22-2) and mushroom-shaped (22-3). However, only the conical and cylindrical forms were observed from the specimens examined in Malaysian Borneo. Among all members of family

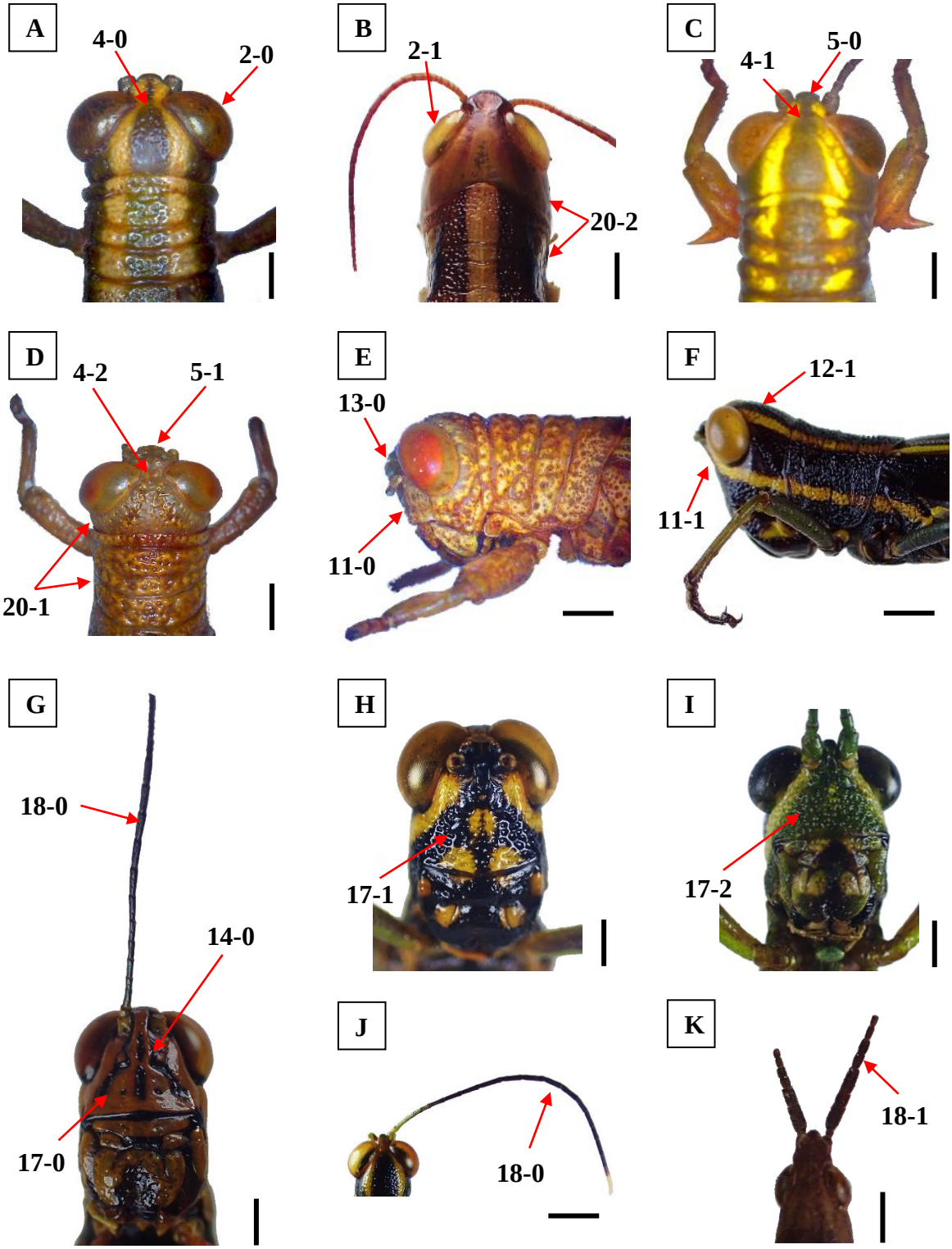


Figure 4.1: Variation of head structures in Acrididae. **A.** *Phalaca waterstradti*; **B.** *Patanga succincta*; **C.** *Craneopsis olivacea*; **D.** *Perakia borneensis* (dorsal view); **E.** *P. borneensis* (left lateral view); **F.** *Coloracris coerulescens*; **G.** *Meltripata* sp. 2; **H.** *Coloracris* sp.; **I.** *Meltripata* sp. 1; **J.** *C. azureus*; **K.** *Phlaeoba infumata*. Scale = 5 mm.

Acrididae, only *Apalacris varicornis*, *Coloracris* sp., *C. azureus*, *C. coerulescens*, *Meltripata* sp. 2, *Traulacris grandis*, *Traulia azureipennis*, *T. borneensis* and *T. sanguinipes sanguinipes* from subfamily Catantopinae were observed to portray conical shaped prosternal process that was straight (23-0) (Figure 4.2A), instead of strongly bent posteriorly (23-1). The rest of the species were observed to exhibit a cylindrical shaped prosternal process that could further be narrowed down into three different forms of cylinder, in particular, straight or slightly bent posteriorly (24-0) (Figure 4.2B), which was the character seen in subfamilies Cyrtacanthacridinae, Oxyinae, and two members of subfamily Catantopinae, *Stenocatantops splendens* and *Xenocatantops humilis*, strongly bent posteriorly and almost reaching the anterior margin of mesosternum (24-1), and compressed laterally and flat apically (24-2) (Figure 4.2C), which was seen in four members of subfamily Catantopinae, namely *Craneopsis olivacea*, *Meltripata* sp. 1, *Perakia borneensis*, *Phalaca waterstradti*, and the outgroup genus *Atractomorpha*.

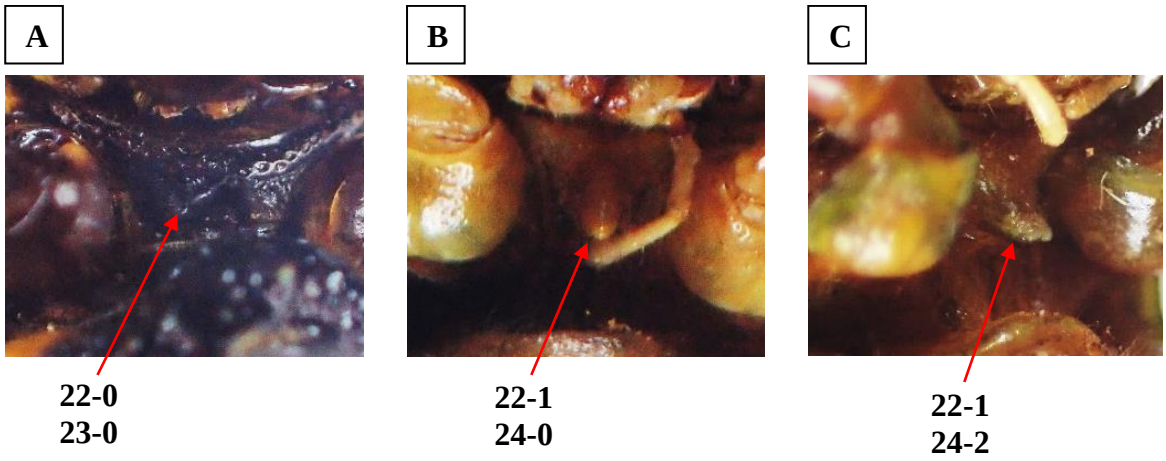


Figure 4.2: Variation of prosternal process in Acrididae. **A.** *Coloracris coerulescens*; **B.** *Patanga luteicornis*; **C.** *Craneopsis olivacea*.

Mesosoma

The dorsal portion of the thoracic segments is covered in a thick membrane namely pronotum. This saddle-shaped structure can be further divided into two segments, specifically prozona and metazona. The overall surface of the pronotum can be distinguished into two different forms, either smooth to finely sculptured (26-0) (Figure 4.3D) or coarsely and distinctly sculptured, with either rough granulates, irregularly carinulated or tuberculated (26-1) (Figure 4.3B). Looking closely on the dorsum of prozona, four types of sculpting pattern could be seen, either no pattern (27-0), which was only observed in *Meltripata* sp. 2, punctured (27-1), which can mostly be seen in subfamily Oxyinae, tuberculosed or covered with tubercles (27-2), which can be seen in some of the oedipodines and the sister group, *Atractomorpha*, and irregularly wrinkled ridges (27-3), which can largely be seen across the family. In profile, the sculpting pattern that can be seen on the lateral lobe of prozona were either smooth (28-0) (Figure 4.3D), distinctly punctured (28-1) (Figure 4.3E) or distinctly wrinkled (28-2), which were mainly seen in the family. The sculpting pattern on the metazona were discriminated into four forms, no pattern (29-0), ridged (29-1), elongated pit (29-2) and large irregular punctures (29-3). Ridged metazona (29-0) can be further used in separating species by narrowing down into three different forms of characters, such as having numerous small pits (30-0) (Figure 4.3D), ridges distinctly thickened (30-1) (Figure 4.3B) or honeycombed (30-2). In terms of the general view on the pronotum dorsally, three different types of posterior margins can be seen, such as expanding caudally (31-0) (Figure 4.3A), subcylindrical (31-1) (Figure 4.3B) and with expanded metazona (31-2). From these characters, members of genus *Oxya* were the only species having portrayed an expanded metazona. Pronotal disc of a grasshopper is generally cut by a few transverse sulci, that were either deeply impressed (32-0) (Figure 4.3A) which was

clearly portrayed by *Craneopsis olivacea*, *Meltripata* sp. 1, *Meltripata* sp. 2, *Perakia borneensis*, *Phalaca waterstradti* and *Trilophidia annulata*, or shallowly impressed (32-1) (Figure 4.3C) as seen in most species across the family. The convexity of median posterior margin of pronotum was also considered in defining the relationship between species of the family. Three different structures were observed, such as nearly linear (33-0), smoothly round or broadly angular (33-1) and projected into an acute angle (33-2). Presence of carinae on the pronotal surface is also a useful feature on a grasshopper that can be used to determine species up to genera level. As such, the presence of median carinae on prozona of pronotal disc can be either flat (34-0) or distinctly elevated (34-1), and its distinctness can be either distinct, from almost complete to complete (35-0) (Figure 4.3E, F) or barely discernible to absent (35-1). In lateral view, the median carinae could be either straight (36-0) (Figure 4.3E) or strongly elevated medially and forms a distinct round ridge (36-1) (Figure 4.3F) as seen clearly in *Gastrimargus marmoratus* and *T. annulata*. On the pronotal disc, incision made by the principal sulcus can either be shallow to indistinct (37-0) (Figure 4.3C) as portrayed by majority of the species, or deep (37-1) (Figure 4.3A) as seen in *C. olivacea*, *P. waterstradti* and *T. annulata*, while additional incisions by minor transverse carinae could be absent (38-0) or present (38-1) (Figure 4.3C). In relations to lateral carinae on the pronotal disc, all species including the outgroup showed no trace of an elevated ridge (39-0) except for the subfamily Acridinae which showed a slightly elevated ridge (39-1). As for species without the appearance lateral carinae, the presence of median carina can be classified into five different forms such as no trace (40-0), present as a low ridge (40-1), present as a narrow and sharp ridge (40-2), present as a thick ridge (40-3) or highly raised (40-4). The number of sulci crossing the median carinae of pronotum can be differentiated into two groups either crossed by only one sulcus (41-0) (Figure 4.3F) which were prominent in Acridinae and

Oedipodinae, or crossed by three sulci (41-1) as seen in members of Oxyinae and Catantopinae, although some species from these subfamilies were revealed to have no sulci crossing the median carinae of pronotal disc. Laterally, the ventral posterior angle of the lateral lobe could take two different forms, either broadly round (42-0) or roundly angular to angular (42-1) (Figure 4.3F), and the posterior margin of the lateral lobe is either not concave to slightly arched (43-0), which defined all members of the family including the outgroup, or strongly concave (43-1). The hindwings and tegmina of a grasshopper are structures connected to the apical margin of the pronotal disc, and two stages of tegmina development could be observed in a species across the family, specifically macropterous (59-0) and brachypterous (59-1). Ventrally, the thorax is divided into three segments, known to be prosternum, mesosternum and metasternum. These three segments all bear each pair of the grasshopper's legs. Most of the defining characters can be seen on the second segment, mesosternum, such as the convexity of anterior border of mesosternum that was either straight or very slightly arched (44-0) (Figure 4.3G), or broadly projected in the middle (44-1) (Figure 4.3H). Other significant character in discriminating the species is length of the mesosternal lobe, either laterally wider than its vertical length (45-0) (Figure 4.3I) or vertically longer than its lateral width (45-1) (Figure 4.3G). This character is especially useful in differentiating cyrtacanthacrids as they are commonly known to have longer mesosternal lobes than its width. Other than the length, shape of mesosternal interspace is also used in defining the relation between species. Three different forms were observed, such as wide, where the vertical and lateral length were almost equal (46-0) (Figure 4.3I), elongated, where the vertical length is longer than its narrowest width (46-1) (Figure 4.3G), or very reduced, with the lateral margins partly or completely contiguous (46-2) (Figure 4.3H). The inner posterior corners of the lateral lobes were shown to take two different

forms, either obtusely round or angularly round (47-0) (Figure 4.3H), or right angular to acutely angular (47-1) (Figure 4.3G) which is a character specific to subfamily Cyrtacanthacridinae. In relation to the metasternum, contact of lateral lobes can be either separated (48-0) (Figure 4.3I) as seen in all members of Acridinae and Oedipodinae, or contiguous (48-1) (Figure 4.3H) as portrayed by members of Cyrtacanthacridinae and Oxyinae. However, this character was shown to be varying across Catantopinae as some members could portrayed either one of the characters.

Legs

Other significant structures that could be useful for characterising the relationship between subfamilies of Acrididae is the leg. The upper and lower carinae of hind femur can either be smooth (49-0, 50-0) (Figure 4.4A) or serrated (49-1, 50-1) (Figure 4.4B). Furthermore, the relative length of dorsal and ventral genicular lobe that was located at the basal part of hind femora could be portrayed in two different forms, either with equal length (51-0) or the dorsal lobe appeared to be longer than the ventral lobe (51-1). The ventral genicular lobe bore an extended process that can be defined as rounded or roundly angular distally (52-0) (Figure 4.4C), or spined distally (52-1) (Figure 4.4D). Similarly, the dorsal genicular lobe can also be further discriminated as it carried two different forms, either rounded distally (53-0), or spined distally (53-1). The distal end of dorsal carina on hind femora were also used as identification, where two forms can be detected, specifically rounded or slightly broadly angular (54-0), and spined, acutely pointed, or narrowly obtuse-angular (54-1). The outer apical spine on hind tibia is a unique character that can either be absent (55-0) (Figure 4.4F) or present (55-1) (Figure 4.4E) on different species. Additionally, the number of spines on outer margin of hind tibia also differs among species

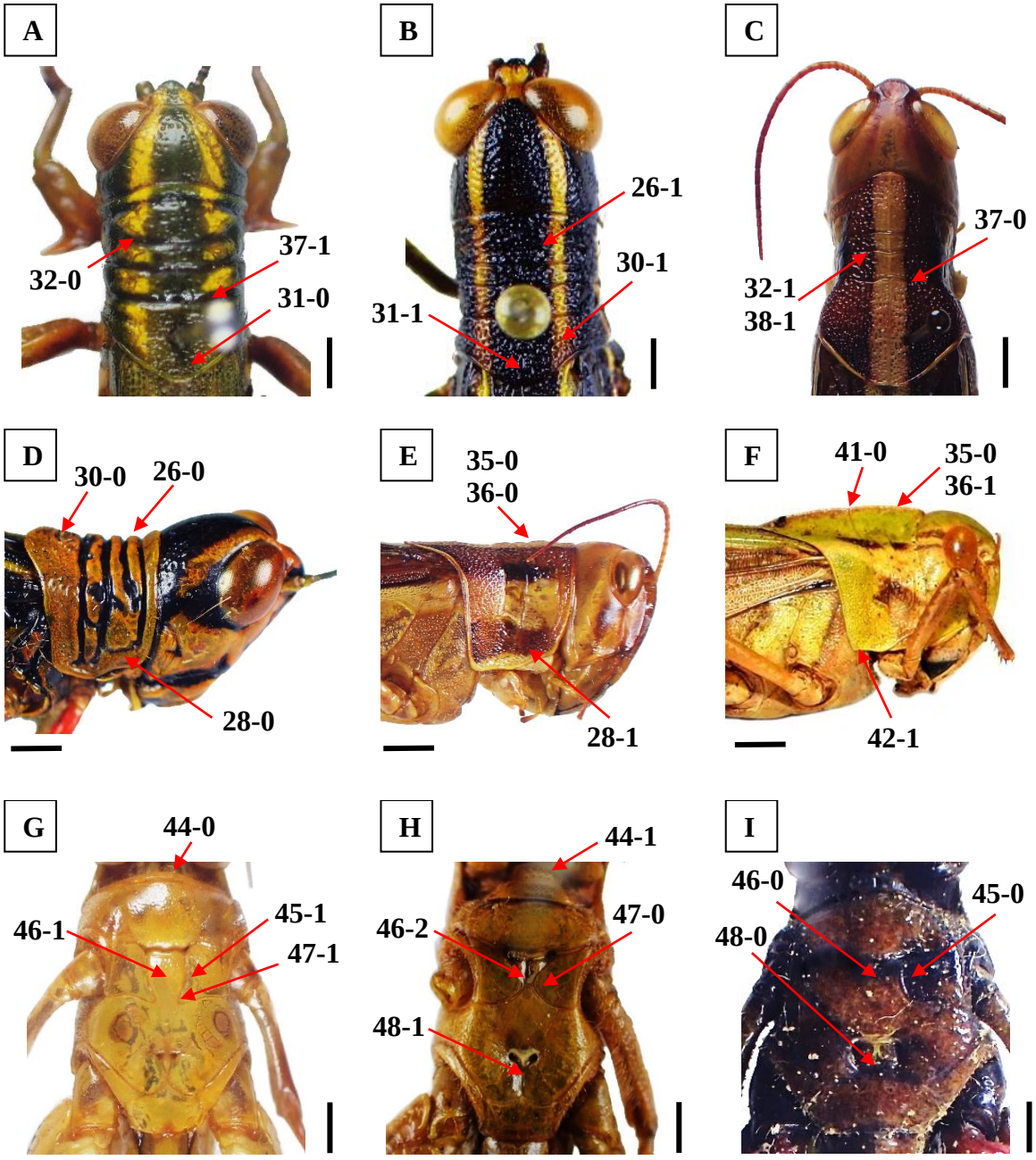


Figure 4.3: Variation of pronotal structures in Acrididae. **A.** *Craneopsis olivacea*; **B.** *Coloracris coerulescens*; **C.** *Patanga succincta*; **D.** *Meltripata* sp. 2; **E.** *P. succincta* (right lateral view); **F.** *Gastrimargus marmoratus*; **G.** *P. succincta* (ventral view); **H.** *Perakia borneesis* (ventral view); **I.** *Traulia borneensis* (ventral view). Scale = 5 mm.

as some would have 5–6 (56-0) (Figure 4.4F), 8–10 (56-1) (Figure 4.4E) or over 12 (56-2) spines. The distance between first and second spines on the inner margin of hind tibia can be observed in two different styles, either as long as any other inter-spine distance (57-0)

(Figure 4.4E) or longer than any other inter-spine distance (57-1). The shape of distal half of hind tibia in a species may also differ, as hind tibia of majority of the species would not be broaden towards apex, without obvious edges running through the spines (58-0) (Figure 4.4F), while other species such as members of subfamily Oxyinae, exhibited quite broaden distal half of hind tibia towards the apex, with distinct outer and inner edges running through the spines (58-1) (Figure 4.4E).

Male genitalia

The male phallic structures have been arguably one of the most significant structure to be used in defining the higher-level relationship between families according to Eades (2000) and Roberts (1941). The sclerotised structure of the phallus is positioned at the last sternum of the abdomen and composed of the cerci, supra-anal plate, paraproct, furcula, which can be absent in certain species, and palium that can be seen dorsally, while being covered with the subgenital plate ventrally. All species observed possessed hair tufts on the last sternum of abdomen (60-0), except for *Trilophidia annulata* (Oedipodinae). Cerci of male genitalia is a protruding structure located between the latero-proximal angles of the supra-anal plate and paraprocts. The overall shape of male cerci in profile can be observed in four different forms, such as simple rod (61-0), narrowing towards the apex (61-1), expanding and round (61-2), and quadrate (61-3). Cerci that are narrowing towards the apex can be further divided into four different forms, which are short triangular (62-0), elongated conical (62-1) (Figure 4.5B), highly elongated and strongly curved inward (62-2), and elongated and apex strongly curved downward (62-3). Additionally, apex of cerci was also observed having four distinct forms, specifically pointed (63-0) (Figure 4.5C, F), rounded (63-1), truncated (63-2) and bifurcated (63-3) (Figure 4.5E). On the other hand, curvature of

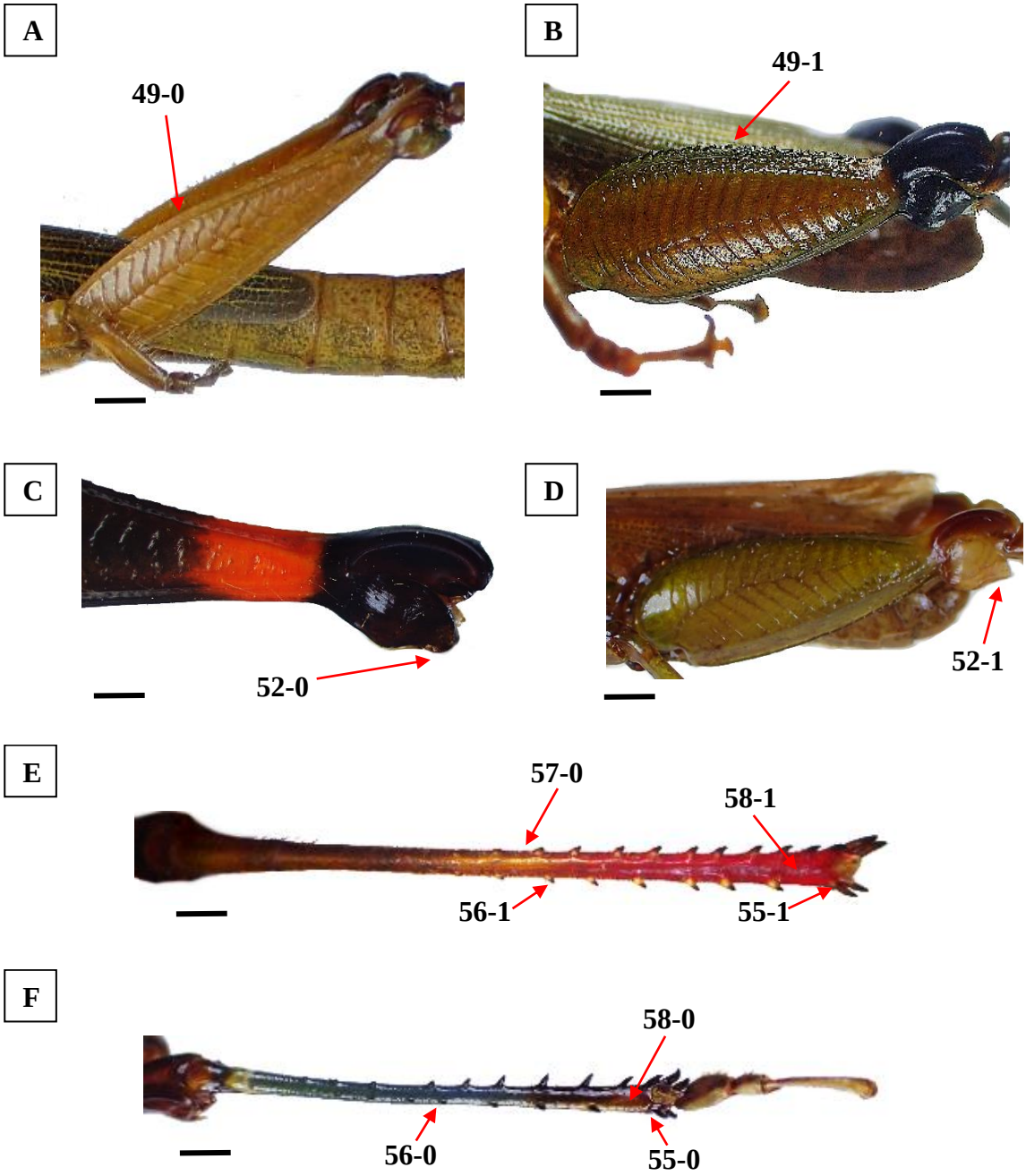


Figure 4.4: Variation of leg structures in Acrididae. **A.** *Perakia borneensis*; **B.** *Craneopsis olivacea*; **C.** *Coloracris coerulescens*; **D.** *Phalaca waterstradti*; **E.** *P. borneensis* (left dorsal view); **F.** *C. azureus* (left dorsal view). Scale = 5 mm.

the overall cerci can be either straight (64-0) (Figure 4.5C, E), curved inward posteriorly (64-1), curved upward posteriorly (64-2) (Figure 4.5D) or curved downward posteriorly (64-

3). As for the supra-anal plate, the shape separated into three forms, such as triangular (65-0) (Figure 4.5F), rectangular or trapezoid (65-1) and scutate (65-2) (Figure 4.5D). The basal field of the supra-anal plate were found to be either smooth without tubercles near lateral margins (66-0) or with two digitiform tubercles near lateral margins (66-1). Dorsally, furculae is a pair of forked median processes on the posterior margin of the 10th tergum and can be presented as absent (67-0), present and small (67-1) or present, large and long (67-2) (Figure 4.5E) in certain species. Ventrally, the apex of the subgenital plate could be divided into two lobes (68-0) or not divided at all (68-1), which was the character possessed by all members of Acrididae. Apex that is not divided would further portray three types of forms such as blunt (69-0), simple conical structure (69-1) or with lateral side expanded (69-2). The overall shape of the subgenital plate from ventral view in comparison with its width were as follows; very short, where the vertical length is equal to or less than the basal width (70-0), long, with the vertical length greater than the basal width (70-1) or strongly elongated, with the vertical length is more than twice the basal width (70-2). Viewed from above, the subgenital plate would be strongly tapering towards apex with pointed or blunted end (71-0) (Figure 4.5A), gradually tapering towards apex with rounded or concaved end (71-1) (Figure 4.5B) or not tapering, sometimes even slightly broaden with truncated end towards the apex (71-2) (Figure 4.5C). Finally, the presence of tubercle at apex of the subgenital plate can either be absent (72-0), present and short (72-1) or present and much prolonged, forming prominent pointed projection (72-2).

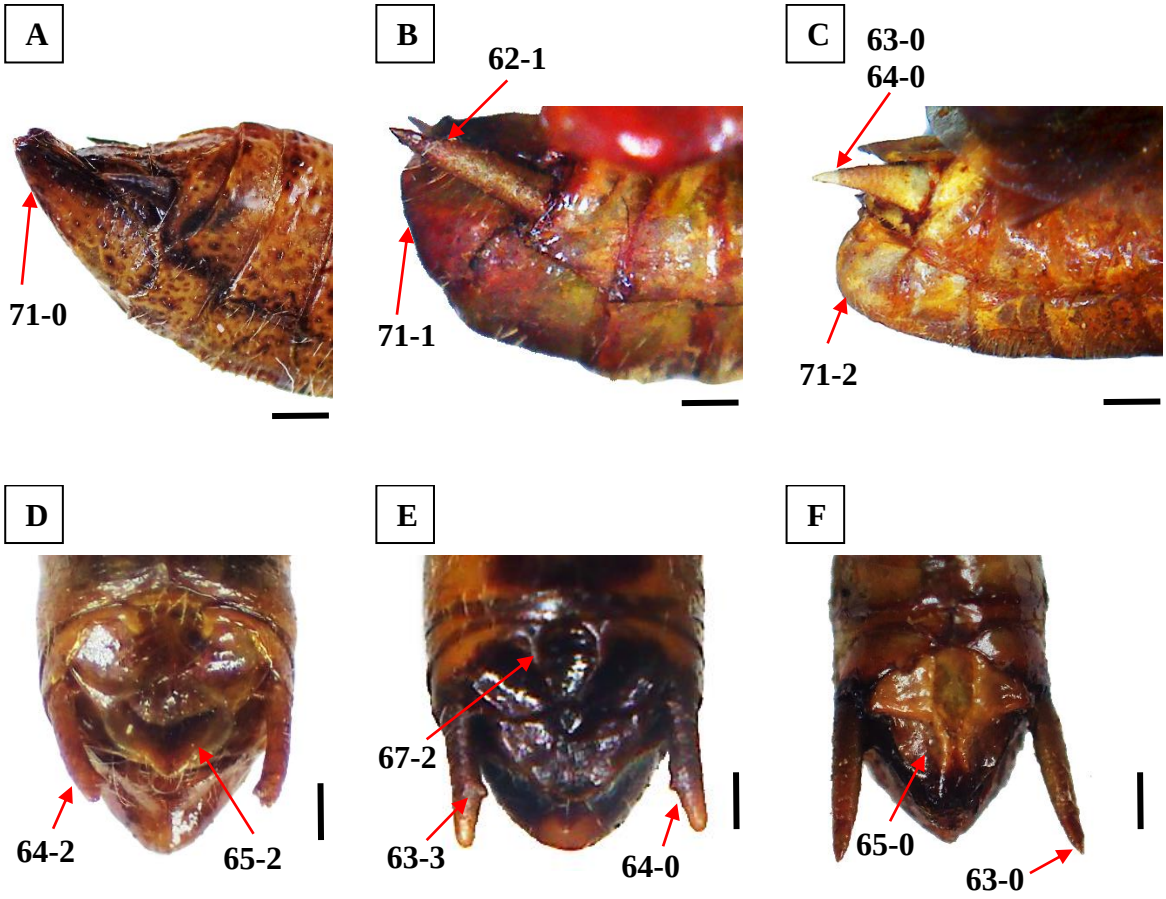


Figure 4.5: Variation of male external genital structures in Acrididae from lateral view; **A.** *Perakia borneensis*, **B.** *Meltripata* sp. 1, **C.** *Craneopsis olivacea*, and dorsal view; **D.** *Coloracris azureus*, **E.** *Coloracris* sp., **F.** *Meltripata* sp. 1. Scale = 1 mm.

Female genitalia

Female ovipositor is an extended pointed process, comprising of two pair of valves, generally known as the dorsal and ventral valves. Overall shape of the ovipositor valves from lateral view were portrayed in two general forms, either curved (73-0) (Figure 4.6A) or straight (73-1). Additionally, the relation between dorsal and ventral valves were also varied as some species would portray the same length between both valves (74-0) (Figure 4.6A) which was the case for all members of the family, while some would exhibit dorsal valve that is twice as long as the ventral valve (74-1). With regard to the dorsal valves, its shape

viewed from above could take form in two directions, either convergent (75-0) (Figure 4.6B) or divergent (75-1), and all species observed exhibited one apical tooth (76-0) (Figure 4.6B) on the apex of dorsal valves. The superior margin of the dorsal valve is highly specialised as the valve of some species would be lowly serrulate (77-0) which was prominent in all species of the family except for members of Oxyinae, serrated (77-1), prominently serrated (77-2) as seen in *Pseudoxya diminuta*, with prominent teeth on distal portion (77-3), or with prominent teeth all over the margin (77-4) as seen in *Oxya hyla intricata* and *O. japonica japonica*. Family Acrididae and its sister group, *Atractomorpha*, from family Pyrgomorphidae were observed to not exhibit any notch on apex of dorsal external margin of the dorsal valves (78-0). From the inferior view, the presence of external apical tooth on the ventral ovipositor valves were also found to be varied within species as some would have very prominent apical tooth (79-0) (Figure 4.6C) and the others would not exhibit any protuberant apical tooth (79-1) (Figure 4.6D). The width of ventral valves is also variable as some species exhibited very narrow valves (80-0), or very wide valves (80-1), while some would portray moderately wide valves (80-2). The ventral ovipositor valves are connected to the subgenital plate, where the posterior margin of the plate took shape in two forms, triangularly projected posteriorly in the middle (81-0) (Figure 4.6D) or straight or broadly rounded (81-1), while the lateral teeth on the posterior margin (82-1) can only be observed in *Aiolopus thalassinus tamulus, O. hyla intricata* and *O. japonica japonica*.

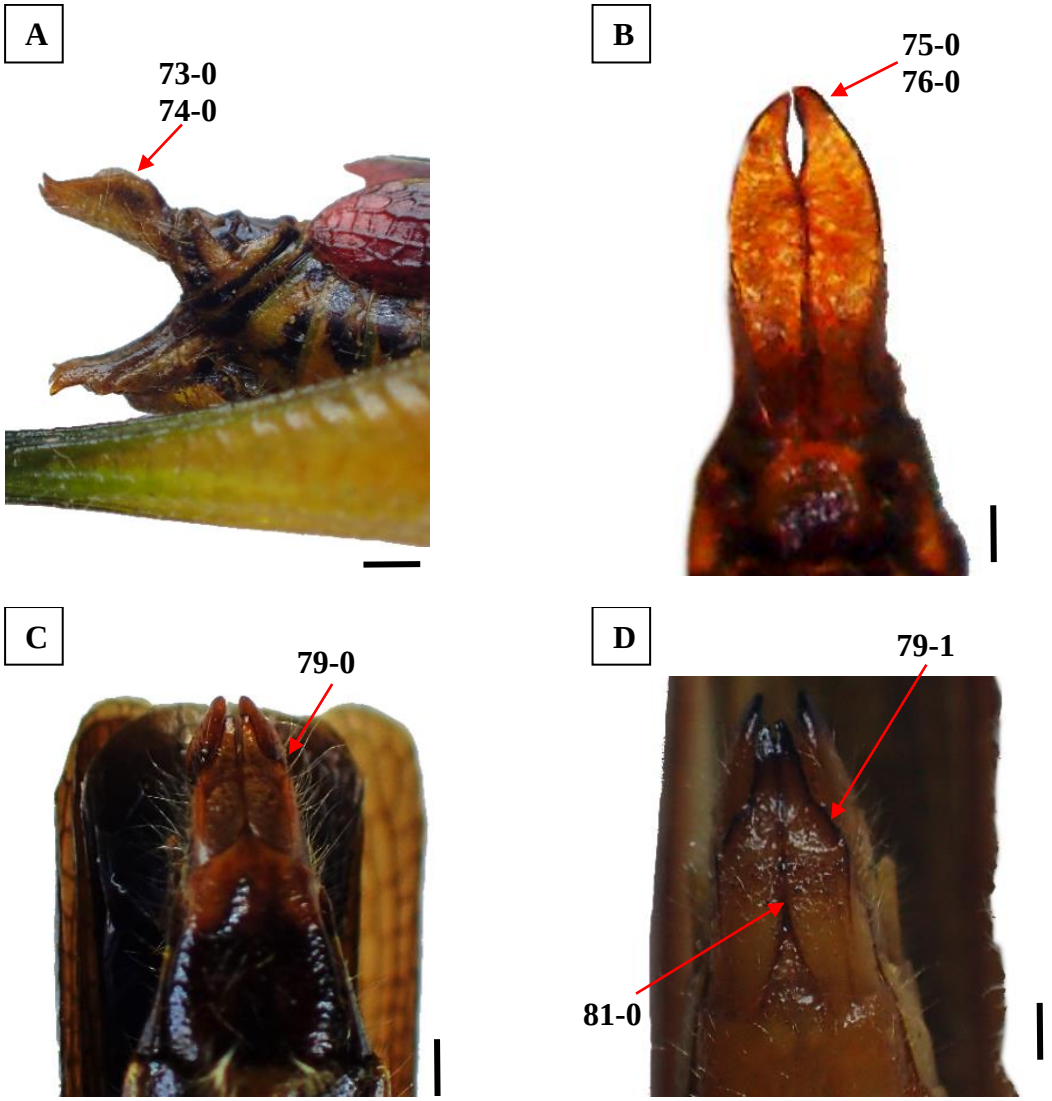


Figure 4.6: Variation of female external genitalia structures in Acrididae; **A.** *Meltripata* sp. 2 (lateral view); **B.** *Meltripata* sp. 2 (dorsal view); **C.** *Coloracris coerulescens* (ventral view) and **D.** *Patanga succincta* (ventral view). Scale = 1 mm.

4.3.2 Phylogenetic Interpretations

The analyses on 28 species of acridids including the pyrgomorphids that were chosen as the outgroups can be concluded as partially accurate according to their ranks in respective subfamilies and genus. Neighbour-joining (NJ) analysis on 100 characters resulted in 10 constant characters, 1 parsimony-uninformative character and 89 parsimony-informative characters. Tree length for the analysis yielded in 484 steps with consistency index (CI) =

0.36, retention index (RI) = 0.55 and homoplasy index (HI) = 0.64. For maximum parsimony (MP) analysis, characters were analysed using the traditional searching method software which yielded 24 most parsimonious trees with 484 state changes. Values of CI and RI were 0.36 and 0.55 respectively, similar to NJ clustering algorithms. The value of CI retrieved from the analyses may be attributed to the selection of characters used in this study that were not informative enough to yield a well-resolved relationships within members of the family.

Tree topologies for NJ (Figure 4.7) and MP (Figure 4.8) analyses deduced a monophyletic Acrididae, while paraphyly were rampant throughout the subfamilies with the exclusion of subfamily Oxyinae which was found to be monophyletic in both analyses, indicating that the subfamily is a relatively primitive group in the family as they diverged earlier than other subfamilies shown in the topology. Results from these topologies to some degree concurred with that of Liu et al. (2008), where they concluded the monophyletic grouping of Oxyinae although the position of the subfamily were not located on the basal position of the tree. According to their study which incorporated the combination of 12S rDNA and 16S rDNA sequence data, Oedipodinae were concluded to be the natural group located on the basal tree, followed by Oxyinae suggesting that Oedipodinae branches off earlier than Oxyinae. The disparities between both studies could be resulted from the lack of samples collected from the study sites or insufficient number of informative characters that were used in these analyses to indicate a good relationship between examined species.

Both analyses yielded in strong bootstrap values (BS) of 99.8% (NJ; Figure 4.7) and 99% (MP; Figure 4.8) to support the monophyletic status of family Acrididae. The analyses indicated relationship between subfamilies Acridinae, Cyrtacanthacridinae and Oxyinae that were fully resolved as they displayed monophyletic groupings with strong nodal support

exceeding 50%. Members of Oxyinae formed basal clade to other acridids supported with significant BS values (higher than 50%). However, the arrangement of a few species of Catantopinae and Oedipodinae have been scattered, causing discrepancies in the clade and instigating doubt on their topological acceptance with low nodal support.

In both analyses, the cosmopolitan subfamilies, Acridinae and Oedipodinae were positioned at the top of the clade, with members of genus *Phlaeoba* (Acridinae) recovered as sister group to *Aiolopus thalassinus tamulus* and *Heteropternis obscurella* from Oedipodinae supported with 63.7% BS values in NJ analysis. However, MP analysis recovered *A. thalassinus tamulus* and *H. obscurella* from clade A to be polytomies to sister group Acridinae with low nodal support. Nonetheless, both analyses recovered monophyletic grouping which formed a clade for both cosmopolitan subfamilies characterised by the synapomorphic traits which were the absence of prosternal process, non-prominent eyes and females with straight or broadly rounded posterior margin of subgenital plate in ventral view. On the other hand, low BS values representing the clade may be justified by the presence of *Apalacris varicornis* (Catantopinae) which possessed prosternal process, that were recovered on the basal node of the subclade in MP analysis. From the analyses, *Gastrimargus marmoratus* and *Locusta migratoria manilensis* from Oedipodinae were resolved as sister species with strong nodal support sharing synapomorphic characters such as male with straight cerci, external apical tooth on ventral ovipositor valves of female genitalia is not prominent and lacking lateral teeth on posterior margin of female subgenital plate. *Gastrimargus marmoratus* and *L. migratoria manilensis* represented the typical oedipodine species known as banded-winged grasshoppers with hind wings that are normally banded or brightly coloured with yellow or orange hues, overlapped with black or smoky bands nearing the basal margin of hind wings, in comparison with other oedipodines

represented in this study (Song et al., 2018). *Phlaeoba antennata* and *P. infumata* were also recovered as sister species with apomorphic characters of frontal ridge of head elongate below frontal ocellus, dorsum of prozona with irregularly wrinkled ridges, lateral lobe of prozona distinctly wrinkled, mesosternal interspace wide and upper carina of hind femora serrated, which exclude these acridines from other oedipodines on the clade in NJ clustering analysis. Synapomorphic traits defining this clade includes dorsum of metazona with distinctly thickened ridges, lacking additional incisions of median carina of pronotum by minor transverse carina and mesosternal lobe laterally wider than its vertical length.

The relationship between the rest of the Old World subfamily Catantopinae remained unsolved as *Stenocatantops splendens* (Catantopinae) formed a clade with Cyrtacanthacridinae in both analyses, while *Xenocatantops humilis* branched out of the clade without forming any clade in MP analysis. The rest of the subfamilies were recovered to be monophyletic albeit without strong nodal support. Paraphyly within members of Catantopinae was predicted due to taxonomic incongruity that was debated for so long by researchers where they taxonomically placed any Old World acridids with prosternal process that were dissimilar and incongruous to other subfamilies into Catantopinae (Xu et al., 2021), thus yielding unresolved clades that needed further revision. Both analyses were unsuccessful in recovering good nodal support to resolve the relationship between members of Catantopinae. However, a clade with significant nodal support were recovered from MP analysis holding *Craneopsis olivacea* and *Perakia borneensis* in one clade characterised by synapomorphic traits such as the absence of transverse groove at the base of fastigium and filiform-shaped antennae. Genus *Craneopsis* was found to be endemic in Borneo (Tan & Wahab, 2018), while Bornean species of *Perakia* were reported to possibly be congeneric from other species from said genus due to incongruity in taxonomic descriptions by Sir

Willemse and Sir Ramme (Rehn, 1944). Thus, the resolved clade might provide insights on relationships within Bornean species. As the scantiness of literature records and shortage of functional data in East Malaysia are part of the research gap in this study, further revision is much needed to prove the theory.

The relationship within bird-grasshopper subfamily Cyrtacanthacridinae were resolved with strong nodal support even though *S. splendens* was included in Clade C as presented in both analyses, suggesting a probable relationship between subfamilies Catantopinae and Cyrtacanthacridinae as implied by Song and Wenzel (2007). On the other hand, monophyletic grouping of this subfamily from both analyses was also strongly supported by Song and Wenzel (2007) in their analysis using morphology to prove the evolution of phase polyphenism caused by physiological mechanisms which was the density-dependent colour plasticity that was plesiomorphic for the subfamily. The cyrtacanthacridines are represented by a group of the largest grasshoppers in this study that are well defined by characters such as vertically longer mesosternal lobe than its lateral width, mesosternal interspace elongated, coarse and distinctly sculpted pronotum, and male cerci narrowing towards the apex, which suggest a common ancestry. From this study, *Patanga* was also recovered as sister group represented by *P. luteicornis* and *P. succincta,* which shares synapomorphic traits of antennae length that is longer than the combined length of head and pronotum, male cerci that is elongated with apex strongly curved downwards, apex of male cerci rounded, and male supra-anal plate scutiform.

Subfamily Oxyinae were the first to branch off from the clade in both analyses forming monophyletic group with strong nodal support and resulted in a well-resolved grouping of genus *Oxya* known as the rice grasshoppers, as presented in Clade D.

Monophyly of the group were supported by synapomorphic characters such as presence of outer apical spine on hind tibia, exceedingly short male subgenital plate and extremely narrow ventral ovipositor valves of female genitalia. *Oxya hyla intricata* and *O. japonica japonica* were recovered as sister group with strong nodal support owing to several synapomorphy which includes frontal ridge of head elongated below frontal ocellus, dorsum of metazona with ridges forming numerous small pits, apex of male subgenital plates not divided into two, dorsal ovipositor valves of female genitalia with one apical tooth and posterior margin of female subgenital plate straight or broadly rounded. The monophyly of Oxyinae in this study conflicted with that of Song et al. (2018) as they recovered Oxyinae to be a non-natural group closely related to Hemiacridinae and the New World Melanoplinae, with support of brachyptery as the mutual characters defining the clade.

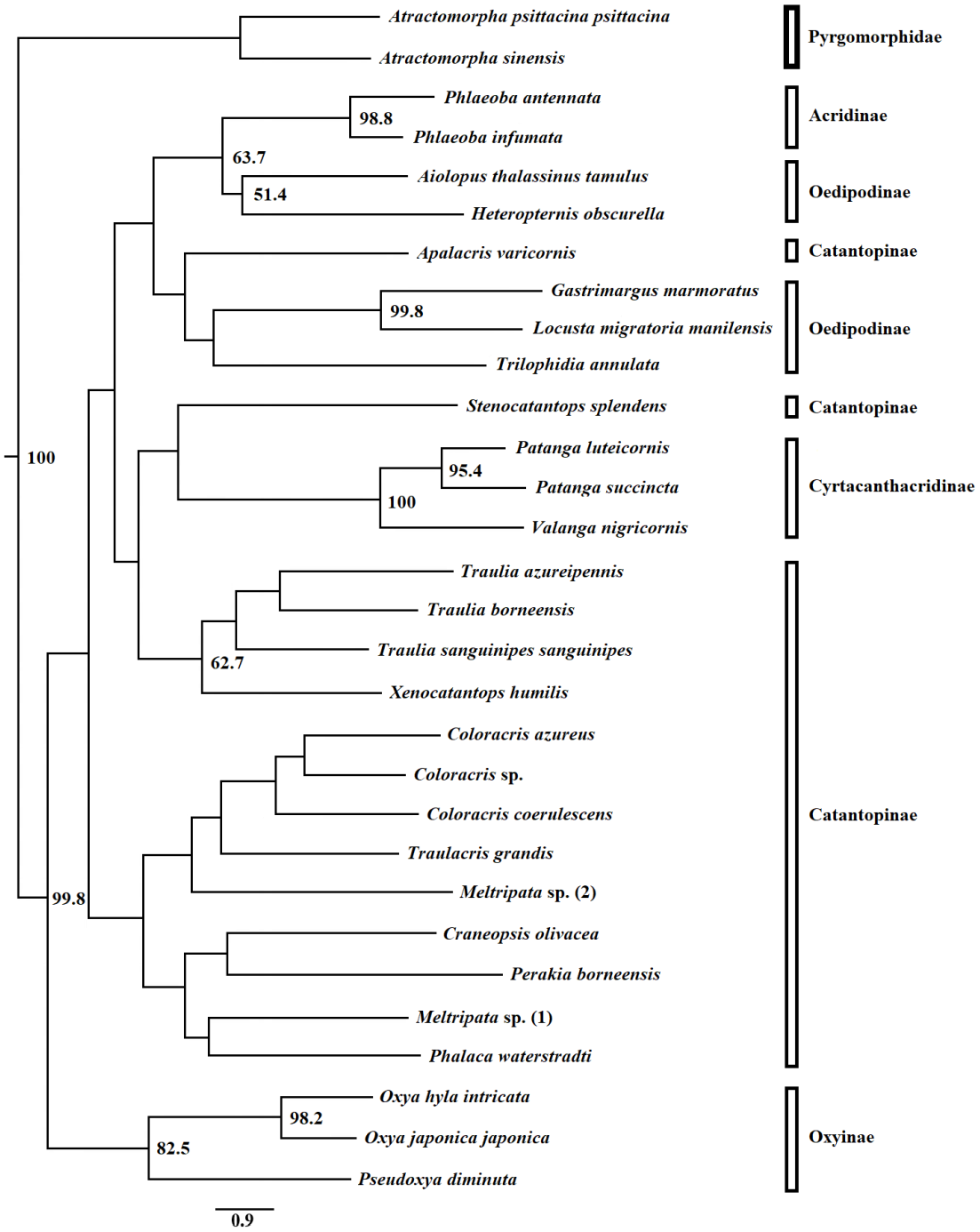


Figure 4.7: Topology of Acrididae based on neighbour-joining analysis with bootstrapping measure of 1,000 replicates. Branch numbers indicates bootstrap values. Only bootstrap values of more than 50% were shown on the branch.

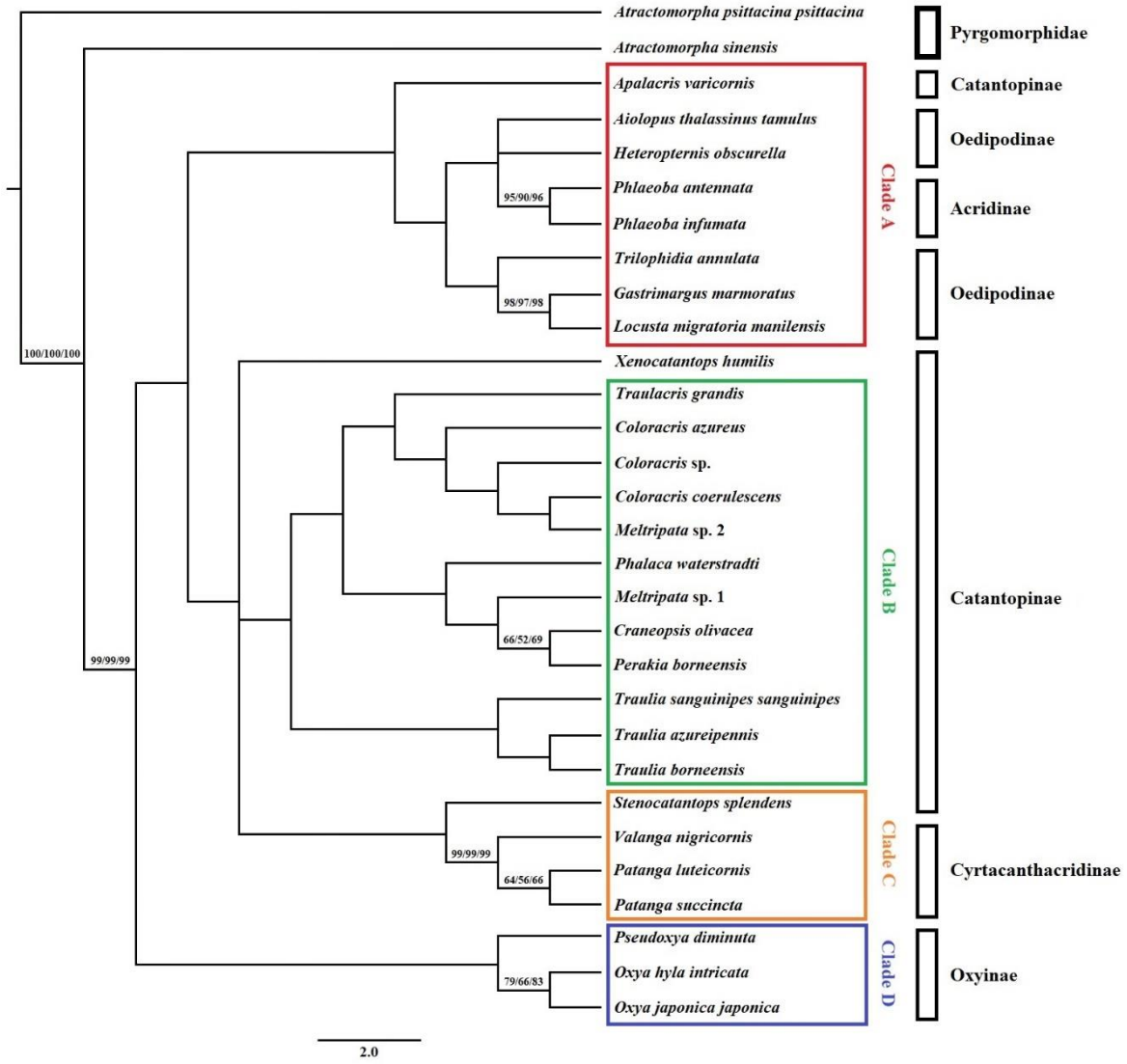


Figure 4.8: Consensus tree of 24 most parsimonious trees of 28 species of Acrididae including the outgroup representatives of Pyrgomorphidae based on 100 morphological structures according to TNT (length = 484; consistency index = 0.36; retention index = 0.55). Number above branches (x/y/z) represents symmetric resampling, standard bootstrap and jacknifing respectively. Only bootstrap values of more than 50% were shown on the branch.

4.4 Chapter Summary

Phylogenetic analysis on 28 ingroup species of Acrididae including two outgroup species of genus Atractomorpha, family Pyrgomorphidae, based on 100 morphological characters using Tree Analysis Using New Technology (TNT) and Phylogenetic Analysis

using Parsimony (*and Other Methods) (PAUP) were successfully constructed. The result of this study supported the monophyly of Acrididae, polyphyly of Oedipodinae and Catantopinae, and monophyly of Acridinae, Cyracanthacridinae and Oxyinae. Even so, bigger taxa sampling and vast set of informative morphological data are required to resolve the phylogenetic status of problematic subfamilies as resulted within Catantopinae and Oedipodinae.

CHAPTER 5

CONCLUSION AND RECOMMENDATIONS

5.1 Conclusion

In a nutshell, a total of five subfamilies, 20 genera and 28 species were successfully recorded in Malaysian Borneo, with no documentation of new species. This thesis provided the phylogeny of Acrididae based on sampled taxa represented by species collected from Malaysian Borneo region using Phylogenetic Analysis Using Parsimony (*and Other Methods) (PAUP) and Tree Analysis Using New Technology (TNT). The analysis included 28 ingroups and two outgroups (Pyrgomorphidae: Pyrgomorphinae: *Atractomorpha psittacina psittacina* and *Atractomorpha sinensis*) based on 100 morphological characters. Results from the analysis concluded the monophyly of Acrididae that was strongly supported with Pyrgomorphidae as the outgroup. The analysis presented the paraphyly of Acridinae, Catantopinae, Cyrtacanthacridinae and Oedipodinae, while Oxyinae was revealed to be monophyletic nesting in the basal position of the clade.

Additionally, systematics descriptions for 28 species of acridids, including redescriptions on selected genera and key to distinguishing between subfamilies of Acrididae were also provided. Redescriptions made were based on the availability of the specimens assessed, as a few species were represented by a singleton. Distribution records based on geological information provided by voucher specimens were illustrated using Quantum Geographic Information System (QGIS) and habitus photographs of the species were presented to give visual representations on the descriptions provided.

5.2 Recommendations

The future approaches to the study of Acrididae would call for the increase in taxon sampling from Malaysian Borneo region, including species represented by the Federal Territory of Labuan as it is part of East Malaysia. Knowledge on the family recorded from Labuan is lacking, unsurprisingly, as it is scanty in the states of Sabah and Sarawak as well. In addition, further examination on specimens represented by the state of Sabah is also required as there are no proper records and documentation on the family available to be used as references.

From the result of this study, the phylogeny of Acrididae has been limited due to the availability of male and female specimens of a few species, such as *Coloracris azureus*, *Craneopsis olivacea*, *Perakia borneensis* and *Phalaca waterstradti* to name a few, which prevented the examination of the external genitalic structures that would provide information on the analysis. Plus, future test should also include the examination of internal genitalic characters that was not achieved in this study, as the inclusion of more intrinsic characters would provide higher discriminating values to distinguish between species in a phylogeny analysis. From this study, the low statistical values resulted from the phylogenetic analyses could be resolved by adding more informative characters and utilising statistical analyses such as principal component analysis (PCA) and discriminant function analysis (DFA) to attain useful and informative characters to be included in the phylogenetic analyses.

Apart from that, it is highly recommended that the direction of this study is shifted to the inclusion of genomic data as more significant information would be unveiled, such as the diversification and evolution of certain traits and characters in a species. In addition, to further examine the minuscule structure of the specimens for morphological analysis, the

use of conventional light microscope, scanning electron microscope (SEM) and photomicrograph microscope could be utilised for elucidation of external surface structures. Furthermore, Wipfler et al. (2016) suggested the use of micro-computed tomography (Micro-CT) and computer-based 3D reconstructions to be incorporated in studies for analysis on interior structure without having to damage any of the specimens, thus leading to the acquisition of a higher quality phylogenetic data based on a much detailed morphological information.

REFERENCES

Adu-Acheampong, S., & Samways, M. J. (2019). Feeding and mobility traits influence grasshopper vulnerability to agricultural production in the Cape Floristic Region biodiversity hotspot. *Neotropical Entomology*, *48*(6), 992–1000. https://doi.org/10.1007/s13744-019-00697-2

Aharoni, I. (1938). On some animals mentioned in the Bible. *Osiris*, *5*, 461–478. https://doi.org/10.1086/368494

Ali, S., & Panhwar, W. A. (2017). A checklist of Acrididae (Orthoptera) of Hazara Division Khyber Pakhtunkhwa Pakistan. *Journal of Entomology and Zoology Studies*, *5*(5), 96–100.

Almeida, A. V., & Câmara, C. A. G. (2008). Distribution of grasshoppers (Othoptera: Acridoidea) in the Tapacurá ecological station (São Lourenço da Mata, PE/Brazil). *Brazilian Journal of Biology*, *68*(1), 21–24. https://doi.org/10.1590/S1519-69842008000100004

Anankware, P. J., Fening, K. O., Osekre, E., & Obeng-Ofori, D. (2015). Insects as food and feed: A review. *International Journal of Agricultural Research and Review*, *3*(1), 2360–7971.

Andersen, A. N., Ludwig, J. A., Lowe, L. M., & Rentz, D. C. F. (2001). Grasshopper biodiversity and bioindicators in Australian tropical savannas: Responses to disturbance in Kakadu National Park. *Austral Ecology*, *26*(3), 213–222. https://doi.org/10.1046/j.1442-9993.2001.01106.x

Arya, M. K., Joshi, P. C., & Badoni, V. P. (2015). Studies on taxonomy, distribution, ecology and behaviour of grasshoppers (Insecta: Orthoptera) in Nanda Devi Biosphere Reserve,

Western Himalayas, India. *Biological Forum - An International Journal*, *7*(2), 591–598.

Ball, E. D., Tinkham, E. R., Flock, R., & Vorhies, C. T. (1942). *The grasshoppers and other Orthoptera of Arizona* (Vol. 93). College of Agriculture, University of Arizona. http://hdl.handle.net/10150/190516

Bazelet, C. S., & Samways, M. J. (2014). Habitat quality of grassland fragments affects dispersal ability of a mobile grasshopper, *Ornithacris cyanea* (Orthoptera: Acrididae). *African Entomology*, *22*(4), 714–725. https://doi.org/10.4001/003.022.0405

Bei-Bienko, G. Y., & Mishchenko, L. L. (1963). *Locusts and grasshoppers of the U.S.S.R. and adjacent countries (Part I)*. Translated from Russian. Israel Program for Scientific Translations Ltd.

Bei-Bienko, G. Y., & Mishchenko, L. L. (1964). *Locusts and grasshoppers of the U.S.S.R. and adjacent countries (Part II)*. Translated from Russian. Israel Program for Scientific Translations Ltd.

Belayneh, Y. T. (2001). *Emergency transboundary outbreak pest management in Africa and Asia*. United States Department of Agriculture.

Belovsky, G. E., & Slade, J. B. (1993). The role of vertebrate and invertebrate predators in a grasshopper community. *Oikos*, *68*(2), 193–201. https://doi.org/10.2307/3544830

Belovsky, G. E., & Slade, J. B. (2000). Insect herbivory accelerates nutrient cycling and increases plant production. *Proceedings of the National Academy of Sciences of the United States of America*, *97*(26), 14412–14417. https://doi.org/10.1073/pnas.250483797

Belovsky, G. E., & Slade, J. B. (2002). An ecosystem perspective on grasshopper control: Possible advantages to no treatment. *Journal of Orthoptera Research*, *11*(1), 29–35.

https://doi.org/10.1665/1082-6467(2002)011[0029:aepogc]2.0.co;2

Blanchard, E. (1853). Description des insectes - Famille des Acrididés (Acrididae). In *Voyage au Pole Sud et dans L'oceanie* (pp. 366–376). Gide et J. Baudry.

Bock, W. J. (1969). Comparative morphology in systematics. *Systematic Biology: Proceedings of an International Conference*, 411–458. https://doi.org/10.17226/21293

Bolivar, C. (1917). Estudio monográfico de la sección: "*Trauliae*" (Orthoptera, Locustinae). *Revista de La Real Academia de Ciencias Exactas, Fisicas y Naturales de Madrid*, *15*(10), 605–644.

Bolivar, I. (1895). Mission scientifique de M. Ch. Alluaud aux îles Séchelles - Orthoptères. In *Annales de la Société Entomologique de France: Vol. LXIV* (pp. 361–386). Au Siège de la Société.

Bolivar, I. (1898). Contributions à l'étude des Acridiens. Espèces de la faune Indo- et Austro-Malaisienne du Museo Civico di Storia Naturale di Genova. In *Annali del Museo Civico di Storia Naturale di Genova* (Vol. 19, Issue 2, pp. 66–101). Tipografia del R. Istituto Sordo-Muti.

Bolivar, I. (1902). Les Orthoptères de St-Joseph's college à Trichinopoly (Sud de l'Inde). In *Annales de la Société Entomologique de France* (pp. 580–633). Au Siège de la Société.

Bolivar, I. (1918a). Contribucion al conocimiento de la fauna Indica Orthoptera (Locustidae vel. Acridiidae). In *Revista de la Real Academia de Ciencias Exactas, Fisicas y Naturales de Madrid* (pp. 374–412). Imprenta Clásica Española. http://library1.nida.ac.th/termpaper6/sd/2554/19755.pdf

Bolivar, I. (1918b). La sección *Oxyae* (Orth. Acrididae). In *Trabajos del Museo Nacional de Ciencias Naturales* (Vol. 34, pp. 1–43). Imprenta Clásica Española.

Bragg, J. H. (1939). The geographic distribution of Acrididae in Northern Oklahoma. *The*

American Midland Naturalist, *22*(3), 660–675. https://doi.org/10.2307/2420344

Britannica. (2019). *Borneo - History* . https://www.britannica.com/place/Borneo-island-Pacific-Ocean/History

British Entomological & Natural History Society. (2020). *Specimen curation*. https://www.benhs.org.uk/resources/collecting/specimen-curation/

Bruner, L. (1915). II.-Preliminary catalogue of the orthopteroid insects of the Philippine Islands. In *The University Studies of the University of Nebraska* (pp. 195–282). The New Era Printing Company.

Brunner, C. von W. (1878). *Monographie der Phaneropteriden*. Kaiserlich-Königlichen Zoologisch-Botanischen Gesellschaft.

Brunner, C. von W. (1882). *Prodromus der Europäischen Orthopteren*. W. Engelmann.

Brunner, C. von W. (1893). *Révision du système des orthoptères et description des espèces rapportées*. Tipografia del R. Istituto Sordo-Muti.

Brunner, C. von W. (1898). Orthopteren des Malayischen Archipels. In *Abhandlungen Herausgegeben von der Senckenbergischen Naturforschenden Gesellschaft*. Frankfurt Am Main.

Burmeister, H. (1838). *Handbuch der Entomologie*. G. Reimer.

Burr, M. (1903). Orthoptera. In *The Fauna and Geography of the Maldive and Laccadive Archipelagoes* (Vol. 1, Issue 3, pp. 234–236). C. J. Clay and Sons.

Capinera, J. L., & Sechrist, T. S. (1982). *Grasshoppers (Acrididae) of Colorado - Identification, biology and management*. Colorado State University.

Chai, J. H. L. (2007). *Systematics and distributions of the family Acrididae (Orthoptera) in Sarawak*. Universiti Malaysia Sarawak.

Chapco, W. (2013). A note on the molecular phylogeny of a small sample of catantopine

grasshoppers. *Journal of Orthoptera Research*, *22*(1), 15–20. https://doi.org/10.1665/034.022.0103

Chapco, W., & Contreras, D. (2011). Subfamilies Acridinae, Gomphocerinae and Oedipodinae are "fuzzy sets": A proposal for a common African origin. *Journal of Orthoptera Research*, *20*(2), 173–190. https://doi.org/10.1665/034.020.0205

Chapman, R. F. (2013). *The insects structure and function* (S. J. Simpson & A. E. Douglas (eds.); 5th ed.). Cambridge University Press. https://doi.org/10.1017/cbo9781139035460.025

Choate, P. M., & Frank, J. H. (2008). Collecting and preserving insects. In *Encyclopedia of Entomology* (pp. 1000–1008). Springer. https://doi.org/10.1093/jee/47.1.192

Chung, A. Y. C. (2010). Edible insects and entomophagy in Borneo. *Edible Forest Insects: Humans Bite Back*, 141–150.

Chung, A. Y. C., Japir, R., & Tan, M. K. (2021, February). Crickets and grasshoppers of Sabah. *Sabah Forestry Department*. https://doi.org/10.13140/RG.2.2.23585.74084

Chung, A. Y. C., Khen, C. V., Unchi, S., & Binti, M. (2002). Edible insects and entomophagy in Sabah, Malaysia. *Malayan Nature Journal*, *56*(2), 131–144.

Chung, A. Y. C., & Majapun, R. (2013). *Insect diversity of Malua Forest Reserve, Sabah*. https://forest.sabah.gov.my/usm/PDF/2013/Insect%20Diversity%20of%20Malua%20Forest%20Reserve,%20Sabah_Y%20C%20Chung%20et%20al%202013.pdf

Chung, A. Y. C., & Tangah, J. (2015). *Insect diversity of Sg. ISME, Sandakan, Sabah*. https://www.researchgate.net/publication/328913332_Insect_diversity_of_Sg_ISME_Sandakan_Sabah

Cigliano, M. M., & Amedegnato, C. (2010). The high-Andean *Jivarus* Giglio-Tos (Orthoptera, Acridoidea, Melanoplinae): Systematics, phylogenetic and biogeographic

considerations. *Systematic Entomology*, *35*(4), 692–721. https://doi.org/10.1111/j.1365-3113.2010.00538.x

Cigliano, M. M., Braun, H., Eades, D. C., & Otte, D. (2021). *Orthoptera Species File*. http://orthoptera.speciesfile.org/

Cigliano, M. M., & Otte, D. (2003). Revision of the *Dichroplus Maculipennis* species group (Orthoptera, Acridoidea, Melanoplinae). *Transactions of the American Entomological Society*, *129*(1), 133–162.

Cigliano, M. M., Pocco, M. E., & Lange, C. E. (2011). Grasshoppers of the Andes: New Melanoplinae and Gomphocerinae taxa (Insecta, Orthoptera, Acrididae) from Huascarán National Park and Callejón de Huaylas, Ancash, Peru. *Zoosystema*, *33*(4), 523–544. https://doi.org/10.5252/z2011n4a5

Cigliano, M. M., Ronderos, R. A., & Kemp, W. P. (1996). Phylogenetic relationships of *Scotussa* and *Leiotettix* (Orthoptera: Acrididae). *Cladistics*, *12*, 125–138.

Cisneiros, R. A., Almeida, A. V. de, Melo, G. R. de, & Câmara, C. A. G. da. (2012). Morphometric variations in the grasshopper, *Chromacris speciosa* from two localities of Pernambuco in northeastern Brazil. *Journal of Insect Science*, *12*(79), 1–10. https://doi.org/10.1673/031.012.7901

Colombo, P., Cigliano, M. M., Sequeira, A. S., Lange, C. E., Vilardi, J. C., & Confalonieri, V. A. (2005). Phylogenetic relationships in *Dichroplus* Stål (Orthoptera: Acrididae: Melanoplinae) inferred from molecular and morphological data: Testing karyotype diversification. *Cladistics*, *21*(4), 375–389. https://doi.org/10.1111/j.1096-0031.2005.00068.x

COPR. (1982). *The locust and grasshopper agricultural manual*. Centre for Overseas Pest Research. https://doi.org/10.2307/2403066

Cullen, D. A., Cease, A. J., Latchininsky, A. V., Ayali, A., Berry, K., Buhl, J., De Keyser, R., Foquet, B., Hadrich, J. C., Matheson, T., Ott, S. R., Poot-Pech, M. A., Robinson, B. E., Smith, J. M., Song, H., Sword, G. A., Vanden Broeck, J., Verdonck, R., Verlinden, H., & Rogers, S. M. (2017). From molecules to management: Mechanisms and consequences of locust phase polyphenism. *Advances in Insect Physiology*, *53*, 167–285. https://doi.org/10.1016/bs.aiip.2017.06.002

Cunningham, C. L., & Sampson, M. W. (1996). *Grasshopper integrated pest management user handbook* (Vol. 1809, pg. 1996–2000). United States Department of Agriculture.

Dadd, R. H. (1963). Feeding behaviour and nutrition in grasshoppers and locusts. *Advances in Insect Physiology*, *1*, 47–109. https://doi.org/10.1016/S0065-2806(08)60174-5

Dammerman, K. W. (1929). *The agricultural zoology of the Malay Archipelago: The animals injurious and beneficial to agriculture, horticulture and forestry in the Malay Peninsula, the Dutch East Indies and the Philippines*. J. H. de Bussy Ltd.

David, A., & Gautam, A. (2021). Cenozoic Era. *Encyclopedia of Animal Cognition and Behavior*, *March*, 1-15. https://doi.org/10.1007/978-3-319-47829-6

Dirsh, V. M. (1956). Some new and little known South African Acridoidea (Orthoptera). *Journal of the Entomological Society of Southern Africa*, *19*(2), 250–288. http://content.ajarchive.org/cgi-bin/showfile.exe?CISOROOT=/0012-8789&CISOPTR=1629

Dirsh, V. M. (1963). The Acridoidea (Orthoptera) of Madagascar - II. Acrididae, Acridinae. *Bulletin of the British Museum (Natural History) Entomology*, *13*(8), 243–286.

Dirsh, V. M., & Uvarov, B. P. (1953). Preliminary diagnoses of new genera and new synonymy in Acrididae. *Tijdschrift Voor Entomologie*, *96*(3), 231–237.

Dring, D. M. (1972). Pests of rice. In *Kew Bulletin* (Vol. 26, Issue 2). London & Harlow,

Longman. https://doi.org/10.2307/4117748

Eades, D. C. (2000). Evolutionary relationships of phallic structures of Acridomorpha (Orthoptera). *Journal of Orthoptera Research*, *9*(9), 181–210. https://doi.org/10.2307/3503648

Eades, D. C. (2001). Version 2 of the Orthoptera Species File online. *Journal of Orthoptera Research*, *10*(2), 153–163. https://doi.org/10.1665/1082-6467(2001)010[0153:VOTOSF]2.0.CO;2

El-Mallakh, O. S., & El-Mallakh, R. S. (1994). Insects of the Qur'an. *American Entomologist*, *40*(2), 82–84. https://doi.org/10.1093/ae/40.2.82

Fabricius, J. C. (1775). *Systema entomologiae, sistens insectorum: Classes, ordines, genera, species, adiectis synonymis, locis, descriptionibus, observationibus*. Officina Libraria Kortii. https://doi.org/10.5962/bhl.title.36510

Fabricius, J. C. (1798). *Supplementum entomologiae systematicae*. C. G. Proft et Storch.

FAO. (2020). Statistical data on forested and conservation areas in. *Sahabat Alam Malaysia (SAM)*, 1–20.

Farah Nabillah, A. H. A. F., Hazali, R., Abang, F., Ahmad Irfan, A. R., & Sazali, S. N. (2020). Checklist of the family Acrididae MacLeay, 1821 (Orthoptera) based on voucher specimens of major repositories in Sarawak. *Serangga*, *25*(2), 56–62.

Fartmann, T., Krämer, B., Stelzner, F., & Poniatowski, D. (2012). Orthoptera as ecological indicators for succession in steppe grassland. *Ecological Indicators*, *20*, 337–344. https://doi.org/10.1016/j.ecolind.2012.03.002

Ferret, M., & Galinier, J. G. (1847). *Voyage en Abyssinie dans les Provinces du Tigre, du Samen et de l'ahmara*. Paulin, Libraire-Editeur.

Figueirêdo, R. E. C. R. de, Vasconcellos, A., Policarpo, I. S., & Alves, R. R. N. (2015).

Edible and medicinal termites: A global overview. *Journal of Ethnobiology and Ethnomedicine*, *11*(29), 1–7. https://doi.org/10.1186/s13002-015-0016-4

Flook, P. K., & Rowell, C. H. F. (1997). The phylogeny of the Caelifera (Insecta, Orthoptera) as deduced from mtrRNA gene sequences. *Molecular Phylogenetics and Evolution*, *8*(1), 89–103. https://doi.org/10.1006/mpev.1997.0412

Flook, P. K., & Rowell, C. H. F. (1998). Inferences about orthopteroid phylogeny and molecular evolution from small subunit nuclear ribosomal DNA sequences. *Insect Molecular Biology*, *7*(2), 163–178. https://doi.org/10.1046/j.1365-2583.1998.72060.x

Forest Department Sarawak. (2021). *Facts and figures*. https://forestry.sarawak.gov.my/page-0-461-1170-FACTS-FIGURES.html

Fox, J. E. D. (1972). *The natural vegetation of Sabah and natural regeneration of the dipterocarp forests*. University of Wales.

Franzke, A., Unsicker, S. B., Specht, J., Köhler, G., & Weisser, W. W. (2010). Being a generalist herbivore in a diverse world: How do diets from different grasslands influence food plant selection and fitness of the grasshopper *Chorthippus parallelus*? *Ecological Entomology*, *35*(2), 126–138. https://doi.org/10.1111/j.1365-2311.2009.01168.x

Fumy, F., Löffler, F., Samways, M. J., & Fartmann, T. (2020). Response of Orthoptera assemblages to environmental change in a low-mountain range differs among grassland types. *Journal of Environmental Management*, *256*, 1–8. https://doi.org/10.1016/j.jenvman.2019.109919

Gandar, M. V. (1982). The dynamics and trophic ecology of grasshoppers (Acridoidea) in a South African savanna. *Oecologia*, *54*(3), 370–378. https://doi.org/10.1007/BF00380006

García-Navas, V., Noguerales, V., Cordero, P. J., & Ortego, J. (2017). Phenotypic disparity in Iberian short-horned grasshoppers (Acrididae): The role of ecology and phylogeny. *BMC Evolutionary Biology*, *17*(1), 1–14. https://doi.org/10.1186/s12862-017-0954-7

Gardiner, T. (2018). Grazing and Orthoptera: A review. *Journal of Orthoptera Research*, *27*(1), 3–11. https://doi.org/10.3897/jor.27.26327

Geoffroy, É. L. (1762). *Histoire abregée des insectes qui se trouvent aux environs de Paris*. Laurent Durand. https://doi.org/10.5962/bhl.title.14710

Goloboff, P. A., & Catalano, S. A. (2016). TNT version 1.5, including a full implementation of phylogenetic morphometrics. *Cladistics*, *32*(3), 221–238. https://doi.org/10.1111/cla.12160

Goloboff, P. A., Farris, J. S., & Nixon, K. C. (2008). TNT, a free program for phylogenetic analysis. *Cladistics*, *24*(5), 774–786. https://doi.org/10.1111/j.1096-0031.2008.00217.x

Gullan, P. J., & Cranston, P. S. (2010). *The insects: An outline of entomology* (4th ed.). Wiley-Blackwell. https://doi.org/10.1007/978-94-009-5857-9

Hamid, A. A. (1987). *Insect pests of Acacia mangium Willd. in Sarawak*.

Hamid, N. H., Mahzan Awang, M., Razaq Ahmad, A., Ab Ghani, S., & Lulong Linang, C. (2021). Education for rural community: Utilisation of social media among multi-ethnic students in Malaysian Borneo. *Psychology and Education*, *58*(2), 2122–2127. http://psychologyandeducation.net/pae/index.php/pae/article/view/2379

Han, K. J., & Chew, P. S. (1978). Control measures and observations in some *Valanga nigricornis* outbreaks in oil palms in Peninsular Malaysia. *Planter Malaysia*, *54*(632), 682–691.

Hill, D. S., & Abang, F. (2010). *The insects of Borneo (including South-east Asia)*. Universiti

Malaysia Sarawak.

Hollis, D. (1965). A revision of the genus *Trilophidia* Stål (Orthoptera: Acridoidea). *Transactions of the Royal Entomological Society of London*, *117*(8), 245–262. https://doi.org/10.1111/j.1365-2311.1965.tb00052.x

Hollis, D. (1968). A revision of the genus *Aiolopus* Fieber (Orthoptera: Acridoidea). *Bulletin of the British Museum (Natural History) Entomology*, *22*(7), 305–355. http://www.biodiversitylibrary.org/item/20341

Hollis, D. (1971). A preliminary revision of the genus *Oxya* Audinet-Serville (Orthoptera: Acridoidea). *Bulletin of the British Museum (Natural History) Entomology*, *26*(7), 267–343.

Hollis, D. (1975). A review of the subfamily Oxyinae (Orthoptera: Acridoidea). *Bulletin of the British Museum (Natural History) Entomology*, *31*(6), 189–234.

Hon, J., & Shibata, S. (2013). A review on land use in the Malaysian state of Sarawak, Borneo and recommendations for wildlife conservation inside production forest environment. *Borneo Journal of Resource Science and Technology*, *3*(2), 22–35. https://doi.org/10.33736/bjrst.244.2013

Husemann, M., Namkung, S., Habel, J. C., Danley, P. D., & Hochkirch, A. (2012). Phylogenetic analyses of band-winged grasshoppers (Orthoptera, Acrididae, Oedipodinae) reveal convergence of wing morphology. *Zoologica Scripta*, *41*(5), 515–526. https://doi.org/10.1111/j.1463-6409.2012.00548.x

Jago, N. D. (1967). A key to the grasshopper species (Orthoptera: Acridoidea) recorded from Ghana. *Transactions of the Entomological Society of London*, *119*(8), 235–266. https://doi.org/10.1017/CBO9781107415324.004

Joern, A. (1979). Feeding patterns in grasshoppers (Orthoptera: Acrididae): Factors

influencing diet specialization. *Oecologia*, *38*, 325–347. https://doi.org/10.1007/BF00345192

Joern, A., Danner, B. J., Logan, J. D., & Wolesensky, W. (2006). Natural history of mass-action in predator-prey models: A case study from wolf spiders and grasshoppers. *American Midland Naturalist*, *156*(1), 52–64. https://doi.org/10.1674/0003-0031(2006)156[52:NHOMIP]2.0.CO;2

Kalshoven, L. G. E. (1981). *Pests of crops in Indonesia*. P.T. Ichtiar Baru-Van Hoeve.

Karny, V. H. (1915). Orthoptera et Oothecaria. *Supplementa Entomologica*, *4*, 56–108.

Khan, M. I., & Usmani, M. K. (2016). Taxonomic studies on Acridinae (Orthoptera: Acridoidea: Acrididae) from the northeastern states of India. *Journal of Threatened Taxa*, *8*(1), 8389–8397.

Khan, M. I., Usmani, M. K., & Usmani, S. (2016). Studies on the taxonomy of Oxyinae (Orthoptera: Acridoidea: Acrididae) from north-eastern states of India. *Munis Entomology & Zoology*, *11*(1), 202–218.

Khoo, K. C., Ooi, P. A. C., & Ho, C. T. (1991). *Crops pests and their management in Malaysia*. Tropical Press.

Kilpatrick, S. K., Foquet, B., Castellanos, A. A., Gotham, S., Little, D. W., & Song, H. (2019). Revealing hidden density-dependent phenotypic plasticity in sedentary grasshoppers in the genus *Schistocerca* Stål (Orthoptera: Acrididae: Cyrtacanthacridinae). *Journal of Insect Physiology*, *118*, 1–17. https://doi.org/10.1016/j.jinsphys.2019.103937

Kirby, W. F. (1825). *Some remarks on the nomenclature of the Gryllina of MacLeay, &c. with the characters of a new genus in that tribe* (Vol. 1). W. Phillips.

Kirby, W. F. (1888). On the insects (exclusive of Coleoptera and Lepidoptera) of Christmas

Island. In *Proceeding of the Scientific Meetings of the Zoological Society of London* (pp. 546–555). Messrs. Longmans, Green and Co. https://doi.org/10.1111/j.1469-7998.1833.tb06418.x

Kirby, W. F. (1902). Report on a collection of African Locustidae formed by Mr. W. L. Distant, chiefly from the Transvaal. In *The Transactions of the Entomological Society of London* (pp. 57–114). Longmans, Green and Co. https://doi.org/10.1038/128689a0

Kirby, W. F. (1910). *A synonymic catalogue of Orthoptera*. Taylor and Francis. https://doi.org/10.5962/bhl.title.6745

Kirby, W. F. (1914). *The fauna of British India, including Ceylon and Burma*. Taylor and Francis.

Krauss, H. (1890). Erklärung der Orthopteren-tafeln J. C. Savigny's in der "Description de l'Égypte." In *Verhandlungen der kaiserlich-königlichen zoologisch-botanischen gesellschaft in Wien* (pp. 227–272). Adolf Holzhausen.

Krauss, H. (1891). Beitrag zur kenntniss Westafrikanischer Orthopteren. In *Zoologische Jahrbücher Abtheilung für Systematik, Geographie und Biologie der thiere* (pp. 647–668). Verlag von Gustav Fischer.

Krauss, H. (1902). Die namen der ältesten Dermapteren- (Orthopteren-) gattungen und ihre verwendung für familien- und unterfamilien-benennungen auf grund der jetzigen nomenclaturregeln. *Zoologisher Anzeiger*, *25*(659–684), 530–543.

Krogmann, L., & Song, H. (2013). Morphology and integrative phylogenetics. *Insect Systematics and Evolution*, *44*(3–4), 239–240. https://doi.org/10.1163/1876312X-44042106

Latchininsky, A. V. (2013). Locusts and remote sensing: A review. *Journal of Applied Remote Sensing*, *7*(1), 1–32. https://doi.org/10.1117/1.jrs.7.075099

Latchininsky, A. V., Sword, G., Sergeev, M., Cigliano, M. M., & Lecoq, M. (2011). 1. Locusts and grasshoppers: Behavior, ecology, and biogeography. *Psyche: A Journal of Entomology*, *2011*, 1–4. https://doi.org/10.1155/2011/578327

Latreille, P. A. (1802). *Histoire naturelle, générale et particulière des crustacés et des insectes*. L'Imprimerie de F. Dufart.

Latreille, P. A. (1825). *Familles naturelles du règne animal, exposées succinctement et dans un ordre analytique, avec l'indication de leurs genres*. Library de J.-B. Baillière. https://doi.org/10.5962/bhl.title.34914

le Gall, M., Overson, R., & Cease, A. (2019). A global review on locusts (Orthoptera: Acrididae) and their interactions with livestock grazing practices. *Frontiers in Ecology and Evolution*, *7*(July), 1–24. https://doi.org/10.3389/fevo.2019.00263

Leach, W. E. (1815). *The Edinburgh encylopaedia*. Blackwood. https://doi.org/10.5962/bhl.title.30911

Leavitt, J. R., Hiatt, K. D., Whiting, M. F., & Song, H. (2013). Searching for the optimal data partitioning strategy in mitochondrial phylogenomics: A phylogeny of Acridoidea (Insecta: Orthoptera: Caelifera) as a case study. *Molecular Phylogenetics and Evolution*, *67*(2), 494–508. https://doi.org/10.1016/j.ympev.2013.02.019

Lefroy, H. M. (1909). *Indian insect life - A manual of the insects of the Plains (Tropical India)*. Thacker, Spink & Co. https://doi.org/10.1017/S0021859600000939

Li, B., Liu, Z., & Zheng, Z. M. (2011). Phylogeny and classification of the Catantopidae at the tribal level (Orthoptera, Acridoidea). *ZooKeys*, *148*, 209–225. https://doi.org/10.3897/zookeys.148.2081

Li, R., Shu, X., Li, X., Meng, L., & Li, B. (2019). Comparative mitogenome analysis of three species and monophyletic inference of Catantopinae (Orthoptera: Acridoidea).

Genomics, *111*(6), 1728–1735. https://doi.org/10.1016/j.ygeno.2018.11.027

Linnaeus, C. (1758). *Systema naturæ per regna tria naturæ, secundum classes, ordines, genera, species, cum characteribus, differentiis, synonymis, locis. Tomus I* (10th ed.). Editio decima, reformata.

Linnaeus, C. (1763). *Centuria insectorum rariorum*. Upsaliae. https://doi.org/10.5962/bhl.title.910

Linnaeus, C. (1767). *Systema naturæ, Tom. I. Pars II*. Tomus I. Editio duodecima, reformata.

Liu, D., Dong, Z., Zhang, D., Gu, Y., Guo, P., Han, R., & Jiang, G. (2008). Molecular phylogeny of the higher category of Acrididae (Orthoptera: Acridoidea). *Zoological Research*, *29*(6), 585–591. https://doi.org/10.3724/sp.j.1141.2008.00585

Liu, Z., & Li, B. (1995). A new genus and two new species of Catantopidae from Hunan Province, China (Orthoptera: Acridoidea). *Entomologia Sinica*, *2*(2), 104–109. https://doi.org/10.1111/j.1744-7917.1995.tb00029.x

Lockwood, J. A., Hong-Chang, L., Dodd, J. L., & Williams, S. E. (1994). Comparison of grasshopper (Orthoptera: Acrididae) ecology on the grasslands of the Asian steppe in Inner Mongolia and the Great Plains of North America. *Journal of Orthoptera Research*, *2*(2), 4–14. https://doi.org/10.2307/3503601

Lomer, C. J., Bateman, R. P., Johnson, D. L., Langewald, J., & Thomas, M. (2001). Biological control of locusts and grasshoppers. *Annual Review of Entomology*, *46*, 667–702.

Louveaux, A., Amédégnato, C., Poulain, S., & Desutter-Grandcolas, L. (2013). Catalogue and keys of the Acridomorpha (Insecta, Orthoptera) from north West Africa. *Zoosystema*, *35*(2), 175–181. https://doi.org/10.5252/z2013n2a3

Lucas, W. J. (1920). *A monograph of the British Orthoptera*. Adlard and Son and West

Newman, Ltd.

MacLeay, W. S. (1821). *Horae Entomologicae or Essays on the annulose animals*. Richard and Arthur Taylor, Shoe Lane.

Magrath, J., & Simms, A. (2005). *Africa - Up in smoke? The second report from the working group on climate change and development*. The New Economics Foundation.

Mahmood, K., Samira, D., & Idris, A. B. (2007). Acrididae (Orthoptera: Acridoidea) of Malaysia with the description of a new species. *Acta Entomologica Sinica*, *50*(11), 1146–1161.

Mahmood, K., Samira, D., Salmah, Y., & Idris, A. B. (2008). Systematic account of Oedipodinae (Acrididae: Orthoptera) of Malaysia with the description of a new species. *Pakistan Journal of Zoology*, *40*(5), 371–377.

Marquier, C. (2010). *Molecular phylogeny of Melanoplinae (Insecta: Orthoptera: Caelifera: Acrididae)*. Université de Grenoble.

Meijaard, E., & Nijman, V. (2003). Primate hotspots on Borneo: Predictive value for general biodiversity and the effects of taxonomy. *Conservation Biology*, *17*(3), 725–732. https://doi.org/10.1046/j.1523-1739.2003.01547.x

Memon, P. R., & Panhwar, W. A. (2021). Study on some selected species of Acrididae (Orthoptera) from district Dadu, Sindh-Pakistan. *Journal of Entomology and Zoology Studies*, *9*(1), 6–11.

Mercer, C. W. L. (1997). Sustainable production of insects for food and income by New Guinea villagers. *Ecology of Food and Nutrition*, *36*(2–4), 151–157. https://doi.org/10.1080/03670244.1997.9991512

Miller, N. C. E. (1932). XV. Acridiidae (Orthoptera) collected on Mt. Kinabalu British North Borneo. *Journal of the Federated Malay States Museum*, *17*(1), 203–208.

Miller, N. C. E. (1937). Two new Malaysian Acrididae (Orthoptera). *Proceedings of the Royal Entomological Society of London, Series B, Taxonomy*, *6*(11), 201–203.

Mitchell, J. E., & Pfadt, R. E. (1974). A role of grasshoppers in a shortgrass prairie ecosystem. *Environmental Entomology*, *3*(2), 358–360. https://doi.org/10.1093/ee/3.2.358

Mitchell, P. (2019). Settling Madagascar: When did people first colonize the world's largest island? *Journal of Island and Coastal Archaeology*, *15*(10), 576–595. https://doi.org/10.1080/15564894.2019.1582567

Mobin, S., Kumar, H., & Usmani, M. K. (2017). A checklist of Acrididae (Orthoptera: Acridoidea) of Uttar Pradesh, India. *Trends in Biosciences*, *10*(43), 8907–8912. https://doi.org/10.21829/azm.2015.312545

Nair, K. S. S. (2001). *Pest outbreaks in tropical forest plantations: Is there a greater risk for exotic tree species?* Center for International Forestry Research (CIFOR). https://doi.org/10.17528/cifor/000984

Naskrecki, P. (2013). Grasshoppers and their relatives. *Encyclopedia of Biodiversity (Second Edition)*, *3*, 722–736. https://doi.org/10.1016/B978-0-12-384719-5.00168-4

Nonaka, K. (2009). Feasting on insects. *Entomological Research*, *39*(5), 304–312. https://doi.org/10.1111/j.1748-5967.2009.00240.x

Otte, D. (1981). *The North American Grasshoppers, Volume 1: Acrididae: Gomphocerinae and Acridinae* (2nd ed.). Harvard University Press.

Pemberton, R. W. (1994). The revival of rice-field grasshoppers as human food in South Korea. *Pan-Pacific Entomologist*, *70*(4), 323–327.

Pflüger, H. J., & Bräunig, P. (2021). One hundred years of phase polymorphism research in locusts. *Journal of Comparative Physiology A: Neuroethology, Sensory, Neural, and*

Behavioral Physiology, *207*(3), 321–326. https://doi.org/10.1007/s00359-021-01485-3

Primack, R. B., & Hall, P. (1992). Biodiversity and forest change in Malaysian Borneo. *BioSience*, *42*(11), 829–837.

Rahaman, M., & Usmani, M. K. (2017). A checklist of Acrididae (Orthoptera: Acridoidea) from West Bengal, India. *International Journal of Entomology Research*, *2*(6), 16–22.

Ramme, W. Von. (1941). Beiträge zur kenntnis der Acrididen-fauna des Indomalayischen und benachbarter gebiete (Orth.). *Mitteilungen Aus Dem Zoologischen Museum in Berlin*, *25*(1), 1–242.

Rehn, J. (1901). The Acrididae, Tettigonidae and Gryllidae collected by Dr. A. Donaldson Smith in Northeast Africa. In *Proceedings of the Academy of Natural Sciences of Philadephia* (Vol. 53). The Academy of Natural Sciences.

Rehn, J. (1902). Contributions toward a knowledge of the Orthoptera of Japan and Korea, I.-Acrididae. In *Proceedings of the Academy of Natural Sciences of Philadelphia* (pp. 629–637). The Academy of Natural Sciences.

Rehn, J. (1944). A review of the Old World *Euthymiae* (Orthoptera, Acrididae, Cyrtacanthacridinae). *Proceedings of the Academy of Natural Sciences of Philadelphia*, *96*, 1–135. https://doi.org/10.1038/139103c0

Rehn, J., & Rehn, J. W. H. (1940). The Orthoptera of the Philippine Islands, Part II: Acrididae; Cyrtacanthacridinae; Group Cyrtacanthacrides. *Proceedings of the Academy of Natural Sciences of Philadelphia*, *92*, 245–287. https://doi.org/10.1038/139103c0

Reissig, W. H., Heinrichs, E. A., Litsinger, J. A., Moody, K., Fiedler, L., Mew, T. W., & Barrion, A. T. (1986). *Illustrated guide to integrated pest management in rice in tropical Asia*. International Rice Research Institute. https://doi.org/10.1016/0305-750X(88)90094-0

Richards, O. W., & Davies, R. G. (1977). *IMMS' General Textbook of Entomology* (10th ed.). Chapman & Hall. https://doi.org/10.1007/978-94-011-6514-3

Ritchie, J. M. (1982). A taxonomic revision of the genus *Gastrimargus* Saussure (Orthoptera: Acrididae). *Bulletin of the British Museum (Natural History) Entomology*, *44*(4), 239–329.

Roberts, H. R. (1941). A comparative study of the subfamilies of the Acrididae (Orthoptera) primarily on the basis of their phallic structures. *Proceedings of The Academy of Natural Sciences of Philadelphia*, *93*, 201–246.

Rodell, C. F. (1977). A grasshopper model for a grassland ecosystem. *Ecology*, *58*(2), 227–245. https://doi.org/10.2307/1935600

Roffey, J. (1979). Locusts and grasshoppers of economic importance in Thailand. *Anti-Locust Memoir - Centre for Overseas Pest Research (UK)*, *14*, 1–200.

Ronderos, R. A., & Cigliano, M. M. (1991). The Andean Dichroplini: Cladistic analysis with description of *Keyacris* n. gen. and *Ponderacris* n. gen. (Orthoptera: Acrididae: Melanoplinae). *Transactions of the American Entomological Society*, *117*(3), 167–191.

Rondon, S., & Corp, M. (2012). Pinning and labeling insects. In *OSU Extension Entomologist and Agronomist*.

Roonwal, M. L. (1958). A bibliography of the Orthopterous insects of the family Acrididae (comprising the short-horned grasshoppers and locusts) from the earliest times to the end of 1954 (with some additions for 1955-57). *Records of the Indian Museum*, *56*, 1–611.

Rowell, C. H. F., & Flook, P. K. (1998). Phylogeny of the Caelifera and the Orthoptera as derived from ribosomal gene sequences. *Journal of Orthoptera Research*, *7*, 147–156. https://doi.org/10.2307/3503512

Sabah Forestry Department. (2021). *Sabah Forestry Department*. http://www.forest.sabah.gov.my/about-us/profile/message-by-head-of-department.html

Saussure, H. de. (1884). *Prodromus oedipodiorum insectorum ex ordine Orthopterorum* (Vol. 28). Librairie H. Georg. https://doi.org/10.5962/bhl.title.9514

Saussure, H. de. (1888). Additamenta ad prodromum Oedipodiorum. In *Mémoires de la Société de Physique et d'Histoire Naturelle de Genève* (pp. 3–180). Imprimerie Charles-Schuchardt.

Schauff, M. E. (2015). *Collecting and preserving insects and mites: Techniques and tools*. Agricultural Research.

Schulthess, S. (1898). Orthoptères du pays des Somalis, recueillis par L. Robecchi-Brichetti en 1891 et par le Prince E. Ruspoli en 1892-93. In *Annali del Museo Civico di Storia Naturale di Genova* (Vol. 19, Issue 2, pp. 161–216). G. Doria e R. Gestro.

Scudder, G. G. E. (1971). Comparative morphology of insect genitalia. *Annual Review of Entomology*, *16*(1), 379–406. https://doi.org/10.1146/annurev.en.16.010171.002115

Sergeev, M. (2011). Distribution patterns of grasshoppers and their kin in the boreal zone. *Psyche*, *2011*, 1–9. https://doi.org/10.1155/2011/324130

Sergeev, M. (2021). Distribution patterns of grasshoppers and their kin over the Eurasian steppes. *Insects*, *12*, 1–23.

Serville, A. M. (1838). Histoire naturelle des insectes - Orthoptères. In *Histoire naturelle des insectes. Orthoptáeres.* Librairie encylopédique de Roret. https://doi.org/10.5962/bhl.title.95609

Showler, A. T. (1995). Locust (Orthoptera: Acrididae) outbreak in Africa and Asia, 1992–1994: An overview. *American Entomologist*, *41*(3), 179–185.

https://doi.org/10.1093/ae/41.3.179

Silva, F., Battirola, L., Lhano, M., Sousa, W., & Marques, M. (2014). Morphometry of *Cornops aquaticum* (Orthoptera: Acrididae: Leptysminae) in the Pantanal of Mato Grosso, Brazil. *Brazilian Journal of Biology*, *74*(3), 730–738.

Siwi, S. S., Trisnaningsih, & Harnoto. (2005). Pengelolaan lingkungan dalam rangka mengantisipasi perkembangan hama belalang *Nomadacris succincta* Linnaeus (Orthoptera: Acrididae). *Jurnal Perlindungan Tanaman Indonesia*, *11*(2), 121–130.

Sjöstedt, B. Y. (1910). *Wissenschaftliche ergebnisse der Schwedischen Zoologischen Expedition nach dem Kilimandjaro, dem Meru und den umgebenden massaisteppen Deutsch-Ostafrikas 1905-1906* (Vol. 17, Issue 7). P. Palmquists Aktiebolag.

Sjöstedt, B. Y. (1920). Results of Dr E. Mjöberg's Swedish scientific expiditions to Australia 1910-1913. In *Arkiv för Zoologi utgivet av K. Svenska Vetenskapsakademien* (Vol. 12, Issue 20, pp. 1–67). P.A. Norstedt & Soner.

Smith, A. D. (2017). *The languages of Borneo: A comprehensive classification*. University of Hawai'i.

Smith, T. R., Froeba, J. G., & Capinera, J. L. (2004). Key to the grasshoppers (Orthoptera: Acrididae) of Florida. *Florida Entomologist*, *87*(4), 537–550. https://doi.org/10.1653/0015-4040(2004)087[0537:kttgoa]2.0.co;2

Song, H. (2004). On the origin of the desert locust *Schistocerca gregaria* (Forskål) (Orthoptera: Acrididae: Cyrtacanthacridinae). *Proceedings of the Royal Society B: Biological Sciences*, *271*(1548), 1641–1648. https://doi.org/10.1098/rspb.2004.2758

Song, H. (2010). Grasshopper systematics: Past, present and future. *Journal of Orthoptera Research*, *19*(1), 57–68. https://doi.org/10.1665/034.019.0112

Song, H. (2011). Density-dependent phase polyphenism in nonmodel locusts: A minireview.

Psyche (London), *2011*, 1–16. https://doi.org/10.1155/2011/741769

Song, H. (2018). Biodiversity of Orthoptera. In *Insect Biodiversity: Science and Society* (pp. 245–279). John Wiley & Sons, Ltd.

Song, H., Amédégnato, C., Cigliano, M. M., Desutter-Grandcolas, L., Heads, S. W., Huang, Y., Otte, D., & Whiting, M. F. (2015). 300 million years of diversification: Elucidating the patterns of orthopteran evolution based on comprehensive taxon and gene sampling. *Cladistics*, *31*(6), 621–651. https://doi.org/10.1111/cla.12116

Song, H., Foquet, B., Mariño-Pérez, R., & Woller, D. A. (2017). Phylogeny of locusts and grasshoppers reveals complex evolution of density-dependent phenotypic plasticity. *Scientific Reports*, *7*(1), 1–13. https://doi.org/10.1038/s41598-017-07105-y

Song, H., Mariño-Pérez, R., Woller, D. A., & Cigliano, M. M. (2018). Evolution, diversification, and biogeography of grasshoppers (Orthoptera: Acrididae). *Insect Systematics and Diversity*, *2*(4), 1–25. https://doi.org/10.1093/isd/ixy008

Song, H., Weissman, D. B., Barrientos-Lozano, L., & Cano-Santana, Z. (2006). The Locust Island. *American Entomologist*, *52*(3), 168–181. https://doi.org/10.1093/ae/52.3.168

Song, H., & Wenzel, J. W. (2007). Phylogeny of bird-grasshopper subfamily Cyrtacanthacridinae (Orthoptera: Acrididae) and the evolution of locust phase polyphenism. *Cladistics*, *23*, 1–28. https://doi.org/10.1111/j.1096-0031.2007.00190.x

Stål, C. (1861). Insecta: Orthoptera. In *Kongliga Svenska fregatten Eugenies Resa omkring jorden under befäl af C. A. Virgin åren 1851-1853 (Zoologi)* (pp. 299–350). P. A. Norstedt & Soner. https://doi.org/10.5962/bhl.title.2467

Stål, C. (1873). *Recensio Orthopterorum: Revue critique des Orthoptères*. P.A. Norstedt & Söner.

Stål, C. (1878). Systema acridiodeorum - Essai d'une systematisation des acridiodees. In

Bihang till Kongliga Svenska vetenskaps-akademiens Handlingar (Vol. 5, Issue 4, pp. 1–100). P.A. Norstedt & Söner. https://doi.org/10.1007/BF03017257

Stoll, C. (1813). *Natuurlijke en naar het leven nauwkeurige gekleurde afbeeldingen en beschrijvingen der spoken, wandelende bladen, zabelspringhanen, krekels, trekspringhanen en kakkerlakken: in alle vier deelen der wereld, Europa, Asia, Afrika, en Amerika, huishoudende*. J. C. Sepp et Fils.

Sun, T., Liu, Z. Y., Qin, L. P., & Long, R. J. (2015). Grasshopper (Orthoptera: Acrididae) community composition in the rangeland of the northern slopes of the Qilian Mountains in Northwestern China. *Journal of Insect Science*, *15*(6), 1–7. https://doi.org/10.1093/jisesa/ieu171

Swofford, D. L. (2003). *PAUP* (Phylogenetic Analysis Using Parsimony (*and Other Methods)* (No. 4). Sinauer Associates.

Tajamul, M., & Ahmad, S. T. (2016). Life history statistics and comparative morphometric assessment of rice grasshopper, *Oxya japonica* (Orthoptera: Acrididae). *International Journal of Pure and Applied Zoology*, *4*(1), 92–98.

Tan, M. K. (2010a). Orthoptera in Pulau Ubin. *Nature in Singapore*, *3*, 245–268.

Tan, M. K. (2010b). Orthoptera of the Vacant Lots in Bedok South. *Nature in Singapore*, *3*, 69–81.

Tan, M. K. (2012a). *Orthoptera in the Bukit Timah and Central Catchment Nature Reserves (Part 1): Suborder Caelifera*. Raffles Museum of Biodiversity Research, National University Singapore. http://rmbr.nus.edu.sg/raffles_museum_pub/caelifera_btnr_ccnr.pdf.

Tan, M. K. (2012b). Orthoptera of the exhumed Bidadari Cemetery, Singapore. *Nature in Singapore*, *5*, 343–350.

Tan, M. K. (2013). Orthoptera in the mangrove forests of Singapore. *Nature in Singapore*, *6*, 289–300.

Tan, M. K. (2019). Orthoptera species checklist of Bukit Timah Nature Reserve in the Zoological Reference Collection, Singapore. *Gardens' Bulletin Singapore*, *71*(suppl.1), 331–338. https://doi.org/10.26492/gbs71(suppl.1).2019-13

Tan, M. K., & Kamaruddin, K. N. (2014). *Orthoptera of Fraser's Hill, Peninsular Malaysia*. Lee Kong Chian Natural History Museum. http://lkcnhm.nus.edu.sg/nus/pdf/lkcnhmbooks/orthorptera_fraser's_hill.pdf

Tan, M. K., & Kamaruddin, K. N. (2016). A contribution to the knowledge of Orthoptera diversity from Peninsular Malaysia: Bukit Larut, Perak. *Zootaxa*, *4111*(1), 21–40. https://doi.org/10.11646/zootaxa.4111.1.2

Tan, M. K., Ngiam, R. W. J., & Ismail, M. R. B. (2012). A checklist of Orthoptera in Singapore Parks. *Nature in Singapore*, *5*(March), 61–67.

Tan, M. K., & Wahab, R. H. A. (2018). Preliminary study on the diversity of Orthoptera from Kuala Belalong Field Studies Centre, Brunei Darussalam, Borneo. *Journal of Orthoptera Research*, *27*(2), 119–142. https://doi.org/10.3897/jor.27.24152

Tan, M. K., & Wang, L. K. (2012). The Orthoptera of Semakau Landfill, Singapore: A project Semakau checklist. *Nature in Singapore*, *5*, 309–318.

Tan, M. K., Yeo, H., Hasnan, S., Zhi, S., Woon, S., & Wu, B. (2013). A rapid comparison of the Orthoptera communities of Bukit Brown Cemetery and Lornie Trail of the Central Catchment Nature Reserve, Singapore. *Nature in Singapore*, *6*, 97–103.

Tang, C., Yang, D., Liao, H., Sun, H., Liu, C., Wei, L., & Li, F. (2019). Edible insects as a food source: A review. *Food Production, Processing and Nutrition*, *1*(8), 1–13. https://doi.org/10.1186/s43014-019-0008-1

The Borneo Project. (2021). *About Borneo – The Borneo Project*. https://borneoproject.org/borneo-2/

Thunberg, C. P. (1815). Hemipterorum maxillosorum genera illustrata plurimisque novis speciebus ditata ac descipta. In *Mémoires de l'Académie impériale des sciences* (Vol. 5, pp. 211–301). Académie impériale des sciences de St. Pétersbourg.

Thunberg, C. P. (1824). Grylli monographia, illustrata. In *Mémoires de l'Académie impériale des sciences* (Vol. 9, pp. 390–430). Académie impériale des sciences de St. Pétersbourg.

Truman, J. W., & Riddiford, L. M. (2019). The evolution of insect metamorphosis: A developmental and endocrine view. *Philosophical Transactions of the Royal Society of London. Series B: Biological Sciences*, *374*(1783), 1–12.

University of Wyoming. (n.d.). *Grasshoppers of Wyoming and the West*. Retrieved September 6, 2022, from http://www.uwyo.edu/entomology/grasshoppers/field-guide/ghcycle.html

Upton, M., & Mantle, B. (2010). *Methods for collecting, preserving and studying insects and other terrestrial arthropods*. Paragon Printers Australasia.

Utah State University. (n.d.). *Grasshopper control*. Retrieved September 6, 2022, from https://extension.usu.edu/pests/ipm/notes_ag/veg-grasshopper-control

Uvarov, B. (1966). *Grasshoppers and locusts: A handbook of general acridology. Vol. 1. Anatomy, physiology, development, phase polymorphism, introduction to taxonomy* (Vol. 1). Cambridge University Press.

Uvarov, B. P. (1921a). A revision of the genus *Locusta*, L. (=*Pachytylus*, Fieb.), with a new theory as to the periodicity and migrations of locusts. *Bulletin of Entomological Research*, *12*(2), 135–163. https://doi.org/10.1017/S0007485308006068

Uvarov, B. P. (1921b). LVIII. Records and descriptions of Indian Acrididae (Orthoptera). In *The Annals and Magazine of Natural History including Zoology, Botany and Geology* (pp. 480–508). Taylor and Francis.

Uvarov, B. P. (1923a). XI.— A revision of the Old World Cyrtacanthacrini (Orthoptera, Acrididæ).—I. Introduction and key to genera. *Annals and Magazine of Natural History*, *11*(61), 130–144. https://doi.org/10.1080/00222932308632832

Uvarov, B. P. (1923b). XL.— A revision of the Old World Cyrtacanthacrini (Orthoptera, Acrididæ).—III. Genera *Valanga* to *Patanga*. *Annals and Magazine of Natural History*, *12*(70), 345–367. https://doi.org/10.1080/00222932308632957

Uvarov, B. P. (1929). Acrididen (Orthoptera) aus Süd-Indien. *Revue Suisse de Zoologie*, *36*(18), 533–563.

Uvarov, B. P. (1937). Some Acrididae from the Solomon Islands (Orthoptera). *Treubia*, *16*(1), 15–20. https://doi.org/doi.org/10.14203/treubia.v16i1.2492

van Huis, A. (2018). Insects as human food. In *Ethnozoology: Animals in Our Lives* (pp. 195–213). Elsevier. https://doi.org/10.1016/B978-0-12-809913-1.00011-9

van Huis, A., Itterbeeck, J. van, Klunder, H., Mertens, E., Halloran, A., Muir, G., & Vantomme, P. (2013). Edible insects: Future prospects for food and feed security. In *Food and Agriculture Organization of the United Nations* (Vol. 171). Food and Agriculture Organization (FAO) of the United Nations.

Walker, F. (1870a). *Catalogue of the specimens of Dermaptera Saltatoria in the collection of the British Museum (Part III)*. E. Newman, Printer.

Walker, F. (1870b). *Catalogue of the specimens of Dermaptera Saltatoria in the collection of the British Museum (Part IV)*. E. Newman, Printer.

Walker, F. (1871). *Catalogue of the specimens of Dermaptera Saltatoria in the collection of*

the British Museum (Part V) - supplement. E. Newman, Printer.

Wan Nurainie, W. I., Hazali, R., Marni, W., Sazali, S. N., Ahmad Irfan, A. R., Farah Nabillah, A. H. A. F., Stia, M. I., Yee, T. S., & Mortada, M. J. (2020). Insects. In J. Mohd-Azlan, A. A. A. Aimran, & I. Das (Eds.), *Sadong Jaya: A Wilderness Unveiled* (pp. 17–24). UNIMAS Publisher.

Willemse, C. (1921). I. - Bijdrage tot de kennis der Orthoptera S. S. van den Nederlandsch Indischen Archipel en omliggende gebieden. *Zoologische Mededeelingen*, *6*(1), 1–45.

Willemse, C. (1925). Revision der gattung *Oxya* Serville (Orthoptera, Subfam. Acridiodea, trib. Cyrtacanthacrinae). *Tijdschrift Voor Entomologie*, *68*, 1–60.

Willemse, C. (1928). Spolia Mentawiensia: Acridiidae (Orthoptera.). *Journal of the Malayan Branch of the Royal Asiatic Society*, *6*(1), 1–12.

Willemse, C. (1930a). Fauna Sumatrensis (Bijdrage Nr. 62): Preliminary revision of the Acrididae (Orthoptera). *Tijdschrift Voor Entomologie*, *73*, 1–210.

Willemse, C. (1930b). Fauna Sumatrensis (Bijdrage Nr. 62): Preliminary revision of the Acrididae (Orthoptera). *Tijdschrift Voor Entomologie*, *73*, 1–210.

Willemse, C. (1935). Description of some new *Traulia* sp., with key to the known species (Orthopt. Acrididae). *Entomologische Berichten Uitgegeven Door de Nederlandsche Entomologische Vereeniging*, *9*(203), 137–146.

Willemse, C. (1936). Description of new Indo-Malayan Acrididae (Orthoptera) - Part V (Continuation). *Natuurhistorisch Maandblad*, *25*(2), 15–17.

Willemse, C. (1938). XXIII.— Results of the Oxford University expedition to Sarawak (Borneo), 1932. Acridiidæ (Orthoptera). *Annals and Magazine of Natural History*, *2*(8), 217–236. https://doi.org/10.1080/03745481.1938.9755455

Willemse, C. (1951). Synopsis of the Acridoidea of the Indo-Malayan and adjacent regions

(Insecta, Orthoptera): Part I (Family Acrididae, Subfamily Acridinae Part I). *Natuurhistorisch Genootschap*, *4*, 41–114.

Willemse, C. (1953). On a collection of Orthoptera from the Solomon Islands, chiefly from the Institut Royal des Sciences Naturelles de Belgique. *Institut Royal Des Sciences Naturelles de Belgique Bulletin*, *29*(7), 1–27.

Willemse, C. (1956). Synopsis of the Acridoidea of the Indo-Malayan and adjacent regions (Insecta, Orthoptera): Part II (Family Acrididae, Subfamily Catantopinae Part I). *Natuurhistorisch Genootschap*, *9*, 1–225.

Willemse, C. (1957). Synopsis of the Acridoidea of the Indo-Malayan and adjacent regions (Insecta, Orthoptera): Part II (Family Acrididae, Subfamily Catantopinae Part II). *Natuurhistorisch Genootschap*, *10*, 227–500.

Willemse, F. (1968). *Revision of the genera Stenocatantops and Xenocatantops (Orthoptera, Acridiidae, Catantopinae)*. Nederlandsche Entomologische Vereniging.

Willemse, L. (2001). *Fauna Malesiana guide to the pest Orthoptera of the Indo-Malayan region*. Backhuys.

Wipfler, B., Letsch, H., Frandsen, P. B., Kapli, P., Mayer, C., & Bartel, D. (2019). Evolutionary history of Polyneoptera and its implications for our understanding of early winged insects. *Proceedings of the National Academy of Sciences of the United States of America*, *116*(8), 3024–3029. https://doi.org/10.1073/pnas.1817794116

Wipfler, B., Pohl, H., Yavorskaya, M. I., & Beutel, R. G. (2016). A review of methods for analysing insect structures - the role of morphology in the age of phylogenomics. *Current Opinion in Insect Science*, *18*, 60–68. https://doi.org/10.1016/j.cois.2016.09.004

Woller, D. A., Fontana, P., Mariño-Pérez, R., & Song, H. (2014). Studies in Mexican

grasshoppers: *Liladownsia fraile*, a new genus and species of Dactylotini (Acrididae: Melanoplinae) and an updated molecular phylogeny of Melanoplinae. *Zootaxa*, *3793*(4), 475–495. https://doi.org/10.11646/zootaxa.3793.4.6

WWF. (2007). *Forests of Borneo*. http://www.panda.org/borneo

WWF. (2020). *Heart of Borneo (HoB)*. https://wwf.panda.org/discover/knowledge_hub/where_we_work/borneo_forests/

Xia, K. L. (1994). *Fauna Sinica, Insecta (Vol. 4). Orthoptera: Acridoidea (Pamphagidae, Chrotogonidae, Pyrgomorphidae)* (Vol. 4). Science Press.

Xu, H., Mao, B., Storozhenko, S. Y., Huang, Y., Chen, Z., & Huang, J. (2021). Phylogenetic position of the genus *Alulacris* (Orthoptera: Acrididae: Melanoplinae: Podismini) revealed by complete mitogenome evidence. *Insects*, *12*(10), 918–936. https://doi.org/10.3390/insects12100918

Yin, X., & Xia, K. (2003). *Fauna Sinica Insecta (Volume: 32): Orthoptera, Acridoidea: Gomphoceridae and Acrididae*. Science Press.

Zheng, Z. M. (1993). *Grasshoppers of China*. Shaanxi Normal University Press.

Zheng, Z. M., & Xia, K. L. (1998). *Fauna Sinica Insecta: Orthoptera, Acridoidea (Oedipodidae and Arcypteridae)*. Science Press.

APPENDICES

Appendix 1: Measurements of external morphological characters of acridids from Malaysian Borneo in millimeter (mm). BL = Body length; FHL = Front of head length; HW = Head width; PL = Pronotum length; FPL = Fastigium to post-occiput length; PHL = Pronotum to head length; PW = Pronotum width; AL = Antennae length; WBE = Width between eyes; ES(H) = Eye size (height); ES(W) = Eye size (width); TL = Tegmen length; TW(1) = Tegmen width at apical area; TW(2) = Tegmen width at its widest; TW(3) = Tegmen width at basal area; HFL = Hind femur length; HTL = Hind tibia length; HSL = Hind tarsi length.

Species		BL	FHL	HW	PL	FPL	PHL	PW	AL	WBE	ES (H)	ES (W)	TL	TW (1)	TW (2)	TW (3)	HFL	HTL	HSL
ACRIDINAE																			
Phlaeoba antennata																			
Male	Mean	19.92	6.62	3.05	3.88	3.87	7.77	2.76	10.6	0.87	2.17	1.53	14.17	1.37	2.30	1.70	12.6	11.65	3.32
	SD	0.88	0.35	0.11	0.31	0.20	0.38	0.18	0.83	0.09	0.13	0.08	1.17	0.23	0.21	0.17	0.55	0.53	0.27
	Min	17.88	5.88	2.83	2.50	3.24	6.38	2.38	8.17	0.64	1.90	1.39	12.57	1.02	1.94	1.32	11.36	10.24	2.73
	Max	21.66	7.62	3.31	4.27	4.34	8.37	3.41	12.24	1.09	2.39	1.72	16.8	1.87	2.72	2.26	13.94	12.88	3.93
	N =	42	42	42	42	42	42	42	42	42	42	42	42	42	42	42	42	42	42
Female	Mean	29.42	8.79	3.79	5.54	4.93	10.46	3.91	10.86	1.27	2.57	1.74	18.89	1.85	3.21	2.40	16.62	15.35	4.15
	SD	1.47	0.45	0.14	0.33	0.33	0.48	0.21	0.87	0.21	0.14	0.10	1.98	0.34	0.34	0.24	0.91	0.87	0.31
	Min	25.01	7.85	3.43	4.72	4.26	9.27	3.35	8.41	1.07	2.31	1.57	14.09	1.22	2.33	1.97	14.74	13.39	3.62
	Max	32.56	9.51	4.14	6.16	5.56	11.29	4.19	12.66	1.58	2.89	1.99	23.23	2.66	3.96	3.14	18.17	16.97	4.70
	N =	33	33	33	33	33	33	33	33	33	33	33	33	33	33	33	33	33	33
Phlaeoba infumata																			
Male	Mean	18.81	6.58	2.9	3.93	3.71	7.53	2.67	10.95	0.79	2.07	1.47	14.07	1.37	2.32	1.66	12.32	11.31	3.22
	SD	0.76	0.27	0.03	0.08	0.10	0.08	0.09	0.15	0.12	0.16	0.01	0.02	0.02	0.06	0.03	-	-	-
	Min	18.27	6.39	2.88	3.87	3.64	7.47	2.60	10.84	0.70	1.95	1.46	14.05	1.35	2.28	1.64	12.32	11.31	3.22
	Max	19.35	6.77	2.92	3.98	3.78	7.58	2.73	11.05	0.87	2.18	1.47	14.08	1.38	2.36	1.68	12.32	11.31	3.22
	N =	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2
Female	Mean	29.10	8.70	3.74	5.49	4.81	10.37	3.90	10.05	1.22	2.53	1.76	18.79	1.75	3.12	2.36	16.41	15.07	4.19
	SD	1.72	0.37	0.15	0.25	0.36	0.55	0.13	1.59	0.15	0.14	0.08	1.79	0.29	0.30	0.16	0.55	0.28	0.16
	Min	26.23	8.23	3.57	5.18	4.09	9.54	3.72	7.23	1.01	2.36	1.64	16.81	1.30	2.82	2.17	15.31	14.49	3.98

Appendix 1 continued.

Species		BL	FHL	HW	PL	FPL	PHL	PW	AL	WBE	ES (H)	ES (W)	TL	TW (1)	TW (2)	TW (3)	HFL	HTL	HSL
	Max	32.25	9.37	4.01	5.89	5.42	11.4	4.11	12.06	1.49	2.84	1.92	22.49	2.19	3.82	2.74	17.13	15.36	4.43
	N =	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10
CATANTOPINAE																			
Apalacris varicornis																			
Male	Mean	17.88	4.38	3.23	4.18	2.13	6.46	2.77	11.56	0.55	2.13	1.35	16.60	2.64	2.94	2.22	11.15	9.97	4.13
	SD	0.70	0.10	0.11	0.12	0.21	0.14	0.12	-	0.04	0.04	0.04	0.39	0.07	0.10	0.11	0.39	0.29	0.08
	Min	17.32	4.27	3.12	4.06	1.92	6.34	2.63	11.56	0.51	2.09	1.31	16.18	2.59	2.87	2.11	10.82	9.65	4.05
	Max	18.66	4.45	3.34	4.29	2.33	6.62	2.85	11.56	0.59	2.16	1.38	16.94	2.72	3.05	2.33	11.58	10.20	4.20
	N =	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3
Female	Mean	26.78	6.14	4.16	6.22	2.81	9.02	4.18	12.96	0.68	2.71	1.72	23.58	3.19	3.88	3.11	15.79	13.87	5.32
	SD	2.29	0.55	0.32	0.29	0.43	0.63	0.30	0.48	0.19	0.25	0.21	2.49	0.49	0.28	0.26	2.35	1.01	0.88
	Min	24.04	5.49	3.94	5.71	2.33	8.08	3.81	12.35	0.43	2.54	1.56	20.75	2.68	3.57	2.76	13.72	12.61	4.52
	Max	30.24	6.77	4.71	6.40	3.32	9.80	4.46	13.36	0.88	3.15	2.09	27.21	3.96	4.29	3.38	19.73	15.09	6.48
	N =	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5
Coloracris azureus																			
Male		21.53	6.60	4.53	3.93	4.27	8.42	3.56	20.43	0.59	2.59	2.06	13.75	1.82	2.78	1.95	13.59	11.83	5.23
	N =	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
Coloracris coerulescens																			
Female		27.31	8.47	5.47	5.59	5.04	10.51	4.76	-	0.71	3.19	2.37	17.58	2.48	3.89	3.42	17.23	14.56	6.32
	N =	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
***Coloracris* sp.**																			
Male		21.32	5.88	4.16	4.57	3.86	8.36	3.62	20.02	0.69	2.51	1.85	14.56	1.65	3.09	2.24	13.57	11.46	5.59
	N=	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
Craneopsis olivacea																			
Male		27.67	7.22	6.47	7.31	4.57	11.51	5.49	18.52	1.54	3.40	2.73	16.13	2.82	4.46	3.56	14.32	11.44	7.70
	N=	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
***Meltripata* sp. 1**																			
Male		24.79	6.08	4.86	4.28	4.10	8.45	3.81	18.17	0.86	2.36	1.93	14.09	1.88	2.91	2.32	12.65	9.96	6.32
	N=	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
***Meltripata* sp. 2**																			
Female		19.43	6.18	3.97	3.77	4.23	7.41	3.77	11.84	0.86	2.48	1.83	9.30	1.43	2.83	2.50	13.37	11.88	4.02
	N=	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1

Appendix 1 continued.

Species		BL	FHL	HW	PL	FPL	PHL	PW	AL	WBE	ES (H)	ES (W)	TL	TW (1)	TW (2)	TW (3)	HFL	HTL	HSL
Perakia borneensis																			
Male	Mean	32.94	6.46	6.49	6.60	3.67	10.23	5.22	13.34	1.20	3.52	2.52	14.12	1.77	4.04	3.47	16.88	15.53	7.53
	SD	0.39	0.19	0.20	0.06	0.24	0.06	0.04	1.49	0.04	0.10	0.15	0.69	0.63	0.21	0.17	0.25	0.13	-
	Min	32.66	6.32	6.35	6.56	3.50	10.19	5.19	12.28	1.17	3.45	2.41	13.63	1.32	3.89	3.35	16.70	15.43	7.53
	Max	33.21	6.59	6.63	6.64	3.84	10.27	5.25	14.39	1.23	3.59	2.62	14.60	2.21	4.19	3.59	17.05	15.62	7.53
	N =	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2
Female		43.75	8.40	7.50	7.11	4.44	11.58	6.40	-	2.18	4.00	2.62	27.01	3.19	5.61	4.28	20.50	18.68	8.72
	N=	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
Phalaca waterstradti																			
Male		22.66	5.22	5.18	5.86	3.64	9.31	4.15	16.91	0.98	2.72	2.21	13.82	2.71	4.05	3.06	12.51	10.16	6.83
	N=	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
Stenocatantops splendens																			
Male	Mean	31.99	6.71	4.20	6.31	3.29	9.60	3.79	10.85	0.57	3.21	1.88	28.88	2.45	3.75	3.21	16.09	13.72	5.08
	SD	1.76	0.39	0.24	0.41	0.25	0.54	0.31	1.06	0.11	0.15	0.10	1.74	0.30	0.33	0.26	1.02	0.95	0.70
	Min	29.43	6.34	3.73	5.62	2.70	8.90	3.45	8.62	0.32	2.95	1.69	25.32	2.00	3.18	2.90	14.37	12.34	2.65
	Max	38.58	8.11	4.97	7.87	3.84	11.30	4.88	13.43	0.71	3.61	2.10	34.97	3.16	4.80	4.17	19.77	17.09	6.18
	N =	28	28	28	28	28	28	28	28	28	28	28	28	28	28	28	28	28	28
Female	Mean	39.24	8.12	4.96	7.86	3.71	11.56	4.79	11.40	0.78	3.55	2.00	35.85	2.92	4.68	4.02	20.02	17.2	5.97
	SD	2.52	0.53	0.24	0.59	0.22	0.71	0.28	1.49	0.15	0.16	0.12	2.73	0.43	0.42	0.38	1.36	1.21	0.58
	Min	31.21	6.03	3.81	5.46	2.95	8.59	3.45	7.35	0.49	3.04	1.74	26.33	2.24	2.93	2.82	14.04	11.63	3.80
	Max	43.68	8.95	5.31	8.59	4.19	12.84	5.23	14.23	1.10	3.87	2.36	39.37	4.27	5.42	4.51	21.94	18.91	6.96
	N =	46	46	46	46	46	46	46	46	46	46	46	46	46	46	46	46	46	46
Traulacris grandis																			
Male	Mean	19.65	6.16	4.21	4.15	3.97	8.14	3.30	21.20	0.65	2.36	1.93	8.93	1.28	2.61	1.98	13.96	12.24	5.44
	SD	0.73	0.17	0.13	0.25	0.34	0.23	0.13	0.51	0.12	0.09	0.13	0.21	0.18	0.22	0.27	0.60	0.53	0.42
	Min	18.64	5.88	3.98	3.75	3.26	7.76	3.11	20.64	0.55	2.18	1.72	8.67	1.16	2.38	1.66	12.81	11.21	4.67
	Max	20.78	6.36	4.40	4.40	4.36	8.49	3.54	21.67	0.89	2.44	2.08	9.34	1.66	2.97	2.48	14.55	12.73	5.91
	N =	7	7	7	7	7	7	7	7	7	7	7	7	7	7	7	7	7	7
Female	Mean	24.56	7.46	4.69	4.86	4.63	9.34	4.02	18.98	0.88	2.59	2.03	9.74	1.27	2.81	2.24	15.41	13.80	5.91
	SD	0.91	0.05	0.12	0.41	0.07	0.10	0.14	2.04	0.08	0.02	0.06	0.38	0.37	0.08	0.44	0.33	0.14	0.59
	Min	23.82	7.41	4.59	4.43	4.56	9.27	3.90	16.96	0.80	2.58	1.99	9.48	0.90	2.76	1.79	15.18	13.70	5.49

Appendix 1 continued.

Species		BL	FHL	HW	PL	FPL	PHL	PW	AL	WBE	ES (H)	ES (W)	TL	TW (1)	TW (2)	TW (3)	HFL	HTL	HSL
	Max	25.57	7.51	4.83	5.25	4.70	9.45	4.17	21.04	0.96	2.62	2.10	10.17	1.64	2.90	2.66	15.64	13.90	6.32
	N =	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3
Traulia azureipennis																			
Male	Mean	21.50	5.64	4.53	4.73	3.42	8.06	3.49	13.04	0.84	2.71	2.15	16.24	2.02	3.07	2.32	12.35	10.85	4.57
	SD	1.06	0.25	0.15	0.21	0.19	0.30	0.14	1.53	0.12	0.11	0.11	0.87	0.18	0.21	0.16	0.48	0.42	0.55
	Min	18.91	5.27	4.22	4.34	3.03	7.35	3.12	9.05	0.59	2.48	1.97	14.36	1.55	2.66	1.83	11.14	9.96	2.39
	Max	24.03	6.22	4.82	5.35	4.01	8.76	3.78	16.37	1.15	2.95	2.58	18.19	2.61	3.84	2.64	13.54	11.74	5.19
	N =	65	65	65	65	65	65	65	65	65	65	65	65	65	65	65	65	65	65
Female	Mean	32.09	7.60	5.31	6.59	4.17	10.67	4.92	12.96	1.28	3.14	2.25	21.66	2.44	4.24	3.21	16.60	14.76	5.94
	SD	2.14	0.38	0.18	0.38	0.29	0.50	0.23	1.49	0.18	0.13	0.10	1.57	0.28	0.29	0.24	0.87	0.77	0.38
	Min	27.44	6.67	4.87	5.50	3.41	9.37	4.39	9.87	0.84	2.79	1.974	17.37	1.84	3.63	2.62	14.44	12.80	4.75
	Max	38.96	9.11	5.92	7.70	5.01	12.53	5.61	19.53	1.61	3.65	2.55	27.04	3.67	5.02	3.96	20.13	17.73	6.86
	N =	83	83	83	83	83	83	83	83	83	83	83	83	83	83	83	83	83	83
Traulia borneensis																			
Male	Mean	21.35	5.59	4.58	5.06	3.36	8.43	3.69	12.20	0.87	2.72	2.23	12.55	1.38	2.81	2.27	12.47	10.67	4.65
	SD	1.17	0.29	0.19	0.12	0.22	0.37	0.12	0.58	0.06	0.20	0.20	1.61	0.15	0.13	0.20	0.43	0.20	0.22
	Min	19.66	5.13	4.22	4.87	2.91	7.62	3.50	11.24	0.76	2.43	2.01	9.55	1.19	2.58	1.91	11.91	10.30	4.44
	Max	22.65	5.89	4.82	5.21	3.60	8.87	3.85	12.72	0.94	2.97	2.66	15.42	1.61	3.02	2.55	13.28	10.89	5.02
	N =	8	8	8	8	8	8	8	8	8	8	8	8	8	8	8	8	8	8
Female	Mean	29.49	7.39	5.23	6.96	4.16	11.01	5.13	12.23	1.11	3.09	2.30	15.68	1.66	3.90	3.09	16.27	13.98	5.68
	SD	1.71	0.30	0.14	0.13	0.12	0.26	0.17	0.66	0.08	0.05	0.11	1.15	0.13	0.05	0.20	0.61	0.51	0.29
	Min	26.64	7.05	5.02	6.79	4.04	10.81	5.02	11.27	1.04	3.04	2.13	14.58	1.45	3.82	2.84	15.53	13.40	5.27
	Max	30.93	7.73	5.42	7.12	4.36	11.44	5.42	13.09	1.21	3.16	2.42	17.52	1.79	3.95	3.34	17.22	14.68	6.07
	N =	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5
Traulia sanguinipes sanguinipes																			
Male	Mean	21.94	6.16	4.82	5.25	3.49	8.70	3.85	13.18	0.94	2.89	2.26	16.82	2.08	3.34	2.53	13.23	11.50	4.80
	SD	0.79	0.29	0.14	0.25	0.27	0.37	0.05	1.64	0.06	0.05	0.08	0.66	0.09	0.13	0.19	0.43	0.38	0.28
	Min	21.01	5.65	4.61	4.98	3.08	8.15	3.78	10.70	0.87	2.85	2.16	16.24	1.99	3.08	2.23	12.69	10.95	4.43
	Max	23.29	6.43	4.98	5.65	3.83	9.10	3.92	14.62	1.03	2.98	2.35	17.97	2.19	3.43	2.73	13.89	12.08	5.27
	N =	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6

Appendix 1 continued.

Species		BL	FHL	HW	PL	FPL	PHL	PW	AL	WBE	ES (H)	ES (W)	TL	TW (1)	TW (2)	TW (3)	HFL	HTL	HSL
Female	Mean	29.75	7.23	5.18	6.53	3.90	10.37	4.93	12.99	1.21	3.05	2.20	20.43	2.40	4.17	3.16	15.71	13.68	5.39
	SD	2.02	0.21	0.14	0.35	0.27	0.37	0.15	0.71	0.12	0.10	0.10	1.19	0.28	0.25	0.30	0.58	0.50	0.36
	Min	26.84	6.84	5.01	6.10	3.59	9.84	4.76	12.17	0.99	2.95	2.09	19.15	1.95	3.82	2.85	14.96	13.01	4.72
	Max	31.57	7.45	5.39	7.01	4.21	11.06	5.19	13.92	1.32	3.17	2.35	22.54	2.88	4.56	3.72	16.61	14.38	5.92
	N =	7	7	7	7	7	7	7	7	7	7	7	7	7	7	7	7	7	7
Xenocatantops humilis																			
Male	Mean	23.28	5.40	3.99	4.98	2.98	7.92	3.36	10.79	0.58	2.69	1.94	20.76	2.11	3.12	2.54	12.73	11.01	4.40
	SD	1.09	0.29	0.38	0.29	0.19	0.39	0.17	1.06	0.12	0.13	0.11	1.24	0.22	0.27	0.24	0.59	0.52	0.66
	Min	20.22	4.86	2.77	4.45	2.60	7.18	3.05	6.89	0.35	2.33	1.68	17.42	1.63	2.52	1.97	11.66	10.20	2.04
	Max	25.40	6.49	4.41	6.21	3.46	9.06	3.97	12.63	0.86	2.91	2.19	25.30	2.77	3.93	3.40	14.33	13.08	5.46
	N =	60	60	60	60	60	60	60	60	60	60	60	60	60	60	60	60	60	60
Female	Mean	31.86	6.92	4.74	6.79	3.50	10.27	4.54	11.79	0.77	3.14	2.08	27.59	2.71	4.29	3.49	16.54	14.67	5.42
	SD	1.92	0.36	0.46	0.39	0.22	0.54	0.29	1.55	0.15	0.14	0.10	1.44	0.27	0.31	0.31	0.79	0.86	0.62
	Min	27.83	6.25	3.57	6.13	3.13	9.15	4.02	6.52	0.49	2.84	1.89	24.45	2.27	2.98	2.46	15.10	13.38	3.42
	Max	39.02	8.06	5.68	7.95	4.25	12.23	5.86	15.25	1.12	3.50	2.44	33.12	3.45	4.95	4.20	19.08	19.11	6.78
	N =	70	70	70	70	70	70	70	70	70	70	70	70	70	70	70	70	70	70
CYRTACANTHACRIDINAE																			
Patanga luteicornis																			
Male	Mean	48.42	10.29	6.69	9.51	5.37	14.68	5.73	19.09	1.58	4.08	2.76	49.97	4.88	6.51	5.16	26.20	23.71	8.76
	SD	2.62	0.88	0.27	0.57	0.35	0.83	0.40	2.30	0.19	0.11	0.12	2.68	0.39	0.75	0.43	1.65	1.76	0.74
	Min	43.25	9.24	5.74	8.69	4.78	13.48	4.99	13.84	1.18	3.89	2.58	45.85	4.17	5.27	4.38	24.12	21.66	6.99
	Max	53.97	12.20	7.08	10.58	6.11	16.16	7.04	23.27	1.93	4.33	3.05	54.4	5.64	7.94	5.84	29.51	26.88	9.84
	N =	24	24	24	24	24	24	24	24	24	24	24	24	24	24	24	24	24	24
Female	Mean	62.10	12.92	8.21	12.22	6.54	18.49	7.59	21.48	2.10	4.78	3.18	64.18	5.98	8.21	6.87	33.48	30.31	11.11
	SD	4.19	0.72	0.45	0.76	0.29	1.02	0.52	2.71	0.25	0.27	0.12	4.25	0.66	0.83	0.82	1.77	1.54	2.09
	Min	56.74	11.76	6.91	10.87	6.10	16.72	6.26	16.45	1.58	4.12	2.98	54.76	4.72	6.20	5.14	29.88	27.56	9.53
	Max	72.59	14.81	9.13	14.09	7.22	20.69	8.52	25.62	2.67	5.27	3.45	73.73	7.17	10.1	9.18	36.94	33.59	19.70
	N =	21	21	21	21	21	21	21	21	21	21	21	21	21	21	21	21	21	21
Patanga succincta																			
Male	Mean	49.92	10.38	6.86	9.63	5.53	14.85	5.81	21.16	1.55	4.25	2.84	48.66	4.46	5.76	5.04	25.94	23.37	8.99
	SD	1.75	0.46	0.17	0.48	0.36	0.29	0.15	3.37	0.10	0.23	0.12	3.06	0.61	0.55	0.37	1.47	1.29	0.67
	Min	47.35	9.81	6.51	9.05	4.99	14.52	5.62	18.64	1.40	4.04	2.66	42.42	3.67	5.05	4.38	23.70	22.28	8.09

Appendix 1 continued.

Species		BL	FHL	HW	PL	FPL	PHL	PW	AL	WBE	ES (H)	ES (W)	TL	TW (1)	TW (2)	TW (3)	HFL	HTL	HSL
	Max	52.21	11.28	7.03	10.42	5.99	15.30	6.05	27.86	1.71	4.66	2.96	52.37	5.17	6.45	5.47	28.68	26.14	10.03
	N =	7	7	7	7	7	7	7	7	7	7	7	7	7	7	7	7	7	7
Female	Mean	60.08	12.84	8.01	12.03	6.11	17.99	7.39	21.70	2.06	4.53	2.97	62.16	5.72	8.44	6.61	33.50	30.85	10.31
	SD	5.18	1.24	0.74	1.19	0.56	1.53	0.59	3.04	0.36	0.31	0.15	5.91	0.96	0.81	0.77	3.44	3.65	0.72
	Min	49.63	10.44	6.70	9.58	4.95	14.75	6.24	18.97	1.53	4.03	2.68	52.01	4.56	6.39	5.63	27.03	24.16	9.12
	Max	65.79	14.06	8.72	13.00	6.72	19.24	8.16	26.57	2.63	4.83	3.14	68.44	8.00	9.13	7.73	37.33	35.20	11.28
	N =	9	9	9	9	9	9	9	9	9	9	9	9	9	9	9	9	9	9
Valanga nigricornis																			
Male	Mean	46.68	9.76	6.59	10.29	4.81	14.81	5.99	20.13	1.34	4.07	2.71	44.86	4.39	6.48	5.44	25.35	23.71	8.88
	SD	2.51	0.46	0.27	0.51	0.27	0.63	0.32	1.53	0.15	0.21	0.13	2.35	0.43	0.57	0.49	1.24	1.21	0.51
	Min	40.25	8.73	5.98	8.64	4.07	13.05	5.36	16.68	1.01	3.46	2.43	40.42	3.37	5.13	4.56	22.75	20.73	7.38
	Max	55.16	11.72	7.56	12.71	5.55	17.42	7.66	23.70	1.82	4.57	3.03	54.27	5.24	8.53	7.20	30.95	29.66	10.11
	N =	80	80	80	80	80	80	80	80	80	80	80	80	80	80	80	80	80	80
Female	Mean	60.16	12.48	7.92	13.30	5.72	18.67	7.97	22.54	1.86	4.76	2.91	57.83	5.24	8.78	7.13	32.78	31.33	10.41
	SD	4.51	0.56	0.30	0.62	0.39	0.87	0.38	2.07	0.19	0.23	0.12	2.64	0.50	0.56	0.55	1.64	1.57	0.64
	Min	50.99	11.29	7.43	11.88	4.66	16.80	7.12	17.65	1.52	4.16	2.57	51.97	4.19	7.50	5.89	28.92	27.85	7.86
	Max	73.32	13.92	8.76	14.99	6.79	21.03	8.94	27.36	2.51	5.22	3.29	66.06	6.88	10.3	8.51	36.92	35.39	12.24
	N =	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100
OEDIPODINAE																			
Aiolopus thalassinus tamulus																			
Male	Mean	19.05	5.17	3.02	3.53	2.79	6.34	2.85	7.72	0.77	2.09	1.49	18.97	2.42	2.89	2.36	11.27	10.18	3.02
	SD	1.46	0.24	0.19	0.24	0.22	0.33	0.19	0.78	0.11	0.14	0.07	1.14	0.24	0.26	0.18	0.63	0.59	0.34
	Min	15.08	4.74	2.36	3.06	2.30	5.75	2.42	6.16	0.48	1.82	1.32	17.06	2.13	2.34	1.95	10.25	9.35	2.30
	Max	23.02	5.78	3.33	4.02	3.18	7.15	3.50	9.37	1.04	2.38	1.62	21.53	2.91	3.32	2.82	13.00	11.66	3.75
	N =	31	31	31	31	31	31	31	31	31	31	31	31	31	31	31	31	31	31
Female	Mean	25.94	6.65	3.72	4.62	3.50	8.07	3.74	7.36	0.93	2.52	1.68	24.49	2.95	3.71	3.05	14.58	12.96	3.73
	SD	1.31	0.37	0.17	0.28	0.25	0.43	0.20	0.91	0.15	0.13	0.10	1.25	0.30	0.32	0.22	0.77	0.69	0.31
	Min	23.21	5.92	3.30	4.03	2.77	7.14	3.06	5.71	0.66	2.29	1.53	20.96	2.29	3.07	2.49	13.05	11.43	2.83
	Max	29.62	7.56	4.18	5.39	4.11	9.30	4.28	10.20	1.26	2.81	1.95	27.48	3.72	4.78	3.43	15.93	14.48	4.46
	N =	53	53	53	53	53	53	53	53	53	53	53	53	53	53	53	53	53	53

Appendix 1 continued.

Species		BL	FHL	HW	PL	FPL	PHL	PW	AL	WBE	ES (H)	ES (W)	TL	TW (1)	TW (2)	TW (3)	HFL	HTL	HSL
Gastrimargus marmoratus																			
Male	Mean	30.65	7.98	5.15	7.84	3.89	11.42	5.13	12.22	2.10	2.62	2.02	31.89	4.48	5.36	4.68	19.38	18.34	5.32
	SD	4.86	1.12	0.79	0.99	0.66	1.48	0.77	0.76	0.35	0.20	0.17	4.87	0.36	0.87	0.65	2.47	2.27	0.59
	Min	25.46	6.76	4.43	6.60	3.33	10.45	4.48	10.71	1.66	2.33	1.82	27.46	3.93	4.42	3.99	17.14	16.24	4.21
	Max	42.61	10.89	7.15	10.34	5.97	15.64	7.01	13.34	2.97	3.20	2.51	42.21	5.26	7.40	6.56	27.15	25.06	6.94
	N =	25	25	25	25	25	25	25	25	25	25	25	25	25	25	25	25	25	25
Female	Mean	42.36	10.72	6.87	10.42	4.74	14.87	6.96	13.65	2.85	3.15	2.39	41.85	5.14	6.87	5.94	25.90	24.19	6.55
	SD	1.89	0.47	0.37	0.57	0.38	0.64	0.29	0.99	0.18	0.18	0.15	1.84	0.50	0.54	0.65	1.11	1.05	0.55
	Min	39.07	10.02	6.08	8.70	3.90	13.55	6.21	11.43	2.50	2.77	2.03	38.60	4.15	6.00	4.03	23.61	21.70	4.55
	Max	46.21	11.87	7.61	11.46	5.68	16.34	7.61	14.96	3.21	3.49	2.79	46.41	5.99	8.08	6.72	28.26	26.24	7.46
	N =	30	30	30	30	30	30	30	30	30	30	30	30	30	30	30	30	30	30
Heteropternis obscurella																			
Male	Mean	19.79	5.22	3.27	3.64	2.68	6.47	3.16	8.46	0.83	2.13	1.79	17.93	2.10	2.56	2.21	11.41	10.41	3.41
	SD	0.98	0.15	0.09	0.22	0.13	0.27	0.13	0.14	0.05	0.14	0.11	0.74	0.19	0.23	0.20	0.56	0.44	0.59
	Min	18.82	5.09	3.19	3.35	2.55	6.11	2.96	8.33	0.78	2.00	1.68	17.11	1.84	2.36	2.01	10.91	10.00	2.82
	Max	21.12	5.42	3.40	3.86	2.86	6.75	3.24	8.65	0.88	2.32	1.93	18.90	2.32	2.88	2.48	12.19	10.95	4.16
	N =	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4
Female		22.56	6.31	4.07	4.14	3.19	7.37	3.83	9.60	1.06	2.23	2.00	20.77	2.22	3.06	2.55	13.67	12.52	3.67
	N=	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
Locusta migratoria manilensis																			
Male	Mean	34.93	8.74	5.64	7.16	4.46	11.56	5.27	12.33	2.29	2.85	2.10	39.10	4.77	6.03	4.71	20.50	19.05	6.41
	SD	1.88	0.48	0.50	0.28	0.63	0.53	0.19	0.60	0.26	0.14	0.11	2.55	0.66	1.08	0.49	0.72	1.06	0.53
	Min	33.14	8.10	4.96	6.78	3.54	10.99	4.95	11.55	1.89	2.58	1.94	37.27	3.59	4.95	3.94	19.81	17.87	5.98
	Max	38.62	9.53	6.38	7.50	5.60	12.42	5.52	13.08	2.68	2.97	2.23	43.99	5.57	7.69	5.46	21.86	20.60	7.62
	N =	8	8	8	8	8	8	8	8	8	8	8	8	8	8	8	8	8	8
Female	Mean	47.22	11.56	7.62	9.89	5.65	15.38	7.16	15.45	3.08	3.46	2.53	50.38	5.48	7.38	6.09	27.10	24.87	7.13
	SD	2.53	0.77	0.28	0.33	0.37	0.38	0.27	-	0.12	0.12	0.14	1.28	0.53	0.93	0.49	1.14	1.09	0.42
	Min	42.42	10.71	7.24	9.65	5.01	14.92	6.64	15.45	2.97	3.31	2.28	48.58	4.74	6.61	5.23	25.91	23.62	6.65
	Max	49.32	12.55	7.95	10.49	5.99	15.87	7.36	15.45	3.27	3.62	2.64	52.10	6.08	8.79	6.75	28.91	26.44	7.66
	N =	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6

Appendix 1 continued.

Species		BL	FHL	HW	PL	FPL	PHL	PW	AL	WBE	ES (H)	ES (W)	TL	TW (1)	TW (2)	TW (3)	HFL	HTL	HSL
Trilophidia annulata																			
Male	Mean	16.02	4.54	3.04	3.44	2.38	5.84	2.83	7.33	0.91	1.63	1.35	17.71	2.21	2.64	2.21	9.66	8.45	2.86
	SD	0.83	0.17	0.11	0.26	0.16	0.30	0.13	0.78	0.12	0.12	0.09	0.64	0.30	0.28	0.19	0.48	0.38	0.41
	Min	13.84	4.18	2.74	3.03	2.15	5.23	2.66	5.37	0.56	1.46	1.15	16.38	1.78	1.96	1.70	9.04	7.84	1.72
	Max	17.25	4.87	3.19	3.98	2.79	6.44	3.22	8.61	1.10	1.94	1.48	18.85	2.87	3.04	2.55	10.78	9.16	3.40
	N =	24	24	24	24	24	24	24	24	24	24	24	24	24	24	24	24	24	24
Female	Mean	20.74	5.54	3.58	4.16	2.83	7.04	3.54	6.64	1.19	1.83	1.48	21.02	2.38	3.24	2.64	11.35	9.80	3.32
	SD	1.41	0.35	0.22	0.24	0.21	0.39	0.25	0.64	0.15	0.11	0.08	1.21	0.29	0.28	0.24	0.63	0.55	0.33
	Min	15.15	4.19	2.91	3.25	2.29	5.54	2.65	4.52	0.89	1.55	1.28	15.78	1.71	2.41	1.95	9.03	8.04	2.57
	Max	22.76	6.40	3.93	4.58	3.22	7.71	3.89	7.85	1.49	2.13	1.65	23.01	3.06	3.75	3.09	12.16	10.79	3.96
	N =	40	40	40	40	40	40	40	40	40	40	40	40	40	40	40	40	40	40
OXYINAE																			
Oxya hyla intricata																			
Male	Mean	19.47	5.23	2.92	3.99	2.92	6.99	2.69	7.29	0.55	2.37	1.59	17.76	1.62	2.30	1.99	10.89	9.20	3.75
	SD	0.89	0.42	0.40	0.31	0.21	0.33	0.19	1.44	0.09	0.14	0.08	1.17	0.20	0.14	0.16	0.85	0.82	0.54
	Min	18.14	4.60	2.21	3.42	2.54	6.34	2.42	5.68	0.44	2.16	1.48	15.24	1.32	2.02	1.76	9.54	8.24	2.71
	Max	21.38	6.40	3.82	4.93	3.28	7.81	3.23	11.06	0.75	2.71	1.72	19.48	1.91	2.52	2.44	13.66	11.83	5.01
	N =	24	24	24	24	24	24	24	24	24	24	24	24	24	24	24	24	24	24
Female	Mean	24.81	6.58	3.88	5.01	3.70	8.67	3.66	7.04	0.89	2.78	1.69	21.48	1.74	3.08	2.57	13.53	11.56	4.33
	SD	2.80	0.70	0.35	0.66	0.47	1.10	0.39	0.37	0.13	0.19	0.13	3.93	0.29	0.49	0.42	1.83	1.52	0.59
	Min	19.13	5.31	3.12	3.73	3.06	6.68	3.01	6.78	0.75	2.43	1.41	13.01	1.26	2.16	1.66	9.93	8.47	3.26
	Max	28.09	7.68	4.14	5.90	4.40	10.20	4.24	7.30	1.14	3.03	1.79	25.08	2.16	3.82	2.90	16.06	13.54	4.93
	N =	7	7	7	7	7	7	7	7	7	7	7	7	7	7	7	7	7	7
Oxya japonica japonica																			
Male	Mean	20.35	5.29	3.28	4.25	3.05	7.29	2.93	8.50	0.59	2.40	1.64	17.58	1.73	2.46	2.11	12.04	10.38	4.04
	SD	1.49	0.48	0.43	0.35	0.35	0.58	0.26	1.31	0.11	0.25	0.15	1.44	0.20	0.19	0.26	0.99	1.04	0.67
	Min	17.61	4.33	2.51	3.40	2.27	6.06	2.34	6.85	0.42	1.68	1.24	14.05	1.15	2.15	1.53	9.94	8.30	2.09
	Max	23.44	6.53	3.93	5.05	3.72	8.49	3.44	10.95	0.84	2.70	1.89	20.14	2.02	2.93	2.58	13.90	12.20	5.20
	N =	30	30	30	30	30	30	30	30	30	30	30	30	30	30	30	30	30	30

Appendix 1 continued.

Species		BL	FHL	HW	PL	FPL	PHL	PW	AL	WBE	ES (H)	ES (W)	TL	TW (1)	TW (2)	TW (3)	HFL	HTL	HSL
Female	Mean	26.46	6.99	4.17	5.52	3.80	9.31	3.92	7.73	0.86	2.89	1.85	22.51	2.03	3.44	2.79	15.10	13.10	4.79
	SD	1.73	0.51	0.39	0.48	0.33	0.67	0.31	1.43	0.16	0.18	0.12	1.86	0.24	0.33	0.27	1.31	1.26	0.58
	Min	23.29	6.04	3.32	4.70	3.12	8.29	3.40	5.89	0.49	2.48	1.58	15.75	1.52	2.66	2.21	13.26	10.98	3.16
	Max	31.27	8.39	5.04	6.92	4.74	11.48	4.87	11.19	1.33	3.34	2.21	27.32	2.86	4.53	3.59	18.98	17.06	6.21
	N =	104	104	104	104	104	104	104	104	104	104	104	104	104	104	104	104	104	104
Pseudoxya diminuta																			
Male	Mean	16.24	4.53	3.03	3.71	2.48	6.15	2.69	5.42	0.47	2.22	1.48	8.19	0.80	1.99	1.64	9.99	8.65	3.27
	SD	1.03	0.48	0.25	0.26	0.19	0.35	0.16	0.57	0.14	0.13	0.08	0.85	0.21	0.19	0.14	0.68	0.52	0.35
	Min	14.48	2.63	2.30	3.29	2.07	5.51	2.44	4.07	0.27	2.00	1.35	6.94	0.35	1.64	1.29	8.96	7.75	1.94
	Max	18.81	5.60	3.50	4.57	2.96	7.14	3.27	6.31	0.90	2.53	1.70	10.72	1.27	2.48	1.89	11.77	10.25	3.65
	N =	27	27	27	27	27	27	27	27	27	27	27	27	27	27	27	27	27	27
Female	Mean	21.74	5.95	3.78	4.83	3.04	7.80	3.56	5.58	0.66	2.63	1.59	10.81	1.02	2.79	2.19	12.79	11.23	4.04
	SD	1.19	0.25	0.18	0.26	0.24	0.41	0.16	0.79	0.15	0.13	0.10	1.55	0.30	0.23	0.19	0.64	0.59	0.37
	Min	19.39	5.42	3.25	4.47	2.50	7.11	3.16	3.69	0.41	2.27	1.37	8.79	0.51	2.31	1.85	11.52	10.12	2.87
	Max	24.62	6.71	4.21	5.43	3.73	8.97	4.04	7.22	1.27	2.98	1.82	16.55	2.14	3.58	2.83	14.53	12.64	4.86
	N =	68	68	68	68	68	68	68	68	68	68	68	68	68	68	68	68	68	68