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Systematics within the Zopheridae Complex (Coleoptera: Tenebrionoidea).

Nathan Lord

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SYSTEMATICS WITHIN THE ZOPHERID COMPLEX
(COLEOPTERA: TENEBRIONOIDEA)

by

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DISSERTATION
Submitted in Partial Fulfillment of the Requirements for the Degree of

Doctor of Philosophy
Biology

The University of New Mexico
Albuquerque, New Mexico

December, 2013
DEDICATION

I dedicate this work to my grandmother, Marjorie Heidt, who always encouraged me to follow my passions. Thank you, Grandma. You were the best.
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ABSTRACT

The Ironclad Beetles, Cylindrical Bark Beetles, and Monommatid Beetles are a cosmopolitan family with over 1,700 species worldwide. Now constituting members from three previous families (Zopheridae, Monommatidae, Colydiidae), Zopheridae represent a wide array of morphological diversity and variability. Larvae of most members are fungivores/detritovores, while some are suspected of boring into sound wood. Adults are predaceous or fungivores, and some zopherids have been linked to the spread of fungal disease. Morphologically, adults are hard to separate from other tenebrionoid families. Zopherids can be distinguished by 9-11 segmented antennae with a usually abrupt, 1-3 segmented club, antennal insertions concealed from above, closed mesocoxal cavities, 4-4-4 or 5-5-4 tarsal formula, heteromeroid trochanters, and a tenebrionoid aedeagus.

Systematically, the constitution and classification of Zopheridae is not yet settled, and the monophyly of the group with respect to other members of the Tenebrionoidea is in question. The research that follows attempts to rectify the classification of this
taxonomically challenging group by investigating the relationships within and among zopherid members, as well as provide useful tools for the identification of these difficult little brown beetles.

In Chapter 1, I present IroncladID: A Tool for Diagnosing Ironclad and Cylindrical Bark Beetles (Coleoptera: Zopheridae) of North America north of Mexico. This is an interactive electronic key designed to aid in the identification of adult Ironclad and Cylindrical Bark Beetles. A web interface was constructed to house a number of resources for the diagnosis of zopherid beetles including a specially-built Lucid interactive key (available from http://coleopterasystematics.com/ironcladid/index.html). Appendices A–F are located in the Appendices section of this document. Appendix F contains the USDA Announcement for IroncladID and is available as a supplementary file via LoboVault. See PDF titled “Appendix_F_USDA_Announcement”.

In Chapter 2, I present an Illustrated Catalogue and Type Designations of the New Zealand Zopheridae (Coleoptera: Tenebrionoidea). This comprehensive catalogue to the New Zealand members of the family Zopheridae was produced in an effort to stabilize the nomenclature preceding extensive revisionary taxonomy within the group. A checklist of the 17 New Zealand zopherid genera and an account for each of the 189 species (by current combination) is provided. Appendix G contains the figures 1–421 for Chapter 2 and is available as a supplementary file via LoboVault. See PDF titled “Appendix_G_Figures_Chapter2”.

In Chapter 3, I present a Phylogenetic Analysis of the Ironclad and Cylindrical Bark Beetles of the World (Coleoptera: Tenebrionoidea: Zopheridae). I inferred the first molecular phylogenetic hypothesis for Zopheridae. Portions of three genes (28S rDNA,
cytochrome c oxidase I and histone III) were analyzed. One hundred eighty three zopherid species were included, representing 2/2 subfamilies, 15/15 tribes, and more than half of the currently recognized genera. Twelve outgroup taxa from eight other families of Tenebrionoidea were included. Parsimony and partitioned Bayesian analyses were performed on the combined data set. In both phylogenetic analyses, Zopheridae was not recovered as monophyletic. The subfamily Zopherinae was not recovered as monophyletic in both analyses, and the subfamily Corticariinae was recovered as monophyletic only in the Bayesian analysis. Appendix H contains the figures 1a–2d for Chapter 3 and is available as a supplementary file via LoboVault. See PDF titled “Appendix_H_Figures_Chapter3”.

In Chapter 4, I present Novel Microscopy Techniques Reveal Multiple Evolutionary Origins of Metal Incorporation into Mandibles of the Megadiverse Beetles (Coleoptera). A broad survey of presence/absence of mandibular metals across the order Coleoptera was conducted. To test for phylogenetic signal and evolutionary correlation between presence/absence of metals and adult mandibular use, we constructed a phylogeny under a Bayesian framework from a subsampling of a pre-existing dataset (Hunt et al. 2007), performed discrete statistical analyses on character evolution via _BayesTraits Discrete_ (Pagel et al. 2004), and performed ancestral state reconstructions under both Parsimony and Bayesian frameworks via _Mesquite_ (Maddison and Maddison 2011) and _BayesTraits Multistate_ (Pagel et al. 2004). Resultant patterns of metal incorporation were strongly correlated with adult mandibular use and appear to have originated several times throughout Coleoptera. Additionally, the location and types of cuticular metals are demonstrated to be potentially valuable characters for taxonomic
diagnoses. Appendix I contains the figures 1–17 for Chapter 4 and is available as a supplementary file via LoboVault. See PDF titled “Appendix_I_Figures_Chapter4”.

Appendix J contains the supplementary ESEM-EDS mandibular scans and is available as a supplementary file via LoboVault. See PDF titled “Appendix_J_EDS_Chapter4”.

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INTRODUCTION

Zopheridae are a worldwide group of small, litter-dwelling or subcortical beetles that exhibit tremendous morphological diversity. Members of the Zopheridae are thought to include both economically beneficial and harmful insects, as several genera (Colydium, Aulonium, Nematidium) are predaceous as both larvae and adults of destructive wood-boring insects, while others have been documented to transmit crop-destroying fungi (Ivie 2002a, b, c; Ślipiński and Lawrence 1997). Thus, studies of the taxonomy and natural history of the group is of economic relevance. Before the economic impact of these beetles can be adequately assessed, however, several major problems persist. As proposed by Ślipiński and Lawrence (1999), Zopheridae (sensu novo) contains three previously separate families: the ironclad beetles (Zopheridae=Zopherinae s.n.), the monommatid beetles (Monommatidae=Zopherinae s.n.), and the cylindrical bark beetles (Colydiidae=Colydiinae s.n.) (for classification history of the groups, see Ślipiński and Ivie, 1990: 2–4). As currently constituted, Zopheridae contains nearly 180 genera, 15 tribes, and over 1,700 species (Ślipiński and Lawrence 2010). Despite their relative diversity and decent amounts of taxonomic attention by previous workers, the monophyly of the family is still strongly questioned. Seemingly few characters unite the groups included in Zopheridae, often making identification of its members quite difficult. In reference to the identification of North American Coleoptera, Ivie (2002a: 445) states: “However if it has 4-4-4 tarsi and doesn’t fit somewhere else, try this family.” Only two comprehensive catalogues to these groups exist: Hetschko (1930) and Ivie and Ślipiński (1990). Hetschko’s catalogue validated the assertion of the group as a “wastebasket taxon” (Lawrence 1980: 305), as his concept of the family was later shown to contain
members from ~85 genera across 14 other families of Coleoptera not currently recognized as Zopheridae (Ivie and Ślipiński 1990: 16-18). Ivie and Ślipiński’s catalogue rectified many issues on the generic level, but higher-level groups remained problematic.

In order to address some of the persistent issues revolving around this family, I conducted several independent studies to 1) aid in positive identification of the North American Zopheridae, 2) stabilize the nomenclature of an important New Zealand subset Zopheridae, and 3) construct the first molecular phylogeny of the group in an effort to eludicate relationships between and among members of Zopheridae and other tenebrionoid families. Additionally, a fourth study of a more general scope was conducted on the presence/absence of mandibular metals in beetles.

Chapter 1 introduces IroncladID, an interactive key to the genera and species of North American Zopheridae. A web interface was constructed to house a number of resources for the diagnosis of zopherid beetles including a specially-built Lucid interactive key (available from http://coleopterasystematics.com/ironcladid/index.html). Taxonomic coverage includes 37 genera and 112 species of North American zopherids, representing all known members from the region. The purpose of this tool is to assist non-experts in the identification of a difficult but oft-encountered little brown beetle group. This work was funded by the Center for Plant Health Science and Technology (CPHST), Animal and Plant Health Inspection Service (APHIS), and the U.S. Department of Food and Agriculture (USDA).

Chapter 2 introduces an illustrated catalogue to the New Zealand Zopheridae. A checklist of the 17 New Zealand zopherid genera and an account for each of the 189 species (by current combination) is provided. Type material for nearly all species was
examined, and type specimens are designated herein (89 confirmed holotypes, 103 lectotypes, 283 paralectotypes). Images of all primary type specimens and labels examined are provided. *Pycnomerus sulcatissimus* Sharp, 1886 is a junior synonym and secondary homonym of *Pycnomerus sulcatissimus* (Reitter, 1880). One replacement name is proposed, *Chorasus beckae* nom. nov., for *Chorasus subcaecus* (Broun), and 24 new combinations are given.

Chapter 3 introduces the first molecular phylogenetic analyses of the family. Portions of three genes (28S rDNA, cytochrome c oxidase I and histone III) were analyzed. One hundred eighty three zopherid species were included, representing 2/2 subfamilies, 15/15 tribes, and more than half of the currently recognized genera. Twelve outgroup taxa from eight other families of Tenebrionoidea were included. Parsimony and partitioned Bayesian analyses were performed on the combined data set. In both phylogenetic analyses, Zopheridae was not recovered as monophyletic. The subfamily Zopherinae was not recovered as monophyletic in both analyses, and the subfamily Corticariinae was recovered as monophyletic only in the Bayesian analysis.

Chapter 4 introduces a broad study of metal incorporation in beetle mandibles across the order, correlated with a known phlogeny and mandibular use. Using a novel combination of microscopy instrumentation and analytical techniques, we demonstrate the ability to rapidly and inexpensively visualize and analyze elemental incorporation and composition. Utilizing these techniques, we investigated metal incorporation within the mandibles of 117 taxa across the megadiverse order Coleoptera. Several lineages were found to incorporate zinc or manganese into various locations on the mandibular surface. To test for phylogenetic signal and evolutionary correlation between presence/absence of
metals and adult mandibular use, we constructed a phylogeny under a Bayesian framework from a subsampling of a pre-existing dataset (Hunt et al. 2007), performed discrete statistical analyses on character evolution via BayesTraits Discrete (Pagel et al. 2004), and performed ancestral state reconstructions under both Parsimony and Bayesian frameworks via Mesquite (Maddison and Maddison 2011) and BayesTraits Multistate (Pagel et al. 2004). Resultant patterns of metal incorporation were strongly correlated with adult mandibular use and appear to have originated several times throughout Coleoptera.

Literature Cited


CHAPTER 1

IroncladID: A Tool for Diagnosing Ironclad and Cylindrical Bark Beetles

(Coleoptera: Zopheridae) of North America north of Mexico.


Appendices A–F are located in the Appendices section of this document. Appendix F contains the USDA Announcement for IroncladID and is available as a supplementary file via LoboVault. See PDF titled “Appendix_F_USDA_Announcement”.

Abstract

IroncladID, an interactive tool for the identification of Ironclad and Cylindrical Bark Beetles of North America north of Mexico is presented herein. Ironclad ID is an interactive electronic key designed to aid in the identification of adult Ironclad and Cylindrical Bark Beetles, a large, worldwide group of diverse, subcortical beetles thought to include both harmful and beneficial species. A web interface was constructed to house a number of resources for the diagnosis of zopherid beetles including a specially-built Lucid interactive key (available from http://coleopterasystematics.com/ironcladid/index.html). Taxonomic coverage includes 37 genera and 112 species of North American zopherids, representing all known members from the region. The purpose of this tool is to assist non-experts in the
identification of a difficult but oft-encountered little brown beetle group. This work was funded by the Center for Plant Health Science and Technology (CPHST), Animal and Plant Health Inspection Service (APHIS), and the U.S. Department of Food and Agriculture (USDA).

**Introduction**

The beetle family Zopheridae is a cosmopolitan group consisting of two subfamilies (Zopherinae and Colydiinae), 190 genera, and ~1,700 species. The current family is composed of members of 3 separate, previously recognized families: Colydiidae, Zopheridae, and Monommatidae. Members of Zopheridae previously resided within the family Tenebrionidae, but were raised to family rank by Böving and Craighead (1931). The bulk of the diversity lies within the subfamily Colydiinae (1,000+ species), where the generic and tribal concepts are still in a state of flux (Ślipiński and Lawrence 2010). The only major family-level analyses were conducted by Lawrence (1994) and Ślipiński and Lawrence (1999). Much work is needed to solidify the higher level classifications within the family, as well as the specific placement of Zopherinae and sister-group relationships within the Tenebrionoidea.

**Biology:** Ironclad and Cylindrical Bark Beetles are usually found under bark of dead or dying trees or in the surrounding litter. Some members are strictly found on conifers, others on hardwoods, and a number on both. Many of these beetles are cylindrical in shape and are frequently found in the holes or passages bored by other insects. Members of the Zopheridae are thought to include both economically harmful and beneficial insects.
**Risk Taxa:** Several zopherid groups may also be destructive, with members frequently associated with particular fungi known to harm or kill valuable hardwood trees. It is speculated that these beetles may play a critical role in the spread of these fungal diseases. *Colobicus parilus* is frequently found on stored roots and fruits and is suspected to transmit Diplodia (Coelomycetes) to yams, sweet potatoes, cassava and citrus. This species is imported in commercial shipments of stored goods (Hinton 1945). *Phloeodalis reitteri* has been recorded as the carrier of *Fusarium moniliforme* var. *subglutinans*, the fungal species causing pineapple gum disease. It has been shown that pineapple crop losses are unusually high when large numbers of the beetle are present, and, when artificially infested with adults, fruits in the flowerings stage rotted in 100% of cases. Several genera (*Bitoma, Synchita, Microsicus, Paha*) are frequently found on dead or dying trees associated with *Hypoxylon*, a fungus that kills many valuable hardwood trees throughout the US. It is possible these beetles play a role in the introduction or transportation of the fungus, although this needs further examination (Stephan 1989). The larvae of several other zopherid groups (*Usechini, Phellopsis*) bore into soft wood in search of fungus. The genera *Phloeodes* and *Zopherus* (*Zopherini*) also have anatomical modifications as both larvae and adults that suggest the ability to bore into sound wood, many having been collected on or under the bark or roots of *Populus, Morus, Cayra, Pinus, Juniperus*, and *Quercus*. These beetles may pose a potential hazard to lumber products. Due to the subcortical, saprophagous/mycophagous nature of these beetles, it is very possible the introduction and subsequent establishment of foreign taxa will be a common occurrence.

**Beneficial Taxa:** Several genera (*Colydium, Aulonium, Nematidium, Lasconotus*)
are frequently encountered in the bored tunnels of platypodine and scolytine ambrosia beetles (*Scolytus, Ips, Dendroctonus* spp.). These genera (and no doubt numerous others) are thought to be predaceous as both larvae and adults on these destructive beetle pests, serving as potential biological control agents (Ivie 2002a; Ślipiński and Lawrence 2010; Stephan 1989).

**Geographic Distribution:** Ironclad and Cylindrical Bark beetles are distributed worldwide, with highest diversity in the Neotropics and Australasia. In North America, 37 genera and ~112 species are known to occur. In the United States, zopherids are found in every state. In Canada, zopherids occur in all provinces and territories except for Yukon, Nunavut, Nova Scotia, Prince Edward Island, and Labrador (Newfoundland) (Ivie 2002).

Accurate identification of zopherid species or even genera is often difficult due to the lack of available resources. This tool was constructed as an attempt to remedy this issue. IroncladID includes an interactive Key to Genera & Species, Genus Fact Sheets, species diagnoses, and hundreds of images to aid in the identification of Ironclad and Cylindrical Bark Beetles found in North America north of Mexico. Upon completion, the tool was peer reviewed by a number of taxonomic experts and then released for distribution. This tool is currently included in the larger USDA Wood Boring Beetle Resource, a comprehensive resource of identification and screening tools for wood boring beetles of the world (available from: http://wbbresource.org/).

**Materials and Methods**

*Web-Based Interface*
Web Site: A web site was constructed to serve as the web-based interface for IroncladID. Individual pages contain general information on Zopheridae including biological information, diagnostic features of zopherid subfamilies and tribes, geographic distribution, and taxonomy. The website also includes access to the Lucid key, explanations of how to run the key, feature/state definitions, genus fact sheets, an extensive gallery, a morphological atlas, a glossary, complete references, and supplemental material. The website is available from the following address (last updated 05 June, 2011): http://coleopterasystematics.com/ironcladid/ All web design and code was written by EHN.

Lucid Key: A Lucid key to the genera and species of North American Zopheridae was constructed in LucidBuilder v.3.5. Potential morphological characters suitable for key construction were taken from the literature and improved upon via specimen study. In an attempt to account for morphological variability within and between genera and species, roughly 1,000 specimens were loaned from the United States National Museum (USNM – Washington, D.C., USA) and the Florida State Collection of Arthropods (FSCA – Gainesville, FL, USA). Exclusively external morphology was used, as an important feature of the Lucid framework is the selection and construction of characters, terminology, and keys as to optimize utility and ease-of-use to a broad audience of non-specialists. The external morphology was scored for nearly all species according to the key features and states. Species not available for study were scored from the literature. The LucidBuilder matrix is available upon request. Before you start the key, please visit the Ironclads and Cylindrical Bark Beetles page. Also, the key assumes that you have
access to a dissecting microscope with strong lighting. This is needed in order to see the morphological details such as the antennal club, elytral ornamentation, etc.

**Fact Sheets:** Fact sheets were created for each genus. A fact sheet includes a diagnostic description, similar genera, known distribution within North America north of Mexico, biology/natural history (if known), relative abundance, a list of North American species, species diagnoses and distributions (if more than one species present), discussion, potential problems with identification, and selected references. Information for the fact sheets was compiled from the literature, specimens, specimen label data, and personal observations and collection by NPL.

**Gallery / Imaging:** Color habitus images were captured using a Visionary Digital™ Passport and BK Plus imaging systems equipped with a Canon 40D and/or 7D DSLR camera. Image stacks were montaged in Zerene Stacker v.1.04 (Zerene Systems LLC, Richland, WA, USA). Images were edited in Adobe Photoshop CS5 v.12.0.4. Dorsal habitus images were taken for all genera and nearly all species of North American Zopheridae and are displayed in a gallery arranged by genus. An images of each species is also linked on the genus fact sheets, as well as the Lucid key entities (viewable during key operation).

**Morphological Atlas / Illustrations:** Line drawings were digitally rendered in Adobe Illustrator CS5, v.15.0.2 (Adobe Systems, Inc., San Jose, CA, USA). A morphological atlas was constructed to aid in the identification and recognition of major morphological structures of a typical zopherid utilized in the key (*Zopherus* illustrated).

Lucid3 System Requirements
The interactive key to the ironclad and cylindrical bark beetles is a Lucid3 Java Applet. Lucid3 (Lucid version 3) is software for creating and using interactive identification keys. Lucid was developed by the QAAFI Biological Information Technology at the University of Queensland in Australia. Visit the Lucidcentral website for more information on Lucid and Lucid3.

HTML pages in Ironclad ID outside of the Lucid3 interactive key are viewable without the Lucid3 Applet Player. Please check the Lucid3 system requirements below if you would like to use the interactive key.

**Operating System:** Windows 2000 (SP3)/XP/Vista, Mac OSX 10.4 or greater, Linux (that supports J2RE), Solaris 7-10. (The key will run on Windows 98/ME/NT4 but these platforms are no longer supported.)

**System Memory:** 256MB RAM (512MB or greater recommended).

**Web browser:** Java-enabled web browser such as Internet Explorer, Firefox, Chrome, or Safari. Note: You may need to adjust your browser settings to allow pop-ups and active content (this particularly applies to Internet Explorer) when viewing the key as a Java applet.

**Hard Drive Space:** 150MB if running tool from hard drive (excluding space required for Java Runtime Environment and web browser).

**Software:** The Lucid3 interactive keys will run embedded within a web browser as a Java applet Player. Java Runtime Environment (JRE) version 1.4.2 (1.5 or greater recommended) must be installed on your computer for the Lucid3 Applet Player to run successfully.
How to Use This Key

**Structure and format:** The Lucid interactive key is a Java applet embedded in an HTML page. For information about Java and other computer settings required in order to use the key, see the System Requirements page.

The Lucid key has four panels. Each feature in the Features Available panel is listed above two or more of its states (also referred to as feature states). For example, "straight or nearly so" and "at least slightly curved" are two states of the feature "Antennomere III shape." Depending on the viewing mode, each state is shown alongside or under a state illustration or icon. State illustrations are indicated by icons, thumbnails, or gallery view, depending on the display options you choose under Features > Display. Once a state has been chosen, it will appear in the lower left Features Chosen panel. The taxa that match the chosen features are displayed in the upper right Entities Remaining panel, while those that do not will be moved to the Entities Discarded panel in the lower right corner.

Each genus in Entities Remaining (possible genera) is linked to an HTML fact sheet page containing informational text and images. This page is indicated by a grey icon to the right of the image or image icon. Each genus is also linked directly to a lateral view image of that entity. Images for each genus are indicated by icons or thumbnails, depending on the display options you choose.

**NOTE:** web pages such as fact sheets attached to items in Lucid v 3.4 interactive key matrices may be considered pop-ups by certain browsers (such as Internet Explorer [IE]) when clicked on by users. If your browser blocks these pop-ups, in your browser's Internet settings you should change the settings to allow pop-ups for this Lucid tool.
Additionally, Internet Explorer may block "active content" on web pages or interactive keys. To allow active content: in Internet Explorer under Tools, Internet Options, Advanced tab, Security category, the box next to the setting "Allow active content to run in files on My Computer" should be checked. Additionally, certain settings under Tools, Internet Options, Security, Custom level, ActiveX controls and plug-ins, may need to be changed depending on your computer settings.

Clicking on an image thumbnail or icon (or, if in state gallery view, on the small corner square within the gallery thumbnail) opens an image window. This image window provides access to all images linked to that taxon or state, as well as to images linked to other taxa or states, via arrows and indices in the image window toolbar.

**Making an identification: recommendations for using the interactive key:** The first suggested step to take is to go to the Ironclads > Diagnostic Features page. Using simple characters, this page shows how to confirm your specimen is an ironclad and not something similar. Once you know that your specimen is an ironclad, you can proceed to the key.

A good way of proceeding into the key is to select what you believe is a strong character in your subject. You may also choose to use Lucid's "Best" mode, which will take you to the feature that will most effectively reduce the number of entities remaining. For this, go to "Features" and select "Best" from the menu, or select the "magic wand" icon in the menu bar. The features are organized (top to bottom) by body, head, thorax, elytra, wings, legs, and abdomen.

For convenience, technical terms used in this tool are defined in the glossary.
however, users may find it worthwhile to familiarize themselves with general morphological features such as antennal club, elytra, pronotal disc, and so on, prior to starting the key. Understanding these terms will allow the user to navigate more effortlessly though the identification of a specimen. Note: this page adapted from Bark Beetle Genera of the United States.

“Best” mode: In order to allow for the fastest identification possible, it is strongly encouraged the user make use of the "Best" feature in the Lucid3 player. This button (located on the top tool bar, represented as a magic wand) automatically selects the "best" character for you to use. Once selected, the key will automatically jump to the next "best" character, re-calibrated due to your previous selections.

Limitations of the Key: This key has been constructed for identifying all genera and species of Ironclad and Cylindrical Bark Beetles known to occur in North America north of Mexico. This key does not include taxa known to occur in Mexico. It is very possible (and likely) additional zopherid taxa have been and will be introduced into or discovered within North America. If you believe you have a specimen that does not properly key to a listed entity, please contact the key author.

Feature / State Explanations

Occasionally, a character is presented that may be too difficult, may not be visible, or perhaps may not be known for a given specimen (e.g., the head has fallen off, or there is no locality data, or it is a "male" character and you are unsure of the sex). In
these situations, it is advisable to select the "Next best" button and skip to the next best feature remaining. This course of action is preferred over guessing at the states of features if you are unsure. Given below are definitions and explanations for the features and states that may be interpreted differently and/or sometimes appear ambiguously.

**GEOGRAPHIC OCCURRENCE**

**Regional occurrence:** this is based on an observation by Karl Stephan (1989) that while many of the genera are widely distributed throughout North America, the vast majority of the species either occur on the eastern or western side of the 100th meridian. This is a very useful distributional character. The 100th meridian passes through more or less the center of North Dakota and South Dakota, the western 1/3 of Nebraska and Kansas, the handle of Oklahoma, and the western 1/3 of Texas (see image).

**State occurrence:** this character is only scored for the taxa where occurrence in a particular state or states within the United States aids in identification. This scoring is by no means comprehensive and should not necessarily be used to completely eliminate taxa, as new distributions will undoubtedly be discovered.

**BODY**

**General Shape:** Elongate, cylindrical is defined as the length being several times the width of the beetle, and there is little question of the cylindrical nature (e.g. *Nematidium, Eudesma, Lobogestoria, Antilissus*).

*Flattened or sub-depressed* is defined as the body not distinctly elongate and
cylindrical, but not dorsally and ventrally convex. This is the standard state for most of
the Zopheridae of this region, and encompasses a variety of forms.

*Oval, dorsally and ventrally convex* is defined as distinctly oval or elliptical in
shape with the lateral margins nearly evenly curved throughout, and both dorsal and
ventral surfaces exhibiting some degree of convexity. This is found within the
Monommatini (*Hyporhagus, Spinhyporhagus*, and *Aspathines*).

**HEAD**

*Antennae*

**Antennal club – Number of segments:** The antennal club is here defined as beginning
with the antennomere that is a departure in size or shape from the previous antennomeres.
While the club segments may be indistinct in some (*Rhagodera*), usually the 9th, 10th, or
11th antennomere is greatly enlarged or of a different shape than the preceding segments.
In some taxa (e.g. *Eucicones*), the terminal segment bears an annulation in which the
apical half is densely setose. This setose portion may be mistaken for a distinct segment,
but should not be scored as such. To define separate segments, there should be a very
clear line separating antennomeres from one another, and generally a difference in size of
the club segments, with the connecting margins not completely flush
(e.g. *Lobogestoria, Endeitoma*).

**Antennal club – structure:** *Loose* is defined as the club segments not completely
abutting one another, with the connecting margins not completely flush. The segments
may be very loose (e.g. *Rhagodera*) to slightly loose (e.g. *Coxelus*). All taxa with a 1-
segmented club were scored as "compact."

Compact is defined as the club segments completely abut one another, the connecting margins being completely flush (e.g. *Acolobicus*). If one antennomere is distinctly smaller than the other but flush with the preceding (e.g. *Endeitoma*), this was scored as "compact."

**Mouthparts**

**Labial palpi insertion – separation:** Approximate is defined by the insertions of the labial palpi being nearly approximate, with little discernable space between each palpus that the base. This is the most common state for the group (e.g. *Nematidium*).

Moderately to widely separated is defined by the bases of the labial palpi being distinctly separated from one another (e.g. *Phloeodes*).

**Head Capsule**

**Antennal groove beneath eye – Presence:** Antennal groove absent is defined as lack of a clear, well-delimited groove or channel below the eye in which the antennae rests when retracted. Several taxa (e.g. *Coxelus*) have a raised subgenal brace and a clearly protruding eye, but the space between the eye and subgenal brace is wide and slightly depressed. This is not considered an antennal groove because it is not delimited. Other taxa have a clearly delimited antennal groove/cavity on the prothoracic hypomeron, but no distinct groove on the head capsule itself (e.g. *Usechus, Usechimorpha, Zopherus*). In this case, the antenna rests across the eye and then fits into the hypomeral antennal groove.
Antennal groove present is defined as the presence of a clear, well-delimited groove or channel below the eye in which the antennae rests when retracted. This groove may be short or long, extending to hind margin of eye or beyond (e.g. *Eucicones, Acolobicus*), straight or curved. In some, the antennal groove is simply a clearly depressed (but defined) area near the antennal insertion.

Eyes

**Eye facets:** Eye facets fine is defined as the individual eye facet not distinctly protruding, eye facets more or less forming a smooth surface.

Eye facets coarse is defined as the individual eye facet distinctly protruding, eye facets more or less forming a rough, raspberry like surface.

THORAX

**Prothorax – Pronotum**

**Mid-lateral secretory pore:** Pronotum with obvious mid-lateral secretory pore is defined as the presence of a clear pore near the lateral margin of the pronotum at middle. This pore secretes an exudate which aids in the adherence of debris to the dorsal surface, therefore the specimen must be thoroughly cleaned for the pore to be visible. This character is only present in two genera (*Lobogestoria, Antilissus*)

Pronotum without mid-lateral secretory pore is defined as no such pore being present.

**Pronotal width – anterior and posterior:** Pronotum distinctly wider anteriorly than
basally is defined by the anterior portion of the pronotum greatly expanded, or the pronotum tapering strongly towards the base. This should not be scored if the lateral margins are arcuate with the anterior portion only slightly wider than basal portions.

Pronotum subquadrate or distinctly wider basally than anteriorly is defined as the pronotal width being nearly equal or distinctly wider basally than anteriorly. This should be scored if the lateral margins are arcuate with the anterior or basal portion slightly wider than opposite portions.

Sublateral carinae on pronotal disc – presence: Pronotum with paired sublateral carinae is defined by the presence of a distinct pair of carinae located sublaterally on the pronotal disc. Most often, these carinae are straight to subtly curved to slightly sinuate, but never complexly sinuate or forming an interlacing network (as in Sesaspis, Lasconotus).

Pronotum lacking paired sublateral carinae is defined by the absence of a distinct pair of carinae located sublaterally on the pronotal disc. In cases where the pronotal carinae (if present at all) are complexly sinuate or forming an interlacing network (as in Sesaspis, Lasconotus), this was scored as lacking.

Metathorax – Metacoxae

Metacoxal separation: Metacoxae nearly contiguous or narrowly separated, intercoxal process usually acute is defined at the distance between the metacoxae distinctly less than 0.75x the width of one coxa.

Metacoxae moderately to widely separated, intercoxal process usually broadly
rounded to truncate is defined at the distance between the metacoxae around or more than 0.75x the width of one coxa.

ELYTRA

Elytral ornamentation: Elytra without carinae or tubercles is defined as the lack of distinct, cuticular carinae and/or tubercles on the elytra. Raised areas of setae are not considered tubercles, and elytral intervals that are slightly elevated (but not distinctly raised or keeled, as in some Lasconotus) are not considered carinate.

Elytra with carinae or tubercles is defined as the presence of distinct, cuticular carinae and/or tubercles on the elytra. In some taxa (e.g. some Lasconotus), suberect setae that converge at the elytral margins may give the impression of underlying carinae, but in fact are not. There must be distinct tubercles or well-defined carinae for the state to be scored.

Elytra color/pattern – presence: Elytra solid colored, patterned is defined as the cuticle of the elytra unicolorous, not creating a distinct, clearly visible pattern, regardless of setae color.

Elytra bi-colored and with patterns/maculations is defined as the cuticle of the elytra varying in color to create a distinct, clearly visible pattern. Setae that are lighter or darker in color than the elytra and form a pattern should not be scored.

LEGS

Protibia – spine: Apex of protibia without stout, apical spine(s) is defined as lacking any
sort of distinct, stout, curved spine or pair of straight, stout spines.

**Apex of protibia armed with single, stout, curved apical spine** is defined as having such spine (e.g. *Aulonium*, *Colydium*, *Lasconotus*, *Nematidium*). Generally the spine is as long as or slightly longer than the first tarsomere. For taxa in which the apex of the protibia bears a single short spine or row of spines, these should not be scored for this state.

**Apex of protibia armed with two subequal, short, stout, straight spines**: In some taxa (most Zopherini), the apex of the protibia (and usually all tibia) bears a single or pair of straight, short, stout spines. These are distinct from the previous state in that they are shorter, paired, and not distinctly curved.

### Identifying Ironclad and Cylindrical Bark Beetles

The family Zopheridae is an extremely diverse assemblage of beetles that, at one time or another, have been a part of 3 separate families (Monommatidae, Zopheridae, Colydiidae). Due to this tremendous heterogeneity, it can often be difficult to correctly identify a zopherid based on any consistent set of diagnostic features. In general, zopherids possess the following features: antennae 9-11 segmented with a usually abrupt, 1-3 segmented club, antennal insertions concealed from above, closed mesocoxal cavities, 4-4-4 or 5-5-4 tarsal formula, heteromeroid trochanters, and a tenebrionoid aedeagus (male genitalia). Due to the great diversity within the group, it is useful to state the diagnostic features of the subfamilies and tribes found in North America to better help separate identifiable groups. Note: the characters listed can be regarded as superficial and cannot be applied to all members of the group on a worldwide scale. The characters given
below should be used strictly for the fauna found in North America.

**Colydiinae**: 4-4-4 tarsi (also found in *Pycnomerus* in Zopherinae) (sometimes appearing 3-3-3), antennal insertions concealed from above, antennae 10- to 11-segmented with an abrupt 1-3 segmented club, open procoxal cavities (most) or with closed procoxal cavities (some; if closed, then apex protibia bearing a stout, curved spine); procoxae usually narrowly separated.

**Zopherinae**: 5-5-4 tarsi (except 4-4-4 in *Pycnomerus*), closed procoxal cavities (most); procoxae usually broadly separated; eyes narrower, extending well onto dorsal surface of head (except eyes round in *Pycnomerus*).

**Colydiinae**

Tribe: **Colydiini**: Includes the North America genera *Aulonium* and *Colydium*.

Diagnostic features: With paired, lateral carinae on pronotum; eye emarginated, with canthus (also in some Synchitini); apex of protibia bearing a stout, curved spine; antennae 11-segmented with 3 segmented antennal club; procoxal cavities closed.

Tribe: **Synchitini**: Includes the North American genera *Acolobicus, Antilissus, Bitoma, Colobicus, Coxelus, Denophloeus, Endeitoma, Eucicones, Eudesma, Lasconotus, Lobogestoria, Lyreus, Megataphrus, Microprius, Microsicus, Namunaria, Neotrichus, Paha, Phloeonemus, Pseudocorticus, Stephaniolus, Synchita*.

Diagnostic features: This is a very diverse group and difficult to diagnose. In most cases, apex of protibia lacking a stout, curved spine (except present in *Lasconotus*); antennae 10-
11 segmented with a 1- or 2-segmented club (3-segmented in *Lasconotus*, some *Bitoma*); antennae lacking scale-like setae; procoxal cavities open (closed in *Lasconotus*).

Tribe: **Adimerini**: Includes the North America genus *Monoedus*.
Diagnostic features: Tarsomere 1 greatly enlarged, often concealing tarsomere 2 or 2+3; antennae 10-segmented with a small, 1-segmented club.

Tribe: **Rhagoderini**: Includes the North America genus *Rhagodera*.
Diagnostic features: Wingless; narrow hind-coxae; antennae 11-segmented with weak, gradual, 3-segmented club; antennae with scales.

Tribe: **Nematidiini**: Includes the North America genus *Nematidium*.
Diagnostic features: Long, cylindrical body; mandibular bases exposed; antennae 11 segmented with 2-segmented club; procoxal cavities closed.

**Zopherinae**

Tribe: **Zopherini**: Includes the North America genera *Zopherus, Sesaspis*, and *Phloeodes*.
Diagnostic features: body large, constricted between prothorax and pterothorax; antennae 9-10 segmented; eyes extending well onto dorsal surface of head but not nearly meeting; hypomeron with at least some development of an antennal cavity; procoxal cavities closed; scutellum not visible; tarsal formula 5-5-4.
Tribe: **Pycnemerini**: Includes the North America genus *Pycnemerus*.
Diagnostic features: Body small, parallel-sided, glabrous, often shiny; eyes not extending well onto dorsal surface of head; hypomeron lacking antennal cavities; procoxal cavities closed; elytra with distinct puncture rows/striae; tarsal formula 4-4-4.

Tribe: **Phellopsini**: Includes the North America genus *Phellopsis*.
Diagnostic features: Body large, constricted between prothorax and pterothorax; antennae 11-segmented; eyes extending well onto dorsal surface of head but not nearly meeting; hypomeron lacking antennal cavities; procoxal cavities open; scutellum visible; tarsal formula 5-5-4.

Tribe: **Usechini**: Includes the North America genera *Usechus* and *Usechimorpha*.
Diagnostic features: Body smaller, constricted between prothorax and pterothrax; antennae 11-segmented with a 3-segmented club; pronotum with distinctive dorsal antennal grooves; eyes extending well onto dorsal surface of head but not nearly meeting; dorsal surface with setae; tarsal formula 5-5-4.

Tribe: **Monommatini**: Includes the North America genera *Hyporhagus*, *Spinhyporhagus*, and *Aspathines*.
Diagnostic features: Body oval, dorsally convex, glabrous; procoxal cavities open; eyes extending well onto dorsal surface of head, nearly meeting; 4 abdominal ventrites connate; hypomeron with distinct antennal groove to receive antenna.
Fact Sheets

Below are the fact sheets for North American zopherid genera.

Genus: Acolobicus

Diagnostic Features

Description: Antennae 11-segmented with a distinct, 2-segmented club. Antennal setation sparse. Subantennal grooves present, as long as eyes. Eyes large, well-developed, facets moderately coarse. Pronotal disc convex, with several pair of faint, weak carinae. Lateral pronotal margins widest posteriorly, distinctly explanate. Procoxal cavities open. Metacoxae narrowly separated, separation less than metacoxal length. Elytra unicolored, weakly carinate with two fine, well-separated puncture rows between carinae. Elytral margins slightly explanate. Tarsal formula 4-4-4.

Similar genera: The genus Acolobicus is similar in general appearance to the genus Eucicones. The absence of carinae on the pronotal disc, presence of thick, flattened, club-shaped setae and variegated dorsal surface serve to distinguish Eucicones.

Known Distribution

Southeast (SC, FL), South Central (TX) USA.

Biology

Acolobicus erichsoni has been collected at UV/MV lights or from under the bark of dead trees.

Abundance: Uncommon.

North American Species (1)

Acolobicus erichsoni (Reitter, 1877)
Potential Problems with Identification

Stephan (1989) and Ivie (2002a) remark that the genus has 10-segmented antennae with a distinct 1-segmented club. Upon close examination, it appears *Acolobicus erichsoni* has a 2-segmented club with the club segments compact, of equal size and completely flush, superficially resembling a 1-segmented club.

Selected References

Ivie 2002a, Reitter 1877b, Stephan 1989.

Genus: *Antilissus*

Diagnostic Features

Description: Body cylindrical. Antennae 10-segmented with a distinct, 1-segmented club. Antennal setation sparse. Subantennal grooves present, extending behind eyes. Eyes small coarsely faceted, with scale-like interfacetal setae. Head with small, distinct temples behind eyes. Pronotal disc convex, lateral margins and pronotal disc with distinct network of pits, grooves and channels, raised areas with short, flattened, pale setae. Procoxal cavities closed. Metacoxae narrowly separated, separation less than metacoxal length. Elytra with distinct striae composed of coarse punctures. Abdominal ventrites 1-3 connate, ventrite 5 with a deep preapical groove. Tarsal formula apparently 3-3-3 (actually 4-4-4, tarsomeres 1 and 2 partially fused). Dorsal surface with short, flattened, pale setae.

Similar genera: The genus *Antilissus* is similar to the genus *Lobogestoria* in having an apparently 3-3-3 tarsal formula and grooved pronotum, but *Lobogestoria* is easily distinguished by the large, horn-like projections of the pronotum extending well
over the head. Superficially, Antilissus resembles the genus Neotrichus, but the 1-segmented antennal club and distinctive network of pits, grooves and channels of the pronotum serve to distinguish Antilissus.

**Known Distribution**

Known only from Hawai‘i, USA.

**Biology**

*Antilissus aper* have been collected off of *Sideroxylon* (Sapotaceae).

Abundance: Rarely encountered.

**North American Species (1)**

*Antilissus aper* Sharp, 1879

**Selected References**

Ivie 2002a, Sharp 1879, Ślipiński and Lawrence 1997.

**Genus: Aspathines**

**Diagnostic Features**

Description: Body small, convex, round to oval, size under 3 mm. Antennae 11-segmented with a 2-segmented club. Antennal setation sparse. Eyes well-developed, elongate-oval, somewhat reniform, coarsely faceted, extending well onto dorsal portion of head. Groove around dorsal edge of eye paralleling eye facets for entire length. Lateral margins of pronotum arcuate. Pronotal disc simple. Hypomeron with deep antennal cavities. Antennal groove and cavity recurved dorsally, meeting or nearly meeting lateral margin of hypomeron. Antennal cavity not concealed by prothoracic leg when retracted. Procoxal cavities open. Metacoxae widely separated, separation as wide or wider than

Similar genera: The genus *Aspathines* is similar to the monommatine genera *Hyporhagus* and *Spinhyporhagus*, can immediately be distinguished by the smaller size and more oval body, the 2-segmented antennal club, the antennal groove and cavity strongly recurved dorsally and ending near lateral margin of hypomeron, and the antennal cavity not concealed by the prothoracic leg when retracted.

**Known Distribution**

Southeast (FL) USA.

**Biology**

Members of the Monommatini are associated with rotting vegetable matter and are suspected to feed on fungus (Ivie 2002)

Abundance: rare.

**North American Species (1)**

*Aspathines aenus ovatus* Champion, 1888

**Species Diagnoses**

*Aspathines aenus ovatus*: This is the only member of the genus thought to occur in North America. The description and differentiation from similar genera above serve to distinguish this species from all other North American monommatines. NOTE: Several subspecies are recognized, but due to the need of revisionary work on the genus, only the subspecies *A. aenus ovatus* will be referred to in this resource.

**Known Distribution**

Florida Keys, Florida, USA.
Discussion

This predominantly occurs from Paraguay to Mexico, and it is possible it may be found in the border states.

Potential Problems with Identification

If correctly identified to Zopheridae, the small size and antennal characters will easily separate this species from all others.

Selected References

Champion 1888, Freude 1993, Ivie 2002b

Genus: *Aulonium*

Diagnostic Features


Similar genera: The genus *Aulonium* is superficially similar in general appearance to *Colydium*. The carinate elytral declivity and presence of a pair of long setae near the
apical margin of the last abdominal ventrite serve to distinguish *Colydium*. The genus *Phloeonemus* also has emarginated eyes formed by a projection of the frons, but is readily distinguished from *Aulonium* and *Colydium* by the 2-segmented antennal club, lack of a stout apical spine on the protibia, explanate lateral pronotal margins, very different sculpturing of the pronotal disc.

**Known Distribution**

Northwest (ID, MT, OR, WA), Southwest (AZ, CA, CO, NM, NV, UT), North Central (SD, IL, IN, MI, OH), Northeast (DC, DE, NJ, NY, MA, MD, PA, WV, VA), Southeast (AL, FL, GA, KY, NC, SC, TN), South Central (AR, LA, MS, OK, TX) USA, and British Columbia, Canada.

**Biology**

*Aulonium* has been collected at MV/UV lights and from under the bark of various dead hardwoods and conifers. Adults and larvae of *Aulonium* have been found in the galleries of scolytine weevils (Curculionidae), and they are suspected to feed on the larvae of those beetles within the galleries (Ivie 2002; Craighead 1920; Marshall 1978; Podoler *et al.* 1990). This genus is a beneficial insect, attacking destructive wood boring beetles.

Abundance: Moderately common.

**North American Species (5)**

*Aulonium aequicolle* LeConte, 1859

*Aulonium ferrugineum* Zimmermann, 1869

*Aulonium longum* LeConte, 1866

*Aulonium paralleloppedum* (Say, 1826)
Aulonium tuberculatum LeConte, 1863

Species Diagnoses

Aulonium aequicolle: Western species. Pronotum quadrate, as long as wide.
Anterior pronotal margin nearly straight. Sublateral carinae slightly curved basally, not distinctly raised anteriorly, merge with raised anterior margin of pronotum. Submedial lines diverge apically and basally, narrowed in apical 1/3. Pronotal disc more or less convex, slightly depressed in between submedial lines. Tubercles of anterior margin of pronotum not sexually dimorphic – in both sexes tubercles extremely reduced or absent. Strial rows of elytra distinct, punctures larger. Color usually piceus. Rarely collected. Associated with oaks.

Distribution: Arizona, California, USA.


Distribution: Pennsylvania, Florida, Georgia, Oklahoma, Texas, Alabama, North Carolina, South Carolina, USA.

Aulonium longum: Western species. Pronotum quadrate, slightly longer than wide. Anterior pronotal margin sinuate. Sublateral carinae straight basally, distinctly
raised and strongly carinate anteriorly. Submedial lines parallel, weak, only present in basal half. Pronotal disc strongly excavated in central 1/3. Tubercles of anterior margin of pronotum sexually dimorphic in males, tubercles strongly raised, in females, tubercles reduced, only slightly raised. Strial rows of elytra indistinct, punctures minute. Color usually reddish brown. Commonly collected. Associated with pines.

Distribution: Arizona, California, New Mexico, Idaho, Nevada, Oregon, Utah, Washington, Colorado, Montana, South Dakota, USA; British Columbia, Canada.


Distribution: Washington D.C., Delaware, Illinois Indiana, Massachusetts, Maryland, Michigan, New Jersey, New York, Ohio, Pennsylvania, Alabama, Arkansas, Florida, Georgia, Kentucky, Louisiana, Mississippi, North Carolina, South Carolina, Tennessee, Virginia, Oklahoma, Texas, USA.

*Aulonium tuberculatum*: Eastern species. Body more elongate, 3.6x longer than wide. Pronotum nearly quadrate, distinctly longer than wide. Anterior pronotal margin sinuate. Sublateral carinae straight basally, distinctly raised and strongly carinate anteriorly in males, not strongly raised anteriorly in females. Tubercles of anterior margin
of pronotum distinctly sexually dimorphic in males, tubercles strongly raised, with an additional pair of raised areas beneath, in females, tubercles absent. Submedial lines parallel, extremely weak. Pronotal disc weakly excrated in central 1/5 in males only. Strial rows of elytra indistinct, punctures minute. Color ferrugineous, with elytral apex darker. Associated with pines.

Distribution: Washington, D.C., Indiana, Maryland, New Jersey, New York, Pennsylvania, Alabama, Florida, Georgia, Louisiana, Mississippi, North Carolina, South Carolina, Virginia, West Virginia, Oklahoma, Texas, USA.

**Potential Problems with Identification**

The species of *Aulonium* seem to fall into two distinct groups, the *A. aequolles*, *A. parallelopipedum* group defined by the larger, darker body and lack of tubercles near the anterior margin of the pronotum, and the *A. longum*, *A. tuberculatum*, *A. ferrugineum* group, with the more elongate body and presence of tubercles (except in *A. ferrugineum*) near the anterior margin of the pronotum. These species can be distinguished by the characters given above, but separation of species within the genus becomes much more difficult on a worldwide scale.

**Selected References**


**Genus: Bitoma**

**Diagnostic Features**
Description: Antennae 11-segmented with a distinct, 2-segmented club (rarely antennomere 9 expanded apically, causing club to appear 3-segmented). Antennal setation sparse. Subantennal grooves greatly reduced to a small depressed area or absent. Eyes large, well-developed, finely to coarsely faceted, nearly always with obvious interfacetal setae. Antennal segment 3 slightly elongate (only slightly longer than 4) Pronotal disc carinate, with at least 2 pairs of longitudinal carinae, lateral margins (in most) slightly to strongly explanate, serrulate to denticulate. Pronotum usually wider than long. Procoxal cavities open. Metacoxae narrowly separated, separation less than metacoxal length. Tarsal formula 4-4-4. Dorsal surface consisting of thin, fine, hair-like setae (rarely clothed in velvet-like setae).

Similar genera: The genus *Bitoma* is similar in general appearance to *Microprium*, *Paha* and *Lasconotus*. In *Microprium*, the antennal groove is long and reaches to the posterior margin of the eye. *Bitoma* differs from *Paha* and *Lasconotus* in having a 2-segmented antennal club (1-segmented in *Paha* and 3-segmented in *Lasconotus*). In *Lasconotus*, the procoxal cavities are closed.

**Known Distribution**

Northeast (VA, WV, MD, DE, NJ, NY, CT, MA, NH, VT), North Central (IA, MO, IN, OH), Southeast (NC, SC, TN, GA, AL, FL), South Central (TX, OK, MS), Northwest (OR, WA, ID), Southwest (NM, AZ, CO, NV, CA) USA; Ontario, Canada.

**Biology**

*Bitoma* has been collected at MV/UV lights and from injured or dead cacti (*B. gracilis*), in leaf axils of dying agave and yucca (*B. gracilis*), in the nest piles of packrats (*B. gracilis, B. sulcata*), in flood debris (*B. ornata*), and under the bark of dead
hardwoods and pines, including: mesquite and palo verde, sotol (*B. neglecta, B. gracilis*), cottonwoods (*B. sulcata, B. ornata*), maples (*B. ornata, B. quadricollis*), pines (*B. pinicola*), oaks (*B. quadricollis, B. sulcata, B. carinata*), and beech (*B. quadricollis*).

Abundance: some species are common.

**North American Species (14)**

*Bitoma brevipes* (Sharp, 1894)
*Bitoma carinata* (LeConte, 1863)
*Bitoma crenata* (Fabricius, 1775)
*Bitoma discolor* Schaeffer, 1907
*Bitoma exarata* (Pascoe, 1863b)
*Bitoma gracilis* Sharp, 1894
*Bitoma granulata* (Blatchley, 1910)
*Bitoma ornata* (LeConte, 1858)
*Bitoma neglecta* Stephan, 1989
*Bitoma pinicola* Schaeffer, 1907
*Bitoma quadricollis* (Horn, 1885)
*Bitoma quadriguttata* (Say, 1826)
*Bitoma sulcata* (LeConte, 1858)
*Bitoma vittata* Schaeffer, 1907

**Common Species:**

*Bitoma quadriguttata* (eastern) and *B. ornata* (western) are, by far, the most abundant species.

**Species Diagnoses**
**Bitoma brevipes**: Eastern species. *B. brevipes* can be readily distinguished by the dark, cylindrical body, pronotum distinctly longer than wide, with 2 pairs of well-defined, full-length, slightly curved to sinuate carinae and an additional pair of short carinae anteriorly, and reduced interfacetal setae. This species can be separated from the similar *B. carinata* by the additional short pair of carinae on the anterior portion of the pronotal disc and less granulate pronotum.

Distribution: Known from Fort Meyers, Florida, although this is probably an introduction. *B. brevipes* is known from Mexico, Panama, and Costa Rica. This species may also occur in the Southwest USA and it is unclear whether or not this species has been established in the United States.

**Bitoma carinata**: Eastern species. *B. carinata* can be readily distinguished by the dark, cylindrical body, pronotum distinctly longer than wide, distinctly granulate with 2 pairs of well-defined, full-length, slightly curved to sinuate carinae, and reduced interfacetal setae. This species can be separated from the similar *B. brevipes* by the lack of an additional short pair of carinae on the anterior portion of the pronotal disc and more granulate pronotum.

Distribution: Alabama, Florida, Georgia, Mississippi, South Carolina, Virginia, USA.

**Bitoma crenata**: Eastern species. This species can be distinguished by the large red spots and apically enlarged 9th antennal segment, causing the antennal club to appear 3-segmented. *B. crenata* most closely resembles *B. sulcata*, but can be separated by the more smooth central area of the pronotal disc, eyes flattened and not nearly as protruding,
reduced to absent interfacetal setae, generally bi-colorous body, and geographic
distribution. This species is locally common.

Distribution: Indiana, New York, Ohio, Vermont, Washington, USA;
Ontario, Canada. This species has been introduced from Europe (apparently twice).

**Bitoma discolor**: Eastern species. *B. discolor* can be distinguished from other
*Bitoma* by the larger eyes with dense, stout, curved interfacetal setae, larger antennal
club, and distinctly denticulate lateral pronotal margins. This species is most similar to
the more common *B. quadricollis*, and can be separated by the dark elytra with lighter
spots and geographical distribution. This species is rare.

Distribution: southern Florida and the Florida Keys, USA. This species is
also found in Cuba.

**Bitoma exarata**: Western species. The larger size and distinctive dorsal
ornamentation consisting of carinae and granules clothed in velvety scales (tomentose)
should adequately distinguish this species.

Distribution: extreme southern Arizona, USA. This species also occurs
from Brazil to Mexico.

**Bitoma gracilis**: Western species. Most similar to *B. neglecta*, but differs in
having a sparsely setose/glabrous prosternum, eyes set closer apart ventrally, narrower
pronotum, more elongate, generally lighter in color and smaller in size.

Distribution: Arizona, California, New Mexico, Texas, USA.

**Bitoma granulata**: Central/eastern species. *B. granulata* can be easily separated
from the remaining North American *Bitoma* by the greatly reduced eyes and the
extremely flattened body. This species is extremely rare.
Distribution: Missouri, Indiana, Iowa, USA.

**Bitoma ornata**: Western species. Most similar to the introduced *B. crenata*, but differs in the smaller 9th antennal segment. This is the only native western species with red spots.

Distribution: Arizona, California, Idaho, Nevada, Oregon, Colorado, USA.

**Bitoma neglecta**: Western species. Most similar to *B. gracilis*, but differs in having a setose prosternum, eyes set farther apart ventrally, wider pronotum, less elongate, generally darker in color and larger in size.

Distribution: Arizona, USA.

**Bitoma pinicola**: Eastern species. This species can be separated from all other eastern species by the larger size, greatly flattened body, and widely separated eyes (ventrally).

Distribution: Delaware, Massachusetts, New Jersey, North Carolina, USA.

**Bitoma quadricollis**: Eastern species. *B. quadricollis* can be distinguished from other *Bitoma* by the larger eyes with dense, stout, curved interfacetal setae, larger antennal club, and distinctly denticulate lateral pronotal margins. This species is most similar to the rarer *B. discolor*, and can be separated by the unicolorous elytra and geographical distribution. This species is uncommon.

Distribution: New Jersey, Maryland, Ohio, Florida, Mississippi, North Carolina, Tennessee, West Virginia, Virginia, Oklahoma, USA.

**Bitoma quadriguttata**: Eastern species. This species varies widely in coloration, and is most often confused with *B. quadricollis*, *B. granulata* (darker specimens), and *B. gracilis*, *B. discolor* (redder specimens). Dark *B. quadriguttata* can be distinguished by
the size and position of the eyes. *B. quadriguttata* can be distinguished from *B. gracilis* by the less narrow body, eyes closer together ventrally, and inner pair of pronotal carinae curved outward. *B. quadriguttata* can be distinguished from *B. discolor* by the more well-separated eyes ventrally and more granulate prosternum.

**Distribution:** Connecticut, Delaware, Indiana, Maryland, New Jersey, New Hampshire, New York, Ohio, Alabama, Florida, Georgia, Mississippi, North Carolina, South Carolina, Tennessee, West Virginia, Virginia, Oklahoma, Texas, USA; Ontario, Canada. This is by far the most commonly encountered North American species of *Bitoma*.

**Bitoma sulcata:** Western species. This species can be distinguished by the apically enlarged 9th antennal segment, causing the antennal club to appear 3-segmented. *B. sulcata* most closely resembles *B. crenata*, but can be separated by the more rugose and setose central area of the pronotal disc, eyes rounder and greatly protruding, interfacetal setae more prominent and dense, generally uni-colorous body, and geographic distribution. This species is locally common.

**Distribution:** Arizona, California, Texas, USA.

**Bitoma vittata:** Western species. *B. vittata* can be immediately distinguished from the other North American *Bitoma* by the lateral margins of the pronotum greatly explanate and distinctly narrowed basally. This species is uncommon.

**Distribution:** extreme southern Texas, USA.

**Discussion**

On a regional level, the genus *Bitoma* appears stable, although the defining characters break down on a worldwide scale. The overall generic concept is still in
question, with many aberrant forms currently included in this large, cosmopolitan genus. A worldwide revision of the genus and a closer investigation of the generic definitions of the genera within the tribe Synchitini is the only way to resolve this issue.

**Potential Problems with Identification**

The North American species within this genus all appear very similar and will be hard to differentiate without a synoptic collection. Most of the species are rarely encountered. If identification is uncertain, it is suggested the specimens are checked against the most common species for that particular geographic region. Teneral specimens are much paler in color and may not exhibit the standard patterns of coloration diagnostic for the species.

**Selected References**


**Genus: Colobicus**

**Diagnostic Features**

length. Elytral lateral margins weakly explanate. Elytra with distinct striae composed flattened, short, recumbent setae. Tarsal formula 4-4-4.

Similar genera: The genus *Colobicus* is superficially similar to the genera *Acolobicus* and *Eucicones*. The smaller size, presence of faint carinae on the pronotal disc, lack of thick, flattened, club-shaped setae and unicolored dorsal surface serve to distinguish *Acolobicus*. The smaller size, variegated elytra, rougher dorsal surface, and distinctly more setose vestiture serve to distinguish *Eucicones*.

**Known Distribution**

Hawai’i, and Southeastern (LA) USA.

**Biology**

*C. parilis* has been found at UV/MV light and from under the bark of a number of trees. It has been noted that this species has been found on commercial shipments and in stores of sweet potatoes and other crops, where it is suspected to spread fungal disease (Hinton, 1945; Ivie, 2002a). Due to the destruction of crops from fungal disease spread by this beetle, it should be considered harmful.

Abundance: Rare.

**North American Species (1)**

*Colobicus parilis* Pascoe, 1860

**Discussion**

This genus is found throughout the Australo-Pacific region. It has likely been introduced into the United States, possibly on crop products.

**Selected References**

Genus: *Colydium*

Diagnostic Features


Similar genera: The genus *Colydium* is superficially similar in general appearance to *Aulonium*. The non-carinate elytral declivity and absence of a pair of long setae near the apical margin of the last abdominal ventrite serve to distinguish *Aulonium*. The genus *Phloeonemus* also has emarginated eyes formed by a projection of the frons, but is readily distinguished from *Colydium* and *Aulonium* by the 2-segmented antennal club, lack of a stout apical spine on the protibia, explanate lateral pronotal margins, very different sculpturing of the pronotal disc.

Known Distribution

Northwest (ID, MT, OR, WA), Southwest (AZ, CA, CO, NM, NV, UT), North Central (SD, IL, IN, MI, OH), Northeast (DC, DE, NJ, NY, MA, MD, PA, WV, VA), Southeast (AL, FL, GA, KY, NC, SC, TN), South Central (AR, LA, MS, OK, TX) USA, and British Columbia, Canada.
Biology

*Aulonium* has been collected at MV/UV lights and from under the bark of various dead hardwoods and conifers. Adults and larvae of *Colydium* have been found in the galleries of scolytine weevils (Curculionidae), and they are suspected to feed on the larvae of those beetles within the galleries (Ivie, 2002; Lawrence, 1991; Węgrzynowicz, 1999). It is unclear whether or not this genus can be considered beneficial, as the feeding on wood boring beetles may be circumstantial.

Abundance: Moderately common.

North American Species (5)

*Colydium glabriculum* Stephan, 1989

*Colydium lineola* Say, 1826

*Colydium nigripenne* LeConte, 1863

*Colydium robustum* Stephan, 1989

*Colydium thomasi* Stephan, 1989

Species Diagnoses

*Colydium glabriculum*: Apex of clypeus glabrous, labrum distinctly setose. Anterior angles of pronotum rounded, not projecting forward. Lateral margins of pronotum narrowing basally. Sublateral sulci of pronotal disc distinct. Elytral carinae distinctly raised basally and for apical half, indistinctly raised medially. Body reddish, apex of elytra darker.

Distribution: Arizona and New Mexico, USA.

*Colydium lineola*: Body 5x longer than wide. Apex of clypeus and labrum both distinctly setose. Anterior angles of pronotum rounded, not projecting forward.
Lateral margins of pronotum narrowing basally. Sublateral sulci of pronotal disc faint to absent. Elytral carinae distinctly raised for entire length. Body dark red to black.


Distribution: Washington D.C., Maryland, Illinois, New Jersey, Alabama, Arkansas, Florida, Georgia, Mississippi, North Carolina, South Carolina, Tennessee, Oklahoma, Texas, USA.


Distribution: Arizona, USA.

*Colydium thomasi*: Apex of clypeus glabrous, labrum distinctly setose. Anterior angles of pronotum rounded, not projecting forward. Lateral margins of pronotum narrowing basally. Sublateral sulci of pronotal disc faint to absent. Elytral carinae distinctly raised for entire length. Body reddish, apex of elytra darker.

Distribution: Florida Keys, Florida, USA, USA.
Selected References


Genus: *Coxelus*

Diagnostic Features


Similar genera: The genus *Coxelus* is similar to the genera *Stephaniolus* and *Megataphtus* in having reduced eyes and wings absent. The distinctive antennal cavities on the hypomeron serve to distinguish *Megataphrus*, and the presence of subantennal grooves serve to distinguish *Stephaniolus*.

Known Distribution

Southern coastal range of California, USA.

Biology

*Coxelus serratus* have been collected sifting duff from Redwood trees, as well as under the bark of Douglas fir.

Abundance: Rarely encountered.

North American Species (1)

*Coxelus serratus* Horn, 1885
Selected References


Genus: *Denophloeus*

Diagnostic Features

Description: Body larger (6-7mm), elongate, somewhat cylindrical. Surfaces opaque, very dark in color (dark brown to black). Antennae 11-segmented with a 2-segmented club (club may appear 3-segmented due to slightly enlarged antennomere 9). Antennal setation sparse. Subantennal grooves present, wide, longer than eyes. Eyes small, round, well-developed, finely faceted. Eyes deeply emarginate anteriorly by projection of frons, forming a distinct canthus. Pronotal disc convex, with a pattern of sinuate carinae. Pronotal lateral margins widest anteriorly, distinctly explanate. Procoxal cavities open. Metacoxae narrowly separated, separation less than metacoxal length. Elytra with irregularly shaped, blunt carinae and several small tubercles near apical declivity. Tarsal formula 4-4-4. Dorsal surface sparsely pubescent, composed of short, curved, thin setae. Body usually encrusted with dirt or debris.

Similar genera: The genus *Denophloeus* is superficially similar in general appearance to *Phloeonemus* and *Acolobicus* but is immediately distinguished by the larger body size, sculpturing of the pronotum and elytra, and distribution.

Known Distribution

Northwestern (Southern OR) and Southwestern (Northern CA) United States.

Biology
Denophloeus nosodermoides has been collected under loose bark and around the stumps of dead conifers.

Abundance: Moderately common locally.

**North American Species (1)**

Denophloeus nosodermoides (Horn, 1878)

**Selected References**


**Genus: Endeitoma**

**Diagnostic Features**

Description: Antennae 11-segmented with a subtle, 2-segmented club. Antennal setation sparse. Subantennal grooves absent. Eyes large, well-developed, finely faceted. Antennal segment 3 distinctly elongate (at least twice as long as 4) Pronotal disc convex, simple. Lateral pronotal margins widest at middle, distinctly denticulate. Procoxal cavities open. Metacoxae narrowly separated, separation less than metacoxal length. Tarsal formula 4-4-4. Dorsal surface consisting of thin, fine, hair-like setae. Members of this genus are frequently covered in a pale, whitish exudate.

Similar genera: The genus Endeitoma is similar in general appearance to the other genera with 10-segmented antennae and a 1-segmented club that lack a subantennal groove, including Microsicus, Synchita, and Paha. Microsicus differs in antennal segment 3 not distinctly elongate, dorsal surface with strongly curved, flattened, multi-colored elytral setae. The genus Synchita differs in antennal segment 3 not distinctly elongate and the dorsal surface with short, bristle-like setae. Paha differs in antennal
segment 3 not distinctly elongate, pronotal disc with two parallel, longitudinal carinae, the lateral margins widest anteriorly and distinctly explanate, and the dorsal pubescence is minute or lacking. In *Endeitoma*, the third antennal segment is distinctly elongate (at least twice as long as segment 4), the lateral pronotal margins are distinctly denticulate, and a dorsal pubescence consists of thin, fine, hair-like setae.

**Known Distribution**

Northeast (DE, MD, PA, WV), North Central (IN, MO), Southeast (AL, FL, GA, MS, NC), South Central (OK, TX) USA.

**Biology**

*Endeitoma* has been collected from under the bark of dead hardwoods and pines.

Abundance: Moderately common.

**North American Species (2)**

*Endeitoma granulata* (Say, 1826)

*Endeitoma dentata* (Horn, 1885)

**Species Diagnoses**

*Endeitoma granulata*: Pronotal lateral margin weakly explanate and moderately translucent, appearing bi-colored. Length of antennal club shorter than diameter of eye.

Distribution: Delaware, Indiana, Maryland, Pennsylvania, Alabama, Florida, Georgia, Mississippi, North Carolina, West Virginia, Oklahoma, Texas, Missouri, USA.

*Endeitoma dentata*: Pronotal lateral margin not explanate, unicolored. Length of antennal club equal to or longer than diameter of eye.

Distribution: Mississippi, Florida, Georgia, Oklahoma, USA.
Potential Problems with Identification

Members of this genus are frequently covered in a pale, whitish exudate which may conceal many of the important features used for identification. Ivie (2002a) remarks that the genus has 10-segmented antennae with a distinct 1-segmented club. Ślipiński and Lawrence (1997) state that the genus has 11-segmented antennae with a distinct, 2-segmented club. In comparison with other *Endeitoma* from around the world, it is clear the North American species also have a 2-segmented club with the last segment being much smaller than the 10th.

Selected References


Genus: *Eucicones*

Diagnostic Features


Similar genera: The genus *Eucicones* is similar in general appearance to the genus *Acolobicus*. The presence of faint carinae on the pronotal disc, lack of thick, flattened, club-shaped setae and unicolored dorsal surface serve to distinguish *Acolobicus*. 
Known Distribution

Northeast (DC, NJ, PA), North Central (IL, IN, KS, MO), Southeast (TN, AL, FL), South Central (OK, TX) USA, and Ontario, Canada.

Biology

_Eucicones marginalis_ has been collected from under the bark of dead oaks and elms.

Abundance: Uncommon.

North American Species (1)

_Eucicones marginalis_ (Melsheimer, 1846)

Selected References


Genus: *Eudesma*

Diagnostic Features

Description: Body cylindrical, elongate. Antennae 11-segmented with a distinct, 2-segmented club. Antennal setation sparse. Subantennal grooves present, as long as eyes. Eyes large, well-developed, facets fine. Pronotum subquadrate, with several raised areas and depressions. Lateral pronotal margins finely serrate. Procoxal cavities open. Metacoxae narrowly separated, separation less than metacoxal length. Elytra weakly carinate, with two rows of large, nearly contiguous punctures between carinae. Tarsal formula 4-4-4. Dorsal surface bi-colored, vestiture consisting of patches of pale setae.

Similar genera: The genus *Eudesma* is extremely distinctive and is not readily confused with other zopherid genera.
Known Distribution

Northeast (PA, VA) and North Central (IL, IN, OH) USA.

Biology

*Eudesma undulata* has been collected from under the bark of dead trees, including buckeye (*Aesculus glabra*) and oak (*Quercus*).

Abundance: Rare.

North American Species (1)

*Eudesma undulata* (Melsheimer, 1846)

Selected References


Genus: *Hyporhagus*

Diagnostic Features

Description: Body larger, convex, elongate-oval, size over 3.5 mm. Antennae 11-segmented with a 3-segmented club. Antennal setation sparse. Eyes well-developed, elongate-oval, somewhat reniform, coarsely faceted, extending well onto dorsal portion of head. Groove around dorsal edge of eye paralleling eye facets for entire length. Lateral margins of pronotum arcuate. Pronotal disc simple. Hypomeron with deep antennal cavities. Antennal groove and cavity slightly curved (not recurved dorsally), ending before lateral margin of hypomeron. Antennal cavity concealed by prothoracic leg when retracted. Procoxal cavities open. Metacoxae widely separated, separation as wide or wider than metacoxal length. Scutellum small, triangular, visible. Abdominal ventrite 5
with deep, curved preapical groove. Tarsal formula 5-5-4. Dorsal surface punctate, glabrous, shiny.

Similar genera: The genus *Hyporhagus* is most similar to the other monommatine genera *Aspathines* and *Spinhyporhagus*. *Hyporhagus* can be separated from *Aspathines* by the larger size, 3-segmented antennal club, antennal groove and cavity not strongly recurved dorsally and not ending near lateral margin of hypomeron, and antennal cavity concealed by the prothoracic leg when retracted. *Hyporhagus* can be separated from *Spinhyporhagus* by the lack of a thin cuticular process on the dorsal margin of the eye.

**Known Distribution**

Southwest (AZ, CA, NM, NV, UT), Southcentral (TX, OK, LA), Southeast (FL) USA.

**Biology**

Members of the Monommatini are associated with rotting vegetable matter and are suspected to feed on fungus (Ivie, 2002). *H. gilensis* was found in *Yucca* stems (Lawrence, 1991).

Abundance: rare.

**North American Species (4)**

*Hyporhagus gilensis* Horn, 1872

*Hyporhagus opaculus* LeConte, 1866

*Hyporhagus pseudogilensis* Freude, 1955

*Hyporhagus punctulatus* Thomson, 1860

**Species Diagnoses**
*Hyporhagus gilensis*: Western species. Body sub-opaque. DORSAL: Lateral margins of pronotum nearly straight, with a distinct angle separating lateral from anterior margins. Anterior pronotal margin nearly straight, distinctly shorter than basal margin. Posterior pronotal angles obtuse, posterior pronotal margin more sharply angled, distinctly convex. VENTRAL: maxillary palpi not distinctly swollen, terminal palpomere subcylindrical, widest at apex, not distinctly wider than preceding palpomeres, apex distinctly truncate. Strip of cuticle between eye and mouthparts wide, expanding towards base of eye. Eye at base mostly concealed, not distinctly expanded. Intercoxal process of abdominal ventrite I shallower, abdominal ventrite I shorter or nearly as long as ventrites 2-4. Male protarsus with 2 tarsomeres dilated and pubescent.

Distribution: Arizona, California, Nevada, New Mexico, Utah, Texas, Oklahoma, USA.


Distribution: California, Arizona, New Mexico, Texas, USA.
**Hyporhagus pseudogilensis**: Western species. Body sub-opaque. DORSAL: Lateral margins of pronotum arcuate, with a slight angle separating lateral from anterior margins (curvature into anterior margin not seamless. Anterior pronotal margin slightly sinuate, distinctly shorter than basal margin. Posterior pronotal angles obtuse, posterior pronotal margin more sharply angled, distinctly convex. VENTRAL: maxillary palpi slightly swollen, terminal palpomere subcylindrical, widest at middle, narrowing slightly towards apex, only slightly wider than preceding palpomeres, apex distinctly truncate. Strip of cuticle between eye and mouthparts wide, expanding towards base of eye. Eye at base mostly concealed, not distinctly expanded. Intercoxal process of abdominal ventrite I shallower, abdominal ventrite I shorter or nearly as long as ventrites 2-4. Male protarsus with 2 tarsomeres dilated and pubescent.

Distribution: Texas, Arizona, USA.


Distribution: Florida, Louisiana, USA.
NOTE: Several subspecies are recognized for *H. gilensis*, *H. punctulatus*, and *H. opaculus*, but due to the need of revisionary work on the genus, only the nominal species for each will be referred to in this resource.

**Potential Problems with Identification**

Members of this genus are extremely difficult to identify without representatives of each species at hand. The group requires extensive revision.

**Selected References**


**Genus: Lasconotus**

**Diagnostic Features**

Description: Antennae 11-segmented with a distinct, 3-segmented club. Antennal setation sparse. Subantennal grooves weakly developed or absent. Eyes large, well-developed, finely faceted. Antennal segment 3 longer than 4, but not as long as 4+5. Pronotal disc with one or two pairs of longitudinal ridges or carinae, often with depressed areas. Lateral pronotal margins variable, subparallel to sinuate. Procoxal cavities closed (narrowly open in *L. fitzgibbonae* and *L. coronatus*). Metacoxae narrowly separated, separation less than metacoxal length. Elytra with distinct carinae. Abdominal ventrite 5 with a deep preapical groove. Tarsal formula 4-4-4. Apex of protibia expanded, armed with a stout, apical spine and several smaller spines. Dorsal surface consisting of thin, fine, hair-like setae, occasionally with tufts of long, thin, golden setae.
Similar genera: The genus *Lasconotus* is similar in general appearance to the genera *Bitoma* and *Microprius*. *Lasconotus* can be immediately distinguished with the distinctly 3-segmented antennal club, closed procoxal cavities, apically expanded protibia armed with a stout apical spine and several smaller spines, and carinate pronotum and elytra.

**Known Distribution**

Northeast (Washington D.C., MD, NH, NJ, NY, PA, VA), North Central (IN, MO, MI, NK, OH, SD), Southeast (AL, FL, GA, NC, SC), South Central (LA, MS, OK, TX), Southwest (AZ, CA, CO, NM, NV, UT), Northwest (ID, MT, OR, WA, WY), Alaska, USA; Ontario, British Columbia, Northwest Territories, Canada.

**Biology**

*Lasconotus* has been collected by beating vegetation, at MV/UV lights, and from under the bark of dead pines, including the root bark of *Pinus edulis* and *Pinus leiophylla* (*Lasconotus fitzgibbonae*). It has been noted that some *Lasconotus* are predators of scolytine weevils (Curculionidae), and are therefore possibly beneficial.

Abundance: Some species are moderately common.

**North American Species (~22)**

*Lasconotus bitomoides* Kraus, 1912

*Lasconotus borealis* Horn, 1878

*Lasconotus complex* LeConte, 1859

*Lasconotus concavus* Casey, 1890

*Lasconotus coronatus* (Hinton, 1935)

*Lasconotus fiskei* Kraus, 1912
Species Diagnoses

*Lasconotus bitomoides*: Western species. This species is in a group of *Lasconotus* with the elytra distinctly concave in from elytral interstitial intervals 1 to 5 for nearly entire length on both elytra and the carina of elytral interstitial interval 5 markedly more raised than other carinae. *L. bitomoides* and *L. fiskei* each have a long, nearly complete
pair of sublateral carinae on the pronotum (between central depression and lateral margin). *L. bitomoides* can be separated by the greater elytral concavity, more granulate central depression, and greater distribution from Texas to California.

Distribution: Arizona, California, New Mexico, Texas, USA.

*Lasconotus borealis*: Northern species. This species is in a group of *Lasconotus* with the elytra distinctly convex to flattened (never concave) for entire length, with all elytral carinae similarly raised, pronotum with network of curving carinae crested with setae, and elytral intervals with 2-3 rows of short setae. *L. borealis* is most similar to *L. intricatus*, but can be separated by the piceu color and the pronotum wider than long.

Distribution: Alaska, Michigan, New Hampshire, New York, USA; Ontario, Northwest Territories, Canada.

*Lasconotus complex*: Western species. This species is distinguished by the reflexed lateral margin of the pronotum forming a distinct longitudinal depression between the lateral margin and the 1st pair of pronotal carina and carina of elytral interstitial interval 3 more distinctly raised near apex than other carinae. *L. complex* and *L. tuberculatus* are readily distinguished by the internal pair of carinae on the prontal disc interrupted into small tubercles. *L. complex* is distinguished from *L. tuberculatus* by the more parallel, sinuate lateral margins of the pronotum, the inner pair of pronotal carinae less distinctly interrupted into tubercles, and the posterior angles of the pronotum nearly right angles, not projecting posteriorly.

Distribution: California, Idaho, Oregon, Utah, Washington, USA; British Columbia, Canada.
**Lasconotus concavus:** Western species. This species is in a group of *Lasconotus* with the pronotum lacking any distinct carinae, instead, two raised ridges laterally bordering a larger central depression, sinuate anterior margin of pronotum, and elytra distinctly concave in from elytral interstitial intervals 1 to 5 for nearly entire length on both elytra and the carina of elytral interstitial interval 5 markedly more raised than other carinae. *L. concavus* can be separated from the other similar *Lasconotus* by the more flattened, wider body, absence of a distinctly carinate anterior margin of pronotum, and the concave portion of the elytra without clear striae.

**Distribution:** Arizona, New Mexico, Colorado, Montana, USA.

**Lasconotus coronatus:** Western species. *L. coronatus* is most similar to *L. fitzgibbonae* and forms a distinct group within *Lasconotus*. These two species can be separated by the remainder of the genus by the distinctive paired tufts of long golden setae at the anterior margin of the pronotum, narrowly open procoxal cavities, and antennal segment 3 longer than either 2 or 4. *L. coronatus* differs from *L. fitzgibbonae* in being slightly larger (~4.5 mm compared to ~3.25 mm in *L. fitzgibbonae*), the marginal pronotal carinae with a deep depression at midpoint, a more acute pronotal margin and broader anterior angles of the pronotum.

**Distribution:** Colorado, USA.

**Lasconotus fiskei:** Southcentral species. This species is in a group of *Lasconotus* with the elytra distinctly concave in from elytral interstitial intervals 1 to 5 for nearly entire length on both elytra and the carina of elytral interstitial interval 5 markedly more raised than other carinae. *L. fiskei* and *L. bitomoides* each have a long, nearly complete pair of sublateral carinae on the pronotum (between central depression and lateral
margin). *L. fiskei* can be separated by the slighter elytral concavity, less granulate central depression, and distribution restricted to Texas.

Distribution: Texas, USA.

**Lasconotus fitzgibbonae**: Western species. *L. fitzgibbonae* is most similar to *L. coronatus* and forms a distinct group within *Lasconotus*. These two species can be separated by the remainder of the genus by the distinctive paired tufts of long golden setae at the anterior margin of the pronotum, narrowly open procoxal cavities, and antennal segment 3 longer than either 2 or 4. *L. fitzgibbonae* differs from *L. coronatus* in being slightly smaller (~3.25 mm compared to ~4. 5 mm in *L. coronatus*), the lateral pronotal carinae with a shallow depression at midpoint, a more straight pronotal margin and narrower anterior angles of the pronotum.

Distribution: Arizona, South Dakota, USA.

**Lasconotus flexuosus**: Western species. This species is distinguished by the reflexed lateral margin of the pronotum forming a distinct longitudinal depression between the lateral margin and the 1\textsuperscript{st} pair of pronotal carina, the carina of elytral interstitial interval 3 more distinctly raised near apex than other carinae, and the presence of a strong flexure or bend in the pronotum slightly ahead of midline (only when viewed laterally).

Distribution: Washington, USA.

**Lasconotus intricatus**: Western species. This species is in a group of *Lasconotus* with the elytra distinctly convex to flattened (never concave) for entire length, with all elytral carinae similarly raised, pronotum with network of curving carinae crested with setae, and elytral intervals with 2-3 rows of short setae. *L. intricatus* is most similar to *L.
*borealis*, but can be separated by the ferrugineus color and the pronotum longer than wide.

Distribution: Idaho, Oregon, Washington, USA; British Columbia, Northwest Territories, Canada.

**Lasconotus knulli**: Western species. This species is in a group of *Lasconotus* with the elytra distinctly convex to flattened (never concave) for entire length and with all elytral carinae similarly raised. *L. knulli* can be distinguished by the restricted distribution, extremely small size, elytra with no distinct carina, pronotum longer than wide with only a hint of paired carinae.

Distribution: Arizona, USA.

**Lasconotus laqueatus**: Western species. This species is in a group of *Lasconotus* with the pronotum lacking any distinct carinae, instead, two raised ridges laterally bordering a larger central depression, sinuate anterior margin of pronotum, and elytra distinctly concave in from elytral interstitial intervals 1 to 5 for nearly entire length on both elytra and the carina of elytral interstitial interval 5 markedly more raised than other carinae. *L. laqueatus* can be separated from the other similar *Lasconotus* by the presence of a distinctly carinate, double “U” shaped anterior margin of pronotum, the width of the central pronotal depression greater than 1/2 the total width of pronotum, and the concave portion of the elytra for majority of elytral length. *L. laqueatus* differs from *L. pusillus* by its western distribution.

Distribution: Arizona, California, New Mexico, Texas, Nevada, South Dakota, Montana, Wyoming USA.
*Lasconotus linearis*: Western species. This species is in a group of *Lasconotus* with the elytra distinctly convex to flattened (never concave) for entire length, with all elytral carinae similarly raised, pronotum with network of curving carinae crested with setae, and elytral intervals with a single row of recumbent setae. *L. linearis* is most similar to *L. pertenuis*, but can be separated by the usually bicolored elytra and antennomere 9 as long as 10.

Distribution: California, USA.

*Lasconotus mexicanus*: This species is distinguished by the reflexed lateral margin of the pronotum forming a distinct longitudinal depression between the lateral margin and the 1st pair of pronotal carina and elytral carinae all equally elevated. To date, *L. mexicanus* does not occur in North America north of Mexico, but is included because it is likely this species will be discovered in the Southwest USA.

Distribution: Mexico.

*Lasconotus nucleatus*: Western species. This species is in a group of *Lasconotus* with the elytra distinctly convex to flattened (never concave) for entire length and with all elytral carinae similarly raised. *L. nucleatus* is readily distinguished by the rounded anterior angles of the pronotum, dorsal vestiture consisting of short, recurved setae, and elytra with numerous small tufts of round, silver-white setae.

Distribution: California, Oregon, Washington, USA.

*Lasconotus pertenuis*: Western species. This species is in a group of *Lasconotus* with the elytra distinctly convex to flattened (never concave) for entire length, with all elytral carinae similarly raised, pronotum with network of curving carinae crested with setae, and elytral intervals with a single row of recumbent setae. *L. pertenuis* is most
similar to *L. linearis*, but can be separated by the unicolored elytra and antennomere 9 distinctly shorter and narrower than 10.

Distribution: California, USA.

*Lasconotus planipennis*: Western species. This species is in a group of *Lasconotus* with the elytra distinctly convex to flattened (never concave) for entire length, with all elytral carinae similarly raised, and pronotum with indistinct carinae (never with network of curved carinae crested with setae). *L. planipennis* can be separated from similar species by the western distribution, smaller size (2.5 mm or less), absence of a distinct pair of sublateral pronotal carinae, and elytra distinctly convex.

Distribution: Arizona, California, New Mexico, Idaho, Washington, South Dakota, Montana, Wyoming, USA; British Columbia, Canada.

*Lasconotus pusillus*: Eastern species. This species is in a group of *Lasconotus* with the pronotum lacking any distinct carinae, instead, two raised ridges laterally bordering a larger central depression, sinuate anterior margin of pronotum, and elytra distinctly concave in from elytral interstitial intervals 1 to 5 for nearly entire length on both elytra and the carina of elytral interstitial interval 5 markedly more raised than other carinae. *L. pusillus* can be separated from the other similar *Lasconotus* by the presence of a distinctly carinate, double “U” shaped anterior margin of pronotum, the width of the central pronotal depression greater than 1/2 the total width of pronotum, and the concave portion of the elytra for majority of elytral length. *L. pusillus* differs from *L. laqueatus* by its eastern distribution.

Distribution: Alabama, Florida, Georgia, Louisiana, Mississippi, North Carolina, South Carolina, Ohio, Oklahoma, Texas, USA.
**Lasconotus referendarius:** Eastern species. This species is in a group of *Lasconotus* with the elytra distinctly convex to flattened (never concave) for entire length, with all elytral carinae similarly raised, and pronotum with indistinct carinae (never with network of curved carinae crested with setae). *L. referendarius* can be separated from similar species by the eastern distribution, smaller length to width ratio, and lack of distinct pronotal carinae.

Distribution: Washington D.C., Indiana, Maryland, New Jersey, Pennsylvania, Alabama, Florida, Georgia, North Carolina, South Carolina, Virginia, Oklahoma, Texas, USA.

**Lasconotus servus:** Western species. This species is in a group of *Lasconotus* with the elytra distinctly convex to flattened (never concave) for entire length, with all elytral carinae similarly raised, and pronotum with indistinct carinae (never with network of curved carinae crested with setae). *L. servus* can be separated from similar species by the western distribution, larger size (3mm +), and presence of a distinct pair of sublateral pronotal carinae.

Distribution: Arizona, California, New Mexico, USA.

**Lasconotus simplex:** Western species. This species is in a group of *Lasconotus* with the elytra distinctly convex to flattened (never concave) for entire length, with all elytral carinae similarly raised, and pronotum with indistinct carinae (never with network of curved carinae crested with setae). *L. simplex* can be separated from similar species by the western distribution, smaller size (2.5 mm or less), absence of a distinct pair of sublateral pronotal carinae, and elytra distinctly flattened.

Distribution: Arizona, California, New Mexico, USA.
**Lasconotus subcostulatus**: Western species. This species is in a group of *Lasconotus* with the pronotum lacking any distinct carinae, instead, two raised ridges laterally bordering a larger central depression, sinuate anterior margin of pronotum, and elytra distinctly concave in from elytral interstitial intervals 1 to 5 for nearly entire length on both elytra and the carina of elytral interstitial interval 5 markedly more raised than other carinae. *L. subcostulatus* can be separated from the other similar *Lasconotus* by the presence of a distinctly carinate, double “U” shaped anterior margin of pronotum, the width of the central pronotal depression 1/3 to 1/2 total width of pronotum, and the concave portion of the elytra for posterior half only.

Distribution: California, Idaho, Nevada, Oregon, Washington, South Dakota, Montana, Nebraska, USA.

**Lasconotus tuberculatus**: Western species. This species is distinguished by the reflexed lateral margin of the pronotum forming a distinct longitudinal depression between the lateral margin and the 1st pair of pronotal carina and carina of elytral interstitial interval 3 more distinctly raised near apex than other carinae. *L. tuberculatus* and *L. complex* are readily distinguished by the internal pair of carinae on the prontal disc interrupted into small tubercles. *L. tuberculatus* differs from *L. complex* by the more arcuate, sinuate lateral margins of the pronotum, the inner pair of pronotal carinae more distinctly interrupted into tubercles, and the posterior angles of the pronotum distinctly angulate, projecting posteriorly.

Distribution: Arizona, California, New Mexico, Oregon, Washington, Utah, South Dakota, Wyoming, USA; British Columbia, Canada.
*Lasconotus vegrandis*: Western species. This species is in a group of *Lasconotus* with the elytra distinctly convex to flattened (never concave) for entire length, with all elytral carinae similarly raised, and pronotum with indistinct carinae (never with network of curved carinae crested with setae). *L. vegrandis* can be separated from similar species by the pronotal width distinctly narrower than the elytral width.

Distribution: California, Idaho, Oregon, Washington, USA; British Columbia, Canada.

**Discussion**

Due to a unique combination of morphological characters, the placement of *Lasconotus* within the tribe Synchitini remains in question.

**Selected References**


**Genus: Lobogestoria**

**Diagnostic Features**

Elytral with 9 rows of evenly spaced, round punctures. Abdominal ventrites 1-3 fused, distinctly convex, ventrite 4 narrow, with transverse groove, ventrite 5 flat. Tarsal formula apparently 3-3-3 (actually 4-4-4, tarsomeres 1 and 2 partially fused). Dorsal surface glabrous.

Similar genera: The genus *Lobogestoria* is similar to the genus *Antilissus* in having an apparently 3-3-3 tarsal formula and grooved pronotum, but *Lobogestoria* is easily distinguished by the large, horn-like projections of the pronotum extending well over the head.

**Known Distribution**

Southeastern (AL, FL, GA, SC) and South Central (LA) United States.

**Probable Distribution**

South Central United States (MS).

**Biology**

Nothing is known about the biology of this group.

**Abundance:** Rare.

**North American Species (1)**

*Lobogestoria gibbicollis* Reitter, 1878

**Discussion**

This genus is also found in Cuba, parts of South America, and the Australo-Pacific region. It has likely been introduced into the United States.

**Selected References**

Genus: *Lyreus*

Diagnostic Features


Similar genera: The genus *Lyreus* is extremely distinctive and is not readily confused with other zopherid genera.

Known Distribution

Southeastern (AL) United States.

Biology

*Lyreus alleni* is known only from a limestone sinkhole in Alabama.

Abundance: Uncommon.

North American Species (1)

*Lyreus alleni* Ivie and Ślipiński, 2001

Discussion

The only other known species of *Lyreus* is European, creating an odd distribution for the genus.

Selected References

**Genus: Megataphrus**

**Diagnostic Features**


Similar genera: The genus *Megataphrus* is similar to the genera *Stephaniolus* and *Coxelus* in having reduced eyes and wings absent. The presence of antennal cavities on the hypomerón serve to distinguish *Megataphrus* from the other two.

**Known Distribution**

Northwestern United States (OR), Southwestern United States (CA, AZ).

**Biology**

Members of this genus are flightless and ground-dwelling. They are most commonly collected by Berlese extraction from the debris of redwood, fir, eucalyptus, laurel, chinquapin (*Castanopsis*), *Ceanothus* (Rhamnaceae) and under the bark of various stumps.

Abundance: Rarely encountered.

**North American Species (3)**

*Megataphrus tenuicornis* Casey, 1890

*Megataphrus arizonicus* Stephan, 1989
Megataphrus chandleri Stephan, 1989

Species Diagnoses

Megataphrus tenuicornis: Antennal cavities on hypomeron margined both on the inside and outside. Elytron with 3 carinae between suture and margin.

Distribution: California and Oregon, USA.

Megataphrus arizonicus: Antennal cavities on hypomeron margined on the outside only. Elytron with 4 carinae between suture and margin.

Distribution: Arizona, USA.

Megataphrus chandleri: Antennal cavities on hypomeron margined on the outside only. Elytron with 3 carinae between suture and margin.

Distribution: Oregon, USA.

Potential Problems with Identification

Members of this genus are frequently encrusted with dirt and other debris which may conceal the pronotal and elytral characters.

Selected References


Genus: Microprius

Diagnostic Features

Description: Antennae 11-segmented with a distinct, 2-segmented club. Antennal setation sparse. Subantennal grooves long, reaching posterior margin of eye. Eyes elongate, well-developed, facets fine. Pronotal disc with network of connecting, bifurcating carinae. Pronotal lateral margins subparallel, minutely serrate, slightly
Procoxal cavities narrowly open. Metacoxae narrowly separated, separation less than metacoxal length. Elytra carinate, with 9 rows of regularly spaced, deep punctures. Tarsal formula 4-4-4. Dorsal surface with minute setae.

Similar genera: The genus *Microptius* is extremely similar to *Bitoma*, and seems to differ only by the length of antennal groove on the ventral side of the head (short to absent in *Bitoma*).

**Known Distribution**

Southwestern (CA) and Northeastern (VA) USA.

**Probable Distribution**

This species is widespread throughout the Old World and will likely be found throughout the US.

**Biology**

*Microptius rufulus* has been found at UV/MV light and from under the bark of a number of trees.

Abundance: Rare.

**North American Species (1)**

*Microptius rufulus* (Motschulsky, 1863)

**Selected References**

Ivie 2002a, Ivie et al. 2001b, Motschulsky 1863.

**Genus: Microsicus**

**Diagnostic Features**

Similar genera: The genus *Microsicus* is similar in general appearance to the other genera with 10-segmented antennae and a 1-segmented club that lack a subantennal groove, including *Synchita, Paha,* and *Endeitoma*. *Synchita* differs in having short, bristle-like, unicolored setae. The genus *Paha* differs in lacking obvious dorsal pubescence, lateral pronotal margins widest anteriorly and distinctly explanate, and having paired carinae on the pronotal disc. *Endeitoma* differs in having a long third antennal segment (at least twice as long as segment 4), lateral pronotal margins distinctly denticulate, and a dorsal pubescence consisting of thin, fine, hair-like setae. In *Microsicus*, the pronotal disc is simple, the lateral margins are not distinctly denticulate, antennal segment 3 is not distinctly elongate, and the dorsal pubescence consists of strongly curved, flattened, multi-colored setae.

**Known Distribution**

Northeast (DE, MD, PA, WV, VA), North Central (IN), Southeast (FL, GA, NC), South Central (AR, OK), Northwest (OR, ID), Southwest (CA, AZ) USA.

**Biology**

*Microsicus* has been collected at MV/UV lights, but can commonly be found under the bark of various dead trees, including cottonwood (*M. variegatus*), oak (*M. parvulus, M. obscurus*), and hickory (*M. parvulus, M. obscurus*).
Abundance: Moderately common.

North American Species (3)

*Microsicus variegatus* (LeConte, 1858)

*Microsicus parvulus* (Guérin-Méneville, 1829)

*Microsicus obscurus* (Horn, 1885)

Species Diagnoses

*Microsicus variegatus*: Elytra variegated, with weak carinae, west of 100th meridian.

Distribution: Idaho, Oregon, California, and Arizona, USA.

*Microsicus parvulus*: Elytra without carinae, eyes large, elongate, head without temples, east of 100th meridian.

Distribution: Delaware, Indiana, Maryland, Pennsylvania, Arkansas, Florida, Georgia, North Carolina, West Virginia, Virginia, and Oklahoma, USA.

*Microsicus obscurus*: Elytra without carinae, eyes smaller, round, protruding, head with temples, east of 100th meridian.

Distribution: Washington D.C., Pennsylvania, New Jersey, and Oklahoma, USA. The true distribution of this species is probably much larger than records indicate.

Discussion

This genus is most closely allied to *Synchita*, with little difference other than setation type and pattern to distinguish between the two.

Selected References

**Genus: Monoedus**

**Diagnostic Features**

Description: Antennae 10-segmented with a distinct, 1-segmented club. Antennal setation sparse. Subantennal grooves absent. Eyes small, round to reniform, finely faceted. Pronotal disc simple, pronotum longer than wide, widest anteriorly, lateral margins weakly serrate. Procoxal cavities narrowly open. Metacoxae narrowly separated, separation less than metacoxal length. Elytral with 9 rows of evenly spaced, round punctures. Tarsal formula 4-4-4 with first tarsomere dilated and encompassing small 2\textsuperscript{nd} and 3\textsuperscript{rd} segments. Dorsal surface glabrous. Elytra pale with a number of small, dark spots. Dorsum with small, curved, pale setae. Body usually encrusted with a pale, waxy exudate.

Similar genera: The genus *Monoedus* is extremely distinctive and is not readily confused with other zopherid genera.

**Known Distribution**

Southeastern (Southern FL, Florida Keys) United States.

**Biology**

*Monoedus guttatus* can be found on milkweed (*Cynanchum scoparium*) (Ivie, 2002a).

Abundance: Locally not rare.

**North American Species (1)**

*Monoedus guttatus* Horn, 1882

**Discussion**
This genus is also found in Central and South America and the West Indies. It has likely been introduced into the United States.

**Potential Problems with Identification**

Members of this genus are frequently encrusted with a pale, waxy exudate which may conceal many of the important features used for identification.

**Selected References**


**Genus: Namunaria**

**Diagnostic Features**


Similar genera: The genus *Namunaria* is superficially similar in general appearance to *Pseudocorticus*. *Pseudocorticus* can be readily distinguished by the open procoxal cavities, antennae covered in dense, short, scale-like setae, antennal club one-segmented, lack of antennal grooves on head, and dorsum covered in short, scale-like setae.
Known Distribution

Northwest (OR, WA), Southwest (CA), South Central (OK, TX, MS), North Central (IN, OH), Northeast (NJ, NY, MD, PA, WV, VA), Southeast (NC, TN) USA, Ontario and British Columbia, Canada.

Biology

*Namunaria* has been collected at MV/UV lights and from under the bark of various dead hardwoods and conifers.

Abundance: Moderately common.

North American Species (2)

*Namunaria guttulata* (LeConte), 1863

*Namunaria pacifica* (Horn), 1878

Species Diagnoses

*Namunaria guttulata*: Antennal segment 3 1.5 times length of segment 4.

Distribution: Indiana, New Jersey, New York, Ohio, Maryland, Pennsylvania, North Carolina, Mississippi, Tennessee, West Virginia, Virginia, Oklahoma, Texas, USA. Ontario, Canada.

*Namunaria pacifica*: Antennal segment 3 subequal or only slightly larger than segment 4.

Distribution: California, Oregon, Washington, USA; British Columbia, Canada.

Selected References

Genus: *Nematidium*

Diagnostic Features


Similar genera: The genus *Nematidium* is extremely distinctive and is not readily confused with other zopherid genera.

Known Distribution

Southeastern (AL, FL, GA, SC, NC, TN) and South Central (LA) United States.

Probable Distribution

South Central United States (MS).

Biology

*Nematidium filiforme* had been collected at MV/UV lights. Adults and larvae of *Nematidium* have been found in the galleries of ambrosia beetles (Curculionidae: Platypodinae), and they are suspected to feed on the larvae of those beetles within the galleries (Ivie, 2002a; Beeson, 1941; Roberts, 1977). This genus is a beneficial insect, attacking destructive wood boring beetles.

Abundance: Uncommon.

North American Species (1)
Nematidium filiforme LeConte, 1863

Discussion

This genus occurs worldwide, from South America to Indo-Malaysia.

Selected References


Genus: Neotrichus

Diagnostic Features


Similar genera: The genus Neotrichus superficially resembles the genus Endeitoma. The 4-4-4 tarsi, narrower antennal club, abdominal ventrites 1-3 not fused, and distribution readily distinguish Endeitoma.

Known Distribution

Hawai’i, USA.

Biology
*Neotrichus latiusculus* has been collected from under the bark of dead *Pipturus* and *Terminalia*.

Abundance: Rare.

**North American Species (1)**

*Neotrichus latiusculus* (Fairmaire, 1881)

**Discussion**

This genus is found throughout the Australo-Pacific region. It has likely been introduced into the United States.

**Selected References**


**Genus: Paha**

**Diagnostic Features**

Description: Antennae 10-segmented with a distinct, 1-segmented club. Antennal setation sparse. Subantennal grooves absent. Eyes large, well-developed, finely faceted. Pronotal disc convex with central depression, with two parallel, longitudinal carinae. Pronotal lateral margins widest anteriorly, distinctly explanate. Procoxal cavities open. Metacoxae narrowly separated, separation less than metacoxal length. Tarsal formula 4-4-4. Dorsum lacking obvious pubescence (if visible, then not distinct).

Similar genera: The genus *Paha* is similar in general appearance to the other genera with 10-segmented antennae and a 1-segmented club that lack a subantennal groove, including *Microsicus*, *Synchita*, and *Endeitoma*. *Microsicus* differs in lacking
pronotal carinae, and the dorsal surface with strongly curved, flattened, multi-colored elytral setae. The genus *Synchita* differs in lacking pronotal carinae, lateral pronotal margins widest at middle and not as distinctly explanate, and the dorsal surface with short, bristle-like setae. *Endeitoma* differs in having a long third antennal segment (at least twice as long as segment 4), pronotal disc lacking carinae, lateral pronotal margins distinctly denticulate, and a dorsal pubescence consisting of thin, fine, hair-like setae. In *Paha*, the pronotal disc has two parallel, longitudinal carinae, the lateral margins are widest anteriorly, distinctly explanate, antennal segment 3 is not distinctly elongate, and the dorsal pubescence is minute or lacking.

**Known Distribution**

Northeast (DC, MD, NY, PA, VA), North Central (IN), Southeast (TN, AL, FL, MS, NC), South Central (OK) USA.

**Biology**

*Paha laticollis* has been collected from under the bark of dead oaks.

Abundance: Uncommon.

**North American Species (1)**

*Paha laticollis* (LeConte, 1863)

**Selected References**


**Genus: Phellopsis**

**Diagnostic Features**
Description: Antennae 11-segmented with a 3-segmented club. Antennal setation sparse. Eyes well-developed, elongate-oval, somewhat reniform, coarsely faceted, extending well onto dorsal portion of head. Males with setose pit on submentum. Lateral margins of pronotum arcuate to sinuate, without distinct lobes. Pronotal disc with several depressions and numerous small, round tubercles. Hypomeron without depressions or antennal cavities. Prosternum without distinct transverse groove. Procoxal cavities narrowly open. Metacoxae widely separated, separation as wide or wider than metacoxal length. Scutellum small, visible. Abdominal ventrite 5 with a deep preapical groove divided medially into two setose depressions. Tarsal formula 5-5-4. Dorsal surface granulose, tomentose. Dorsal and ventral surfaces commonly encrusted with dirt and debris.

Similar genera: The genus *Phellopsis* is similar to the genera *Sesaspis*, *Phloeodes*, and *Zopherus*, but can immediately be distinguished by the 11-segmented antennae with a 3-segmented club, narrowly open procoxal cavities, hypomeron with lack of depression/antennal cavity, and a small but visible scutellum.

**Known Distribution**

Southwest (CA, NV), Northwest (AK, ID, MT, OR, WA), Northeast (CT, MA, ME, MD, NH, NJ, NY, PA, VA, VT, WV), North Central (MI, WI), Southeast (GA, NC, TN) USA; Alberta, British Columbia, New Brunswick, Newfoundland, Nova Scotia, Ontario, Quebec, Canada.

**Biology**

*Phellopsis* feeds on fungus found in old growth boreal forests. *P. obcordata* have been reported to feed on *Piptoporus betulinus* (Polyporales) on birch (*Betula papyrifera,*
B. lenta) and Heterobasidion annosum (Bondarzewiaceae) on balsam fir (Abies balsamea). P. porcata have been reported to feed on fungi on western hemlock (Tsuga heterophylla) and on Lentinus (Polyporaceae).

Abundance: moderately common.

**North American Species (2)**

*Phellopsis obcordata* (Kirby, 1837)

*Phellopsis porcata* (LeConte, 1853)

**Species Diagnoses**

*Phellopsis obcordata*: Eastern species. Hypomeron lacking dense setation in between tubercles.


*Phellopsis porcata*: Western species. Hypomeron with dense setation in between tubercles.


**Discussion**

The taxonomic history of this genus in North America is quite complex, but following the thorough revision by Foley and Ivie (2008), only two species are currently recognized.
Potential Problems with Identification

Members of this genus are frequently encrusted with dirt and other debris which may conceal the diagnostic characters.

Selected References


Genus: Phloeodes

Diagnostic Features

Description: Antennae 10-segmented with a 2-segmented club. Antennal setation sparse, with stout, bristle-like setae. Eyes well-developed, elongate-oval, somewhat reniform, coarsely faceted, extending well onto dorsal portion of head. Lateral margins of pronotum arcuate to sinuate, without distinct lobes. Pronotal disc with several depressions and numerous small, round tubercles. Apical margin of hypomeron variable, with weak depression to complete antennal cavity. Prosternum without distinct transverse groove. Procoxal cavities closed. Metacoxae widely separated, separation as wide or wider than metacoxal length. Scutellum greatly reduced or absent from view. Abdominal ventrite 5 with an irregular preapical groove. Tarsal formula 5-5-4. Dorsal surface granulose. Dorsal and ventral surfaces commonly encrusted with dirt and debris.

Similar genera: The genus Phloeodes is similar to the genera Sesaspis, Phellopsis, and Zopherus. Phloeodes is most similar to Sesaspis, but can be distinguished by antennomere 3 distinctly longer than 4 (in Sesaspis, antennomere 3 only slightly longer than 4) and the pronotal disc mostly flat, bearing small, round tubercles (in Sesaspis, with
more well-defined raised ridges). *Phellopsis* can immediately be distinguished by the 11-segmented antennae with a 3-segmented club, narrowly open procoxal cavities, hypomeron with lack of depression/antennal cavity, and a small but visible scutellum. The genus *Zopherus* can immediately be distinguished by the 9-segmented antennae with a 1-segmented club composed of 3 fused segments, the deep antennal cavities on the prothoracic hypomera, and the paired rows of fine golden setae on all femora and tibiae.

**Known Distribution**

Southcentral (TX), Southwest (AZ, CA), Northwest (OR) USA.

**Biology**

It is speculated that some members may be morphologically adapted (as larvae) for boring into sound wood (Doyen and Lawrence, 1979; Ślipiński and Lawrence, 1999).

Abundance: moderately rare.

**North American Species (2)**

*Phloeodes diabolicus* (LeConte, 1851)

*Phloeodes plicatus* (LeConte, 1859)

**Species Diagnoses**

**Phloeodes diabolicus**: Antennal cavities of prothoracic hypomeron complete, clearly limited (enclosed) posteriorly. Elytral apical declivity with several small, round tubercles and one larger raised area. Body generally dark black, elytra often with pale velvety patches of setae at humeral angles and apex.

Distribution: Arizona, Oregon, California, USA.

**Phloeodes plicatus**: Antennal cavities of prothoracic hypomeron incomplete, not limited (enclosed) posteriorly. Elytral apical declivity with several large, irregular
tubercles/raised areas, each elytron with three main nodules. Dorsal vestiture even throughout, generally clothed in lighter colored setae.

Distribution: Arizona, California, USA.

Discussion

Other specimens of *Phloeodes* have been seen bearing locality data from Alaska, Washington, Oklahoma, Pennsylvania, Texas and Wisconsin, but these records are questionable. It is doubtful natural populations occur there.

Potential Problems with Identification

Members of this genus are frequently encrusted with dirt and other debris which may conceal the diagnostic characters.

Selected References

Foley and Ivie 2008 a, b, LeConte 1851, 1859, Ivie 2002c, Ślipiński and Lawrence 1999.

Genus: *Phloeonemus*

Diagnostic Features

Description: Antennae 11-segmented with a 2-segmented club (club may appear 3-segmented due to slightly enlarged antennomere 9). Antennal setation sparse.

Subantennal grooves present, as long as eyes. Eyes large, well-developed, finely faceted.

Eyes deeply emarginate anteriorly by projection of frons, forming a distinct canthus.

Pronotal disc convex, with a pattern of sinuate carinae. Procoxal cavities open.

Metacoxae narrowly separated, separation less than metacoxal length. Elytra carinate,
with two rows of punctures between carinae. Tarsal formula 4-4-4. Dorsal surface glabrous.

Similar genera: The genus *Phloeonemus* is superficially similar in general appearance to *Denophloeus* and *Acolobicus* but is immediately distinguished by the deeply emarginate eyes.

**Known Distribution**

South Central (TX), Southwest (AZ, CA) USA.

**Probable Distribution**

Southwestern United States (NM).

**Biology**

*Phloeonemus* has been collected at MV/UV lights and from under the bark of mesquite.

Abundance: Moderately common.

**North American Species (2)**

*Phloeonemus catenulatus* Horn, 1878

*Phloeonemus interruptus* Reitter, 1877

**Species Diagnoses**

*Phloeonemus catenulatus*: Elytral carinae uninterupted, solid.

Distribution: California, Arizona, Texas, USA.

*Phloeonemus interruptus*: Elytral carinae numerously interrupted.

Distribution: Extreme South Texas, USA.

**Selected References**

Horn 1878, Ivie 2002a, Reitter 1877a, Stephan 1989.
**Genus: Pseudocorticus**

**Diagnostic Features**


Similar genera: The genus *Pseudocorticus* superficially resembles the genera *Rhagodera* and *Namunaria*. The distinctly carinate elytra and weak, 3-segmented antennal club serve to distinguish *Rhagodera*. The lack of scale-like setae on the antennae, presence of antennal grooves, a distinctly 2-segmented antennal club, and closed procoxal cavities and serve to distinguish *Namunaria*.

**Known Distribution**

South Central (TX) and Southwestern United States (NM).

**Probable Distribution**

Southwestern United States (AZ).

**Biology**

Members of this genus have been found under the bark of dead hackberry (*Celtis reticulata*) and oak (*Quercus muhlenbergii*).
Abundance: Rare.

North American Species (1)

*Pseudocorticus blairi* Hinton, 1935

Potential Problems with Identification

Antennal segments and antennal club segments are often difficult to count due to dense, scale-like setae. The antennae appears to be 10-segmented with a one-segmented club composed of apparently 2 fused (connate) segments, denoted by an annulation, or 11-segmented with a composite, 2-segmented club.

Selected References


Genus: *Pycnomerus*

Diagnostic Features

Similar genera: The genus *Pycnomerus* is distinct among the genera of North America zopherids in having 4-4-4 tarsi, widely separated metacoxae, sparse antennal setation, and a shiny, glabrous body.

**Known Distribution**

Northeast (DE, MD, NJ, NY, PA, VA), North Central (IL, IN, OH), Southeast (AL, FL, GA, NC, SC, TN), South Central (AR, LA, MS, OK, TX), Northwest (OR, ID), Southwest (AZ) USA. Ontario, Canada

**Biology**

*Pycnomerus* is commonly collected under the bark of dead, rotting wood (both hardwoods and pines), on rotting palm fronds, and at MV/UV lights at night.

Abundance: Very common.

**North American Species (7)**

*Pycnomerus arizonicus* Stephan, 1989

*Pycnomerus haematodes* (Fabricius, 1801)

*Pycnomerus quercus* Stephan, 1989

*Pycnomerus reflexus* (Say, 1826)

*Pycnomerus sulcicollis* LeConte, 1863

*Pycnomerus thrinax* Ivie and Ślipiński, 2000

**Species Diagnoses**

*Pycnomerus arizonicus*: Western species. Antennal club 1-segmented. Pronotum convex, without median, longitudinal depressions. Punctures of pronotum more or less uniform in size. Lateral margins of pronotum straight to slightly sinuate. Pronotal disc
evenly convex to lateral margins. Anterior angles of pronotum angulate, distinct, posterior angles rounded.

Distribution: Arizona, USA.

*Pycnomerus haematodes*: Eastern species. Antennal club 2-segmented. Pronotum with 2 median, longitudinal depressions. Punctures of pronotum more or less uniform in size. Lateral margins of pronotum sinuate. Pronotal disc with central area flattened or subdepressed. Anterior and posterior angles of pronotum angulate, distinct.

Distribution: Indiana, Maryland, New Jersey, New York, Ohio, Pennsylvania, Alabama, Florida, Georgia, Mississippi, South Carolina, Virginia, Oklahoma, Texas, USA.

*Pycnomerus quercus*: Western species. Antennal club 2-segmented. Pronotum convex, without median, longitudinal depressions. Punctures of pronotum more or less uniform in size. Lateral margins of pronotum arcuate. Pronotal disc evenly convex to lateral margins. Anterior angles of pronotum angulate, distinct, posterior angles rounded.

Distribution: Arizona, USA.

*Pycnomerus reflexus*: Eastern species. Antennal club 2-segmented. Pronotum convex, without median, longitudinal depressions. Punctures of pronotum more or less uniform in size. Lateral margins of pronotum arcuate. Pronotal disc evenly convex to lateral margins. Anterior and posterior angles of pronotum angulate, distinct.

Distribution: Illinois, Indiana, Maryland, New Jersey, Ohio, Pennsylvania, Georgia, Mississippi, North Carolina, Louisiana, South Carolina, Tennessee, Virginia, USA; Ontario, Canada.
**Pycnomerus sulcicollis**: Eastern species. Antennal club 1-segmented. Pronotum with 2 median, longitudinal depressions. Punctures of pronotum variable in size, punctures in central portion of disc larger than surrounding punctures. Lateral margins of pronotum arcuate. Pronotal disc with central area flattened or subdepressed. Anterior and posterior angles of pronotum angulate, distinct.

Distribution: Delaware, Indiana, New Jersey, Alabama, Arkansas, Florida, Georgia, Mississippi, North Carolina, South Carolina, Tennessee, Virginia, Oklahoma, USA.

**Pycnomerus thrinax**: Eastern species. Antennal club 2-segmented. Pronotum convex, without median, longitudinal depressions. Punctures of pronotum more or less uniform in size. Lateral margins of pronotum arcuate. Pronotal disc with central area flattened or subdepressed. Anterior and posterior angles of pronotum rounded.

Distribution: Known only from the Florida Keys, Florida, USA.

**Potential Problems with Identification**

It is possible that a West Indian species, Pycnomerus infimus Grouvelle, might also occur in the Florida Keys area. This species is extremely similar to Pycnomerus thrinax (above), and can be differentiated from P. infimus in having round pronotal punctures, pronotum lacking longitudinal wrinkles, and sides of elytra sinuate medially. In P. infimus, the pronotal punctures are elongate, longitudinal wrinkles on the pronotum are present, and the sides of the elytra are straight.

**Selected References**

Fabricius 1801, Ivie 2002c, Ivie and Ślipiński 2000, LeConte 1863, Say 1826, Stephan 1989,
Ślipiński and Lawrence 1999.

**Genus: Rhagodera**

**Diagnostic Features**

Description: Antennae 11-segmented with an indistinct, 3-segmented club. Antennal setation dense, scaly. Subantennal grooves/depressions present or absent. Eyes small, coarsely faceted, with scale-like interfacetal setae. Pronotal disc with a pair of costae. Lateral margin of pronotum serrate, appearing curved or sinuate when teeth are filled with debris. Procoxal cavities narrowly open. Metacoxae narrowly separated, separation less than metacoxal length. Elytra fused. Each elytron with 3 costae. Tarsal formula 4-4-4. Body usually encrusted with sand, dirt, or debris.

Similar genera: The genus *Rhagodera* is superficially similar to the genus *Pseudocorticus*. The lack of elytral carinae and 1-segmented antennal club serve to distinguish *Pseudocorticus*.

**Known Distribution**

Southwestern United States (CA, AZ, TX), Mexico.

**Probable Distribution**

Southwestern United States (NM).

**Biology**

Members of this genus are flightless and ground-dwelling. They inhabit arid, deserted regions. The larvae are unknown. Little is known about the biology of this group.

Abundance: Rarely encountered.
North American Species (4)

*Rhagodera tuberculata* Mannerheim, 1843

*Rhagodera interrupta* Stephan, 1989

*Rhagodera costata* Horn, 1867

*Rhagodera texana* Stephan, 1989

Species Diagnoses


Distribution: California and Arizona, USA.


Distribution: California, USA.


Distribution: Southern Arizona, USA.


Distribution: Texas, USA.
Discussion

Members of this genus are quite distinct from all other members of the subfamily Colydiinae, with a number of characters separating it as a distinct group. The specific placement of this genus in the overall classification of the family is uncertain.

Potential Problems with Identification

Members of this genus are frequently encrusted with sand and other debris, which may conceal the pronotal and elytral characters. *Rhagodera costata* and *Rhagodera texana* are very similar. Although unsatisfactory, their distribution serves as the best diagnosis.

Selected References

Horn 1867, Ivie 2002a, Mannerheim 1843, Stephan 1989.

Genus: *Sesaspis*

Diagnostic Features

Description: Antennae 10-segmented with a 2-segmented club. Antennal setation sparse, with thick, bristle-like setae. Eyes well-developed, elongate-oval, somewhat reniform, coarsely faceted, extending well onto dorsal portion of head. Lateral margins of pronotum arcuate to sinuate, without distinct lobes. Pronotal disc with several raised ridges. Apical margin of hypomeron with short, arcuate depression. Prosternum without distinct transverse groove. Procoxal cavities closed. Metacoxae widely separated, separation as wide or wider than metacoxal length. Scutellum greatly reduced or absent from view. Abdominal ventrite 5 with a narrow arcuate preapical groove. Tarsal formula
Dorsal surface tomentose. Ventral surface with punctures from which a single seta arises. Dorsal and ventral surfaces commonly encrusted with dirt and debris.

Similar genera: The genus *Sesaspis* is similar to the genera *Phloeodes*, *Phellopsis*, and *Zopherus*. *Sesaspis* is most similar to *Phloeodes*, but can be distinguished by antennomere 3 only slightly longer than 4 (in *Phloeodes*, antennomere 3 distinctly longer than 4) and the pronotal disc with more well-defined raised ridges (in *Phloeodes*, mostly flat, bearing small, round tubercles). *Phellopsis* can immediately be distinguished by the 11-segmented antennae with a 3-segmented club, narrowly open procoxal cavities, hypomeron with lack of depression/antennal cavity, and a small but visible scutellum. The genus *Zopherus* can immediately be distinguished by the 9-segmented antennae with a 1-segmented club composed of 3 fused segments, the deep antennal cavities on the prothoracic hypomera, and the paired rows of fine golden setae on all femora and tibiae.

**Known Distribution**

Southcentral (TX), Southwest (NM) USA.

**Biology**

*Sesaspis* has been collected from under loose bark of pine and oak.

Abundance: uncommon.

**North American Species (1)**

*Sesaspis emarginata* (Horn, 1878)

**Potential Problems with Identification**

Members of this genus are frequently encrusted with dirt and other debris which may conceal the diagnostic characters.

**Selected References**

**Genus: Spinhyporhagus**

**Diagnostic Features**


Similar genera: The genus *Spinhyporhagus* is most similar to the other monommatine genera *Aspathines* and *Hyporhagus*. *Spinhyporhagus* can be separated from *Aspathines* by the larger size, 3-segmented antennal club, antennal groove and cavity not strongly recurved dorsally and not ending near lateral margin of hypomeron, and antennal cavity concealed by the prothoracic leg when retracted. *Spinhyporhagus* can be separated from *Hyporhagus* and *Aspathines* by the presence of a thin cuticular process on the dorsal margin of the eye.

**Known Distribution**
Southcentral (TX) USA.

**Biology**

Members of the Monommatini are associated with rotting vegetable matter and are suspected to feed on fungus (Ivie, 2002)

Abundance: known from only a single specimen.

**North American Species (1)**

*Spinhyporhagus cuneispinatus* Freude, 2000

**Species Diagnoses**

*Spinhyporhagus cuneispinatus*: Southcentral species. This is the only member of the genus thought to occur in North America. The description and differentiation from similar genera above serve to distinguish this species from all other North American monommatines.

Distribution: Texas, USA.

**Discussion**

According to Ivie (2002), Freude (2000) described *S. cuneispinatus* from a single specimen labeled “Texas.” No specimens of this species have been seen, and it is unclear whether or not the genus is established in the United States or if this species is valid.

**Potential Problems with Identification**

The nature of the head usually contracted within the pronotum will make this species difficult to separate from the genus *Hyporhagus* unless the head is removed.

**Selected References**

**Genus: Stephaniolus**

**Diagnostic Features**


Similar genera: The genus *Stephaniolus* is similar to the genera *Coxelus* and *Megataphus* in having reduced eyes and wings absent. The distinctive antennal cavities on the hypomeron serve to distinguish *Megataphrus*, and the absence of subantennal grooves serve to distinguish *Coxelus*.

**Known Distribution**

Southwestern United States (SE AZ). High-elevation mountains.

**Probable Distribution**

Southwestern United States (NM). High-elevation mountains.

**Biology**

Members of this genus have been found on the bark of old pine stumps.

Abundance: Rarely encountered.

**North American Species (1)**

*Stephaniolus longus* (Stephan, 1989)

**Selected References**

**Genus: Synchita**

**Diagnostic Features**


Similar genera: The genus *Synchita* is similar in general appearance to the other genera with 10-segmented antennae and a 1-segmented club that lack a subantennal groove, including *Microsicus, Paha,* and *Endeitoma. Microsicus* differs in having strongly curved, flattened, multi-colored elytral setae. The genus *Paha* differs in lacking obvious dorsal pubescence, lateral pronotal margins widest anteriorly and distinctly explanate, and having paired carinae on the pronotal disc. *Endeitoma* differs in having a long third antennal segment (at least twice as long as segment 4), lateral pronotal margins distinctly denticulate, and a dorsal pubescence consisting of thin, fine, hair-like setae. In *Synchita,* the pronotal disc is simple, the lateral margins are not distinctly denticulate, antennal segment 3 is not distinctly elongate, and the dorsal pubescence consists of short, bristle-like, unicolored setae.

**Known Distribution**

Northeast (DC, NH, NH, NJ, ME, MD, PA, WV), North Central (IL, IN, MO, OH), Southeast (FL, NC, SC), South Central (AR, OK, TX) USA, and Ontario, Canada.

**Biology**
*Synchita fuliginosa* has been collected at MV/UV lights, but can commonly be found under the bark of various dead trees, including oak, hickory, elm, maple, and pecan.

Abundance: Moderately common.

**North American Species (1)**

*Synchita fuliginosa* Melsheimer, 1846

**Selected References**


**Genus: Usechimorpha**

**Diagnostic Features**


Similar genera: The genus *Usechimorpha* is similar to the genus *Usechus*. *Usechimorpha* can be readily distinguished by the more abrupt and compact antennal club, open procoxal cavities, truncate apex of the prosternal process, and the
posterolateral depressions of pronotum connected by a transverse groove at the base. In *Usechus*, the antennal club is less compact, the procoxal cavities are closed, the apex of the prosternal process is distinctly widened, and the posterolateral depressions of pronotum are not connected by a transverse groove at base.

**Known Distribution**

Northwest (OR), Southwest (CA) USA, Vancouver Island, British Columbia (Canada).

**Biology**

*Usechimorpha* has been collected sifting leaf litter and detritus in conifer forests and from decaying fruiting bodies of *Laetiporus sulphureus* (Polyporaceae).

Abundance: Moderately rare.

**North American Species (2)**

*Usechimorpha barberi* Blaisdell, 1929

*Usechimorpha montanus* Doyen and Lawrence, 1979

**Species Diagnoses**

*Usechimorpha barberi*: Clypeus densely setose. Elytra with a number of setose tubercles. Elytral setae distributed throughout, but more dense on elytral tubercles.

Distribution: California, Oregon, USA; British Columbia, Canada.

*Usechimorpha montanus*: Clypeus sparsely setose or glabrous. Elytral intervals 1, 2, and 4 regular, not carinate. Elytral setae more or less evenly distributed.

Distribution: California, USA.

**Potential Problems with Identification**
Members of this genus are frequently encrusted with dirt and other debris which may conceal the diagnostic characters.

**Selected References**


**Genus: Usechus**

**Diagnostic Features**


Similar genera: The genus *Usechus* is similar to the genus *Usechimorpha*. *Usechus* can be readily distinguished by the less compact antennal club, closed procoxal cavities, distinctly widened apex of the prosternal process, and posterolateral depressions of pronotum not connected by a transverse groove at base. In *Usechimorpha*, the antennal club is more abrupt and compact, procoxal cavities are open, the apex of the prosternal
process is truncate, and the posterolateral depressions of pronotum are connected by a transverse groove at base.

Known Distribution

Northwest (OR, WA), Southwest (CA) USA.

Biology

*Usechus* has been collected sifting leaf litter and detritus of oaks, maples and conifers. *Usechus lacerta* larvae and pupae have been collected in *Quercus* and associated with fungus under bark of dead maple (*Acer macrophyllum*) (Doyen and Lawrence, 1979).

Abundance: Moderately rare.

North American Species (2)

*Usechus lacerta* Motschulsky, 1845

*Usechus nucleatus* Casey, 1889

Species Diagnoses

*Usechus lacerta*: Elytral intervals 1, 3, and 5 merge at elytral base to form a transverse carina that does not project forward. Pronotum more uniformly setose except for glabrous posterolateral depressions.

Distribution: California, USA.

*Usechus nucleatus*: Elytral intervals 1, 3, and 5 merge at elytral base to form an abruptly raised tubercle that projects forward. Pronotum less uniformly setose, with larger glabrous posterolateral depressions and a glabrous mediobasal depression.

Distribution: California, Oregon, Washington, USA.

Discussion
Blaisdell (1929) divided the genus Usechus into two species, *U. nucleatus* and *U. lacerta*. He further divided *U. lacerta* into 4 varieties (*U. lacerta lacerta*, *U. l. santaclarae*, *U. l. horni*, and *U. l. trinitatis*). For the purposes of this work, all *Usechus lacerta* varieties will be treated under one species.

**Potential Problems with Identification**

Members of this genus are frequently encrusted with dirt and other debris which may conceal the diagnostic characters.

**Selected References**

Blaisdell 1929, Boddy 1965, Casey 1889, Doyen and Lawrence 1979, Ivie 2002c, Motschulsky 1845, Ślipiński and Lawrence (1999)

**Genus: Zopherus**

**Diagnostic Features**

Similar genera: The genus *Zopherus* is similar to the genera *Sesaspis*, *Phloeodes*, and *Phellopsis*, but can immediately be distinguished by the 9-segmented antennae with a 1-segmented club composed of 3 fused segments, the deep antennal cavities on the prothoracic hypomera, and the paired rows of fine golden setae on all femora and tibiae.

**Known Distribution**

Southwest (AZ, CA, CO, NM, NV, UT), Southcentral (TX) USA; Mexico.

**Biology**

*Zopherus* occurs in rotting wood and plant matter. It is speculated that some members may be morphologically adapted (as larvae) for boring into sound wood (Doyen and Lawrence, 1979; Ślipiński and Lawrence, 1999). Larvae of *Zopherus nodulosus* has been found in pecan timber (*Carya* sp.) and larvae of *Z. granicollis* have been collected from the root crown of *Pinus monophylla* (Doyen and Lawrence, 1979).

Abundance: Some species are locally common.

**North American Species (11)**

*Zopherus championi* Triplehorn, 1972

*Zopherus concolor* LeConte, 1851

*Zopherus elegans* Horn, 1870

*Zopherus gracilis* Horn, 1867

*Zopherus granicollis* Horn, 1885

*Zopherus opacus* Horn, 1867

*Zopherus nodulosus* Solier, 1841

*Zopherus sanctaehelena*e (Blaisdell, 1931)
Species Diagnoses

**Zopherus championi**: This species can be readily distinguished by the elytral apex bearing 2 swollen, oblique ridges on each side and the lateral margins of the elytra and pronotum bordered in white (some specimens lack white lateral margins). This species is most similar to *Z. elegans*, and can be distinguished by pronotal surface consisting of simple punctures (compared to small, scabrous bumps or tubercles in *Z. elegans*) and the prosternum anterad of procoxae with punctured but lacking distinct tubercles. This species may sometimes be covered in a greasy exudate, rendering the specimen almost entirely black in color. If this is the case, *Z. championi* will greatly resemble *Z. gracilis*, but can be separated by the distribution, more convex pronotal disc, punctures on pronotal disc deeper, and a hint of coloration on the elytra.

Distribution: Texas, USA; Mexico.

**Zopherus concolor**: This species can be readily distinguished by the elytral apex bearing 2 swollen, oblique ridges on each side, solid black body, pronotum with small, deep, moderately sparse punctures, and distinctly scabrous, irregularly tuberculate elytral sculpture (as opposed to vermiculate in other species). *Z. concolor* is most similar to *Z. tristis*, but can be distinguished by the shallower and more sparse pronotal punctures and the elytral scabrous tubercles more distinctly raised and prominent.

Distribution: New Mexico, Texas, USA.
**Zopherus elegans:** This species can be readily distinguished by the elytral apex bearing 2 swollen, oblique ridges on each side and the lateral margins of the elytra and pronotum bordered in white (some specimens lack white lateral margins). This species is most similar to *Z. championi*, and can be distinguished by pronotal surface consisting of small, scabrous bumps or tubercles (compared to simple punctures in *Z. championi*) and the prosternum anterad of procoxae with distinct tubercles, not punctures. This species may sometimes lack the whitish lateral pronotal and elytral margins, rendering the specimen almost entirely black in color. If this is the case, *Z. elegans* will greatly resemble *Z. granicollis* and *Z. uteanus*, but can be separated by the evenly curved anterior margin of the pronoun (when viewed anteriorly), as opposed to bisinuate in *Z. granicollis* and *Z. uteanus*.

Distribution: Arizona, New Mexico, Utah, USA.

**Zopherus gracilis:** This species can be readily distinguished by the elytral apex bearing 2 swollen, oblique ridges on each side and the pronotum smooth, impunctate, the elytra impunctate, smooth to slightly wrinkled, and the solid black dorsum. *Z. gracilis* is most similar to *Z. gracilis* but can immediately be distinguished by the 2 slightly swollen oblique ridges at the elytral apex, whereas in *Z. xestus* the elytral apex bears 2 large, swollen, oval tubercles.

Distribution: Arizona, New Mexico, USA; Mexico.

**Zopherus granicollis:** This species can be readily distinguished by the elytral apex bearing 2 swollen, oblique ridges on each side, solid black body, pronotum and elytra bearing small, regular scabrous tubercles subequal in size and more or less evenly distributed. *Z. granicollis* is most similar to *Z. uteanus*, but differs in the prosternal
process between the coxae more densely punctate (as opposed to sparsely punctate in *Z. uteanus*), coarser clypeal punctures, and pronotum usually narrower than elytra.

NOTE: This species has two subspecies, *Z. granicollis granicollis* and *Z. granicollis ventriosus*. *Z. granicollis granicollis* can be separated from *Z. granicollis ventriosus* in the overall larger size of the elytral tubercles and lateral tubercles of the elytra similar in size and shape to those on rest of elytra, whereas in *Z. granicollis ventriosus*, the elytral tubercles are overall smaller in size and the lateral tubercles of the elytra are transversely elongate.

Distribution: Arizona, California, Nevada, USA; Mexico.

**Zopherus opacus**: This species can be readily distinguished by the elytral apex bearing 2 swollen, oblique ridges on each side, solid black body, pronotum with small, moderately dense punctures, and distinctly vermiculate and minutely tuberculate or bumpy elytral sculpture (as opposed to with scabrous, flattened tubercles in other species). The similar size and density of the small bumps/tubercles of the pronotum and elytra serve to separate this species.

Distribution: California, Nevada, Utah, USA.

**Zopherus nodulosus**: This species can be readily distinguished by the elytral apex bearing 4 distinct tubercles, the inner pair being smaller than the outer, and the bicolourous, black and white dorsum.

NOTE: This species has two subspecies, *Z. nodulosus nodulosus* and *Z. nodulosus haldemani*. *Z. nodulosus nodulosus* can be separated from *Z. nodulosus haldemani* in the pronotum and elytra mostly white with black coloration mostly restricted to midline, whereas in *Z. nodulosus haldemani*, the black coloration is more widespread. There can
also be darker color morphs (nearly all black) of both subspecies. *Z. nodulosus nodulosus* occurs in Mexico whereas *Z. nodulosus haldemani* occurs in Texas and Mexico. This species may sometimes be covered in a greasy exudate, rendering the specimen almost entirely black in color. If this is the case, *Z. nodulosus* can still be easily recognized by the 4 distinct tubercles at the elytral apex.

Distribution: Texas, USA; Mexico.

*Zopherus sanctaehelenae*: This species can be readily distinguished by the elytral apex bearing 2 swollen, oblique ridges on each side, solid black body, pronotum with small, moderately sparse punctures, and distinctly vermiculate and minutely punctate elytral sculpture (as opposed to with scabrous, flattened tubercles in other species).

Distribution: California, USA.

*Zopherus tristis*: This species can be readily distinguished by the elytral apex bearing 2 swollen, oblique ridges on each side, solid black body, pronotum with small, deep, moderately sparse punctures, and distinctly scabrous, irregularly tuberculate elytral sculpture (as opposed to vermiculate in other species). *Z. tristis* is most similar to *Z. concolor*, but can be distinguished by the deeper and more dense pronotal punctures and the elytral scabrous tubercles less distinctly raised.

Distribution: Arizona, California, Colorado, Texas, USA; Mexico.

*Zopherus uteanus*: This species can be readily distinguished by the elytral apex bearing 2 swollen, oblique ridges on each side, solid black body, pronotum and elytra bearing small, regular scabrous tubercles subequal in size and more or less evenly distributed. *Z. uteanus* is most similar to *Z. granicollis*, but differs in the prosternal process between the coxae sparsely punctate (as opposed to more densely punctate in *Z.*
*granicollis*), clypeal punctures smaller and sparser, and pronotum usually as wide or wider than elytra.

Distribution: Arizona, California, Nevada, Utah, USA.

**Zopherus xestus:** This species can be readily distinguished by the elytral apex bearing 2 distinct tubercles, the pronotum smooth, impunctate, the elytra impunctate, smooth to slightly wrinkled, and the solid black dorsum. *Z. xestus* is most similar to *Z. gracilis* but can immediately be distinguished by the 2 tubercles at the elytral apex large, swollen, and oval in shape, whereas in *Z. gracilis* the elytral apex bears a slightly swollen oblique ridge.

Distribution: Texas, USA.

**Potential Problems with Identification**

Many of the North American members of this genus are quite similar in general appearance and can be difficult to accurately identify. The species which exhibit patterns of black and white coloration also have black forms, which greatly hinder identification. This black coloration is caused by a greasy exudate, which conceals the white coloration and many of the surface sculpture. The exudate can be removed by soaking the specimen in a grease solvent.

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Edrotini, Epiphysini, Adesmiini, Craniotini, Leptodini, Zopherini, Usechini,
Eurychorini, Araeoschizini, Stenosini, Dacoderini, Typhlusechini, Cryptochilini,
Calognathi, Batuliini, Anepsiini, Vacronini, Nyctoporini, Cryptoglossini, Elenophorini, Asidini, Nyctelliini, Molurini, Sepidiini, Akidini, Ceratanisini, Scaurini, Scotobiini, Platyopini, Pimeliini, Remipedellini, Blaptini, Index 1).


CHAPTER 2

Illustrated Catalogue and Type Designations of the New Zealand Zopheridae
(Coleoptera: Tenebrionoidea).

To be published as: Lord, N.P. and R.A.B. Leschen: “Illustrated Catalogue and Type
Designations of the New Zealand Zopheridae (Coleoptera: Tenebrionoidea)” in the peer-
reviewed journal *Zootaxa*.

Appendix G contains the figures 1–421 for Chapter 2 and is available as a supplementary
file via LoboVault. See PDF titled “Appendix_G_Figures_Chapter2”.

Abstract

This paper provides a comprehensive catalogue of the New Zealand members of
the family Zopheridae Solier (Coleoptera: Tenebrionoidea) in an effort to stabilize the
nomenclature preceding extensive revisionary taxonomy within the group. A checklist of
the 17 New Zealand zopherid genera and an account for each of the 189 species (by
current combination) is provided. Type material for nearly all species was examined, and
type specimens are designated herein (89 confirmed holotypes, 103 lectotypes, 283
paralectotypes). Images of all primary type specimens and labels examined are provided.

*Pycnomerus sulcatissimus* Sharp, 1886 is a junior synonym and secondary homonym of

*Pycnomerus sulcatissimus* (Reitter, 1880). One replacement name is proposed, *Chorasus
beckae* nom. nov., for *Chorasus subcaecus* (Broun), and 24 new combinations are given.
Introduction

Zopheridae (= Colydiidae) are cosmopolitan, litter-dwelling or saproxylic beetles that feed on dead plant material or fungi. Of a total of 190 genera and over 1,700 species, a disproportionate diversity (nearly half) is restricted to the Australo-Pacific region (Ślipiński and Lawrence 2010). Zopherids are well-represented in New Zealand in particular, constituting the fourth most speciose family (Leschen et al. 2003). Based on the current classification (Ślipiński and Lawrence 2010; Bouchard et al. 2011), the New Zealand fauna consists of species contained in both subfamilies: Zopherinae (Pycnomerodes Broun, Pycnomerus Erichson) and Colydiinae (all other genera). Despite their extraordinary diversity in New Zealand, the family has not been studied in great detail and no new species have been described since Broun (1923).

Several workers documented the New Zealand fauna fragmentally; six different workers described a total of 16 species prior to 1880; David Sharp described a large portion (33 species) from the mid-1870s through to the mid-1880s; the remaining species were described by the prolific Thomas Broun. In one of his earlier works on the fauna, Sharp (1876: 18) listed 24 species of Zopheridae and speculated that the number of known colydiids was sure to increase (“...highly probably even quadrupled”), and “...it is pretty certain that, like the Atlantic islands, New Zealand will prove to be very rich in species closely allied to Tarphius Erichson…I anticipate that some very interesting comparisons will be suggested when the New Zealand forms of the family are better known, as I hope may soon be the case.” Thomas Broun, a New Zealand beetle specialist, military man, and teacher, had initially sent specimens to the British Museum of Natural History. He was soon encouraged by Sharp to describe the fauna, and Broun did so
impetuously (though not without some early objections by Sharp 1882: 73–76),
describing large numbers of New Zealand Zopheridae (=Colydiidae) from 1880 until
1923. Altogether, Broun described 146 species of zopherids. Surprisingly, all but three
(as secondary homonyms) of Broun’s names are currently valid, but revisions are needed
for species validations and generic assignments. Description of New Zealand zopherids
ended with Broun’s last publication in 1923. Thereafter, work on the fauna was nil,
though species were catalogued or listed by Hutton (1904), Hudson (1923), Hetschko
(1930), and Maddison (2010) with numbers of species from Hudson (1923) recapitulated
in Watt (1982a), and Klimaszewski and Watt (1997).

Ślipiński and Lawrence (1997) presented a comprehensive generic revision and a
key to the Australo-Pacific colydiine genera, providing a suitable starting point for
focused studies of the New Zealand species. Most species can readily be identified to
genus, though some difficulties are encountered, especially with smaller specimens and
those covered by waxy excretions and encrustations (e.g. Figs. 39, 121, 158, 169). Closer
examination of the named species, notably the type material, yields further problems with
identification. For example, in related population studies (Marske et al. 2011), a cursory
examination types and dissections of Epistranus Sharp and the Pristoderus bakewellii
group (= Enarsus Pascoe) did not indicate well-defined species breaks that correlated
with well-supported haplotype lineages. Phenotypic variation, therefore, requires careful
scrutiny, especially in lineages of New Zealand saproxylic beetles that have been
subjected to a rather unique set of geographic, climatic, and geologic processes
confined to a relatively small landmass separated from the rest of Gondwana for some
We are part of a small team of researchers studying the systematics of New Zealand zopherids employing a combined morphological and molecular approach to document species diversity, classification, and their evolution in New Zealand (a sister study is under way by our counterparts in Australia; *e.g.*, Turco *et al.* 2012). Because of the hyperdiversity that exists in New Zealand, it is imperative that sound taxonomic work begins with a study of the primary literature and museum specimens. For this paper, we examined nearly all types, photorecorded primary types and associated labels, designate lecto- and paralectotypes, and provide synonymies and replacement names where necessary. The purpose of this paper is to stabilize the nomenclature of the New Zealand species in a critical foundational step before proceeding with revisionary studies. This paper does not attempt to make any taxonomic changes outside of the new combinations, a synonymy, and a single replacement name given via an application of current genus-group names.

**Materials and Methods**

**Literature and format**

Most relevant taxonomic and primary literature for New Zealand Zopheridae was checked by the authors, including major catalogues and checklists (*e.g.*, Hutton 1904; Hudson 1923; Hetschko 1930; Ivie and Ślipiński 1990). An attempt was made to include all spelling errors within publications and the Zoological Records. Pagination of combinations given in abstracts and indices at the beginning and end of works were omitted. In order to provide additional interpretability to the nomina listed in the synonymical tables, a comma is used between the author and year for attributions of
original combinations (e.g. *Ablabus brevis* Broun, 1882: 292), whereas a comma is not used between the author and year for citations of original combinations (e.g. *Ablabus brevis* Maddison 2010: 426). Subsequent combinations of nomina are separated by a colon from the citations for that combination (e.g. *Notoulus brevis*: Hutton 1904: 168).

Format largely follows Leschen and Gimmel (2012). A complete synonymical listing, type locality, Broun number (see below), remarks, and type material examined sections are presented under each species entry. Where possible, detailed information about the type specimens (including mounting method, damage, etc.) is recorded in each account.

Label data for all type specimens are recorded under the following conventions: double quotes (“”) enclose label data quoted verbatim; double forward slashes (//) separate labels; brackets [ ] enclose our comments or notes. Label text is typed, unless noted in brackets. All primary types (incl. card-mounts, if informative) and type labels were imaged (Figs. 1–421). Images of primary types were taken on a Visionary Digital Passport Imaging system utilizing a Canon 40D DSLR camera, stacked using Zerene Stacker v. 1.04, and edited in Adobe Photoshop CS5.

**Remark on Broun Numbers**

Thomas Broun allocated unique numbers to the 4,000 plus species of New Zealand Coleoptera treated throughout his works (though some were omitted, see May 1967) and also listed or described several varietal forms to which he often gave unique names (e.g. *Vitiacus costatus* var. *incertus* Broun, 1895: 195). We treated these varieties as species in the cases where a new name was provided (accompanied by a description
and generally a Broun number), as these were usually listed as formal species in later works (e.g. Hetschko 1930).

Examination and designation of type material

An effort was made to examine all holotypes and syntypes and designate primary and (when applicable) secondary types for each of the New Zealand species in accordance with Art. 74.7 of the International Code of Zoological Nomenclature. The following collections were examined (museum coden and curator in parentheses): Auckland War Memorial Museum (AMNZ; John Early), Muséum National d’Histoire Naturelle, Paris, France (MNHN; Thierry Deuve, Azadeh Taghavian), Natural History Museum, London (BMNH; M. Barclay, Roger Booth) and the New Zealand Arthropod Collection, Auckland (NZAC). The Hungarian Natural History Museum, Budapest (HNHM; Otto Merkl) and the Museum für Naturkunde, Berlin (MNHUB; Bernd Jaeger, Manfred Uhlig) were also consulted for potential Reitter material. It is possible (and in some cases, probable) that additional syntype specimens not identified in this paper exist. Material was frequently traded between workers (e.g., Broun, Sharp, and Brookes) and some syntypic series were split up, re-sorted, and in some instances and re-labeled in various collections (e.g. Broun material in MNHN, Brookes Collection in NZAC). Primary type specimens were located for all but the following species: Bolitophagus anguliferus Blanchard (MNHN?), Ectomida lacerata Pascoe (BMNH? Presumed lost), and Penthelispa acutangulum Reitter (Presumed lost). All type specimens examined and designated were affixed with appropriate labels by the authors with the following form (e.g.) “LECTOTYPE Ulonotus plagiatus Broun, 1911 designated by N.P. Lord and
R.A.B. Leschen, 2010”. Red labels were affixed to holotypes and lectotypes; blue labels were affixed to paralectotypes. For the sake of brevity, our type labels are not included in the label data and figures.

**Remarks on Syntype Material**

Handwriting on card-mounts and labels was confirmed by the authors using Horn *et al.* (1990) and with assistance from R. Booth (BMNH) and Trevor Crosby (NZAC). The following conventions were used in determining members of syntypic series of previously described species:

Many BMNH specimens, especially those contained in the Broun and Sharp collections, bear a round label with a red/orange or blue border and the word “TYPE.” These specimens should be regarded as potential syntypes, but not as definitive holotypes, lectotypes, or paratypes as may be indicated by the affixed labels. Over the course of the BMNH Coleoptera Collection’s history, various parts of the collection were moved and later re-amalgamated. Curators went through the collection and placed these labels on specimens in a conservative fashion (R. Booth, personal communication). When there was some doubt of the constituents of the syntypic series, conservative lectotype and paralectotype designations were made by us where specific information in the original descriptions or on specimens/labels was ambiguous or incomplete.

Much of Sharp’s material is labeled as “Type” or “Ind. typ.”, usually written at the base of the card-mount in his distinctive hand. It is unclear what Sharp meant by “Ind. type,” as these were probably syntypes or material compared to his concept of his “type” specimens. When possible, we regard this material as part of the syntypic series. This
assertion is strengthened when the locality information, collector, and/or collection dates on the specimens match those of the original descriptions.

The labels on Broun material are often diagnostic for syntypes. If written in Broun’s hand, labels with a full stop (.) after the determination and/or Broun number labels usually indicate syntypic material. This information helped to confirm syntypical material held in other collections outside of the principal Broun collection maintained at the BMNH (i.e., MNHN and NZAC). There are a number of presumed Broun syntype specimens in the NZAC with labels in Albert Brookes’ (a late contemporary of Broun, see preface for Broun, 1923: 667) distinctive hand, confirmed from handwriting on other labels and texts (including a Hutton catalogue annotated by Brookes himself). Broun and Brookes exchanged material, and several of the NZAC specimens match the exact date and locality given in the original description. These specimens are most likely original Broun material and were either originally or subsequently labeled by Brookes. Thus, we consider many of these specimens to be syntypes.

**Remark on Type Localities**

In an attempt to conform to Article 76.2, the place of origin of a designated lectotype becomes the type locality of the nominal species-group taxon. In some instances, the locality recorded on the labels was lacking or less specific than that published in the original description (e.g. label data states “Otago,” whereas original description states “Moeraki,” which is in the Otago Region). In these cases the more specific of the two localities is given, or the locality was inferred from collector data (e.g. “New Zealand Helms Reitter” = Greymouth, as Reitter received Helms’ material from
Greymouth; much of Sharp’s (1876) material was received from Broun from Tauria, but not labeled as such). Occasionally, the localities on designated paralectotypes rather than the designated lectotype more accurately matched the locality given in the original description (e.g. *Ablabus nodosus* Broun). In these instances, the additional information listed in the section above (e.g. Sharp “Type” on card-mount, Broun hand-written determination labels, label formatting) was taken into account in order to select the most appropriate specimen for type designation. Additional information from the original descriptions or labels is provided in brackets ([]).

**Nomenclatural Acts**

We present 24 new combinations. All remaining New Zealand members of the genus *Coxelus* Dejean, 1821 are herein moved to *Notocoxelus* Ślipiński and Lawrence 1997. For the sake of clarity, all combinations of species-group names resulting from genus-group synonymies within Ivie and Ślipiński 1990 and Ślipiński and Lawrence 1997 that were not explicitly stated as new combinations in those works are listed as “implied combinations” herein. The majority of these combinations was later given in Maddison 2010 and are listed as such in the synonymical tables for each species.

One replacement name is proposed: *Chorasusbeckae*, replacement name for *C. subcaecus* (Broun), 1921a: 528, preoccupied by *Chorasus subcaecus* Sharp, 1882: 80.

One new synonymy is reported: *Pycnомерus sulcatissimus* Sharp, 1886 is a junior synonym and secondary homonym of *Pycnомерus sulcatissimus* (Reitter, 1880).
CHECKLIST OF THE GENERA OF NEW ZEALAND ZOPHERIDAE

(species numbers = N.Z. species)

Subfamily: Colydiinae, Tribe: Synchitini (154 spp.)

1. *Ablabus* Broun, 1880 (= *Notoulus* Broun, *Symphysius* Broun) (19 spp.)

2. *Allobitoma* Broun, 1921 (1 sp.)


4. *Chorasus* Sharp, 1882 (= *Vitiacus* Broun) (10 spp.)

5. *Ciconissus* Broun, 1893 (= *Caanthus* Champion) (1 sp.)


7. *Glenentela* Broun, 1893 (2 spp.)

8. *Heterargus* Sharp, 1886 (= *Protarphius* Broun, *Gathocles* Broun) (17 spp.)


10. *Norix* Broun, 1893 (1 sp.)

11. *Notocoxelus* Ślipiński and Lawrence, 1997 (22 spp.)


13. *Rytinotus* Broun, 1880 (= *Edalus* Broun) (1 sp.)

14. *Syncalus* Sharp, 1876 (= *Acosmetus* Broun) (9 spp.)

15. *Tarphiomimus* Wollaston, 1873 (= *Ectomida* Pascoe) (3 spp.)
Subfamily: Zopherinae, Tribe: Pycnomerini (35 spp.)

16. *Pycnomerodes* Broun, 1886 (1 sp.)


CATALOGUE

**Family ZOPHERIDAE** Solier, 1834: 505.

**Subfamily COLYDIINAE** Billberg, 1820: 394.

Tribe SYNCHITINI Erichson, 1845: 254. Type genus: *Synchita* Hellwig, 1792.

**ABLATUS** Broun, 1880


Remarks: *Notoulus* was listed as an objective synonym of *Ablabus* by Ivie and Ślipiński 1990: 9. Hetschko (1930: 37) listed *Ablabus obscurus* (Blackburn) from “Neu-Seeland” in error, as this species was described from South Australia.

*Ablabus brevis* Broun, 1882

(Figs. 1–3)


Type locality: Tairua (Auckland).

Broun number: 1353.

Remarks: The description of this species was re-printed in Part III of Broun’s Manual of New Zealand Coleoptera (1886: 763). Broun did not mention the number of specimens examined. In order to stabilize this name, a lectotype and paralectotype are here designated from the material of *Ablabus brevis*.

acetate card as lectotype, bottom specimen is a paralectotype, mounted venter-up, labels same as lectotype.

*Ablabus crassulus* (Broun, 1914)

(Figs. 4–5)


*Ablabus crassulus*: Implied combination based on *Notoulus* as an objective synonym of *Ablabus* in Ivie and Ślipiński 1990: 9.


**Type locality**: Mount Te Aroha.

**Broun number**: 3405.

**Remarks**: Broun mentioned that he based this species on two specimens collected in November, 1910. In order to stabilize this name, a lectotype and paralectotype are here designated from the material of *Notoulus crassulus*.


*Ablabus demissus* (Broun, 1912)

(Figs. 6–7)

*Ablabus demissus*: Implied combination based on *Notoulus* as an objective synonym of *Ablabus* in Ivie and Ślipiński 1990: 9).


**Type locality**: Mount Pirongia.

**Broun number**: 3224.

**Remarks**: Broun based this species on a single specimen collected in December, 1909.


*Ablabus discors* (Broun, 1921)

(Figs. 8–9)


*Ablabus discors*: Implied combination based on *Notoulus* as an objective synonym of *Ablabus* in Ivie and Ślipiński 1990: 9.

*Ablabus discors*: Combination by Maddison 2010: 426.

**Type locality**: Titirangi.

**Broun number**: 4048.

**Remarks**: Broun based this species on a single specimen collected on 21 November, 1914.

*Ablabus facetus* (Broun, 1893)

(Figs. 10–11)


*Ablabus facetus*: Implied combination based on *Notoulus* as an objective synonym of *Ablabus* in Ivie and Ślipiński 1990: 9.


**Type locality:** Moeraki.

**Broun number:** 2353.

**Remarks:** Broun based this species on a single specimen.


*Ablabus fervidulus* Broun, 1880

(Figs. 12–13)


**Type locality:** Tairua.
**Broun number:** 329.

**Remarks:** Broun based this species on a single specimen.


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**Ablabus libentus** (Broun, 1886)

(Figs. 14–15)


*Ablabus libentus*: Implied combination based on *Notoulus* as an objective synonym of *Ablabus* in Ivie and Ślipiński 1990: 9.


**Type locality:** Waitakere Range, Auckland.

**Broun number:** 1705.

**Remarks:** Broun did not mention the number of specimens examined. In order to stabilize this name, a lectotype is here designated from the material of *Notoulus libentus*.


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**Ablabus lobifer** (Broun, 1909)

(Figs. 16–17)

Ablabus lobifer: Implied combination based on synonymy of Symphysius with Ablabus in Ślipiński and Lawrence 1997: 351, figs. 9–11 on pg. 352 (Note: figs. 9–11 labeled as Ablabus lobifer (Sharp), but this is a misidentification, as illustration is of Ablabus serratus (Broun), and authority is incorrectly attributed to Sharp).


Type locality: Invercargill.

Broun number: 2776 (as given in May 1967: 178).

Remarks: Broun based this species on a single specimen.


Ablabus longipes (Broun, 1914)

(Figs. 18–19)


Ablabus longipes: Implied combination based on Notoulus as an objective synonym of Ablabus in Ivie and Ślipiński 1990: 9.


Type locality: Hump Ridge, near Invercargill.

Broun number: 3543.
Remarks: Broun mentioned that he based this species on two specimens collected in February, 1912. In order to stabilize this name, a lectotype and paralectotype are here designated from the material of Notoulus longipes.


Ablabus nodosus Broun, 1886

(Figs. 20–21)


Type locality: Hooper’s Inlet; near Dunedin [Otago Region].

Broun number: 1594.

Remarks: Broun mentioned that he based this species on a specimen from Hooper’s Inlet and “2 or 3” others from near Dunedin. Two specimens from Dunedin and Otago, respectively, were located in the BMNH. In order to stabilize this name, a lectotype and paralectotype are here designated from the material of Ablabus nodosus.


**Ablabus ornatus** Broun, 1880

(Figs. 22–23)


**Type locality**: Mount Manaia [Whangarei Heads].

**Broun number**: 326.

**Remarks**: Broun mentioned that he based this species on five specimens. Two specimens with similar localities were located at the BMNH. In order to stabilize this name, a lectotype and paralectotype are here designated from the material of *Ablabus ornatus*.


**Ablabus pallidipictus** Broun, 1880

(Figs. 24–25)


**Type locality:** Parua Bay [vicinity of Whangarei Harbour].

**Broun number:** 327.

**Remarks:** Broun mentioned that he based this species on four specimens from Whangarei Harbour, but only two specimens were located in the BMNH. In order to stabilize this name, a lectotype and paralectotype are **here designated** from the material of *Ablabus pallidipictus*.


*Ablabus punctipennis* Broun, 1880

(Figs. 26–27)


**Type locality:** Tairua.

**Broun number:** 330.

**Remarks:** Broun based this species on a single specimen.


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Ablabus scaber Broun, 1880

(Figs. 28–29)

Ablabus scabra Broun, 1880: 185.


Type locality: Tairua.

Broun number: 328.

Remarks: Note that the male gender ending of the Latin “scabr-” is formed as scaber (as listed above). Broun based this species on a single specimen. Broun’s determination label on the holotype reads “Notoulus scabrus,” but the name given in the original description is Ablabus scabra.


Ablabus sellatus (Sharp, 1886)

(Figs. 30–32)


Hudson 1934: 58.

Ablabus sellata: Implied combination based on Notoulus as an objective synonym of Ablabus in Ivie and Ślipiński 1990: 9.

**Type locality:** Greymouth.

**Broun number:** 1927.

**Remarks:** Note that the male gender ending of the Latin “*sellata*” is formed as *sellatus* (as listed above). Sharp did not mention the number of specimens examined. Sharp lists the specimen data as “Greymouth. Helms, No. 289.” In the BMNH there are 21 specimens identified by Sharp from Greymouth, with Sharp’s distinctive handwriting on the card-mount. There are two specimens with “Types” hand-written by Sharp on the same card, and we designate the specimen on the right as the lectotype, the left specimen as a paralectotype. All remaining specimens in the assumed syntypic series have the “Greymouth New Zealand [red underline] Helms.” label, and the “Sharp Coll. 1905-313.” label. In order to stabilize this name, a lectotype and 20 paralectotypes are here designated from the material of *Bitoma sellata*. There is one card-mounted specimen in the BMNH bearing the labels “Greymouth, New Zealand. [red underline] Helms. // Sharp Coll. 1905-313.” another card-mounted specimen [card has five black lines] bearing the labels: “Greymouth, New Zealand. [red underline] Helms. // Sharp Coll. 1905-313. // sellatus n.sp. [handwritten, appears to be in Sharp’s hand]”, and three specimens card-mounted together with a determination label of “Bitoma sellata Greymouth” in Sharp’s hand, but the bottom label states “N.Zeal / [red line] / 86 20”. We do not regard these as syntypes due to the lack of a determination and different card style.

**Type material examined:** Lectotype (BMNH): mounted on same card as a paralectotype, right specimen is the lectotype, “Bitoma sella- ta. Types. D.S. Greymouth. N. Zeal^d_. Helms. [written at base of card in Sharp’s hand] // Type [round label with red border] //


*Ablabus serratus* (Broun, 1909)

(Figs. 33–34)


**Type locality**: Southland.

**Broun number**: 2775 (as given in May 1967: 178).

**Remarks**: Broun mentioned that he based this species on three specimens: two specimens from “Southland” and one with the number “5237” on it sent by J.H. Lewis that was caked with dried sap and dirt. The two specimens from “Southland” were located and are mounted on the same card type, but we did not locate the specimen with the “5237” number as Broun described. There are two specimens with “Greymouth Lewis” labels, one of which bears a “37” label, the other lacking this label and mounted ventrally on the card. We assume that Broun miscounted the number of specimens and/or also quoted or miswrote the Lewis batch label. In order to stabilize this name, a lectotype and two paralectotypes are here designated from the material of Symphysius serratus.

Ablabus sparsus (Broun, 1886)

(Figs. 35–36)


Ablabus sparsus: Implied combination based on Notoulus as an objective synonym of

Ablabus in Ivie and Ślipiński 1990: 9.


Type locality: Stratford, base of Mount Egmont [Taranaki Region].

Broun number: 1704.

Remarks: Broun did not mention the number of specimens examined. In order to stabilize this name, a lectotype and three paralectotypes are here designated from the material of Notoulus sparsus.


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**Ablabus truncatus** (Broun, 1914)

(Figs. 37–38)


*Ablabus truncatus*: Implied combination based on *Notoulus* as an objective synonym of *Ablabus* in Ivie and Ślipiński 1990: 9.

*Ablabus truncatus*: Maddison 2010: 426.

**Type locality**: McClennan’s Bush, near Methven.

**Broun number**: 3542.

**Remarks**: Broun mentioned that he based this species on two specimens collected on 15 March, 1912. In order to stabilize this name, a lectotype and paralectotype are here designated from the material of *Notoulus truncatus*.


**Ablabus varicornis** (Broun, 1910)

(Figs. 39–40)


*Ablabus varicornis*: Implied combination based on *Notoulus* as an objective synonym of *Ablabus* in Ivie and Ślipiński 1990: 9.


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Type locality: Dunedin.

Broun number: 3086.

Remarks: Broun based this species on a single specimen.


**ALLOBITOMA** Broun, 1921

*Allobitoma* Broun, 1921a: 526. Type species: *Allobitoma halli* Broun, 1921, fixed by monotypy.

*Allobitoma halli* Broun, 1921

(Figs. 41–42)


Type locality: Glenhope.

Broun number: 4049.

Remarks: Broun mentioned that he based this species on two specimens collected on 20 December, 1914. In order to stabilize this name, a lectotype and paralectotype are here designated from the material of *Allobitoma halli*.  

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*BITOMA* Herbst, 1793


*Ditoma* Illiger, 1807: 320, unjustified emendation of *Bitoma* Herbst. Type species:

*Tritoma crenata* Fabricius, 1775, by subsequent designation of Latreille, 1810: 431.


*Euditomum* Gistel, 1857: 26 (also cited as p. 524). Type species: *Ditoma unicolor* Gistel, 1857, fixed by monotypy.


Synchytodes Crotch, 1873: 45. Type species: Bitoma quadriguttata Say, 1827, designated by Ivie and Ślipiński 1990: 5.

Synchitodes Reitter, 1882: 130. Incorrect subsequent spelling, not available.

**Bitoma auriculata** Sharp, 1886

(Figs. 43–45)


**Type locality**: New Zealand.

**Broun number**: 1928.

**Remarks**: Sharp based this species on a single specimen.


**Bitoma brouni** (Hetschko, 1928)

(Figs. 46–47)
**Bitoma brouni** (Hetschko, 1928: 141; as *Ditoma*). Replacement name for *Bitoma obsoleta* Broun 1914b: 176, preoccupied by *Bitoma obsoleta* Grouvelle, 1903: 182.


*Bitoma obsoleta* Broun: Hudson 1923: 369.

**Type locality:** Rakaia Gorge, near Methven.

**Broun number:** 3544.

**Remarks:** Broun based his *Bitoma obsoleta* on a single specimen collected on 1 November, 1912. This was given the replacement name *Bitoma brouni* (Hetschko, 1928: 142; as *Ditoma*).


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**Bitoma costicollis** (Reitter, 1880)

(Figs. 48–49)


*Bitoma costicollis:* Implied combination based on synonymy of *Phormesa* with *Bitoma* in Ślipiński and Lawrence 1997: 361.

*Bitoma costicollis:* Maddison 2010: 426 (attributed to Reitter, although author and year were not in parentheses).

**Type locality:** Greymouth.
Broun number: 3085.

Remarks: Reitter did not mention the number of specimens examined. In order to stabilize this name, a lectotype and seven paralectotypes are here designated from the material of Phormesa costicollis.


Paralectotypes (MNHN): 5, individually mounted on separate cards and pins, with identical labels, “EX. COLL. REITTER”. Paralectotypes (MNHN): 2, individually mounted on separate cards and pins, with identical labels, “New Zealand Helms Reitter”.

Bitoma discoidea Broun, 1880

(Figs. 50–51)


Type locality: Mount Manaia [Whangarei Heads].

Broun number: 349.

Remarks: Broun mentioned that he based this species on two specimens. In order to stabilize this name, a lectotype and paralectotype are here designated from the material of Bitoma discoidea.


155

**Bitoma distans** Sharp, 1876

(Figs. 52–54)


**Type locality**: Tairua.

**Broun number**: 345.

**Remarks**: Sharp did not mention the number of specimens examined. In order to stabilize this name, a lectotype and four paralectotypes are here designated from the material of *Bitoma distans*.


**Bitoma distincta** Broun, 1880

(Figs. 55–56)


**Type locality**: Tairua.
**Bitoma guttata** Broun, 1886

*(Figs. 57–58)*


**Type locality:** near Dunedin [Otago Region].

**Broun number:** 1597.

**Remarks:** Broun based this species on a single specimen.


**Bitoma insularis** White, 1846

*(Figs. 59–61)*

**Type locality:** Port Nicholson.

**Broun number:** 343.

**Remarks:** White did not mention the number of specimens examined. In order to stabilize this name, a lectotype and paralectotype are here designated from the material of *Bitoma insularis*.

**Type material examined:** *Lectotype* (BMNH): mounted on same card as paralectotype, left specimen is the lectotype, “Type [round label with red border] // Port. Nicholson N. Zealand [dark green label with black border, in White’s hand] // 67. 78- [round blue label, handwritten] // Bitoma insularis White. Zool. Ereb & Terro [handwritten]”. *Paralectotype* (BMNH): mounted on same card as lectotype, right specimen is a paralectotype, mounted on right side and missing head and prothorax, labels same as lectotype.

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**Bitoma lobata** Broun, 1886

*(Figs. 62–63)*


**Type locality:** Woodhill, near Waitakere Range.

**Broun number:** 1482.

**Remarks:** Broun based this species on a single specimen.


158
Bitoma morosa Broun, 1921

(Figs. 64–65)


Type locality: Lake Rotoiti, Nelson.

Broun number: 4181.

Remarks: Broun based this species on a single specimen collected on 17 March, 1916.


Bitoma mundula Sharp, 1886

(Figs. 66–68)


Type locality: Picton.

Broun number: 1930.

Remarks: Sharp based this species on a single specimen.

Type material examined: Holotype (BMNH): card-mounted, “Bitoma mundu- la Type D.S. Picton N. Zeal\textsuperscript{d} Helms [written at base of card in Sharp’s hand] // Type [round label with red border] // Sharp Coll 1905-313. // BMNH(E) #651700”.

Bitoma nana Sharp, 1876
(Figs. 69–71)


**Type locality:** Tairua.

**Broun number:** 347.

**Remarks:** Sharp based this species on a single specimen.

**Type material examined:** *Holotype* (BMNH): card-mounted, “Bitoma nana Type N. Zeal’d D.S. [written at base of card in Sharp’s hand] // Type [round label with red border] // Sharp Coll 1905-313.”

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*Bitoma novella* Hetschko, 1929

(Figs. 72–73)


**Type locality:** Waimarino.

**Broun number:** 3225.

**Remarks:** Broun based this species on a single specimen collected in January, 1910.


160
**Bitoma picicornis** Broun, 1909

(Figs. 74–75)


**Type locality**: Broken River.

**Broun number**: 2762 (as given in Broun 1914b: 177; May 1967: 178).

**Remarks**: Note that the female gender ending of the Latin “*picicorn*” is formed as *picicornis* (as listed above). Broun based this species on a single specimen.


**Bitoma rugosa** Sharp, 1876

(Figs. 76–78)


Maddison 2010: 426.

**Type locality**: Tairua.

**Broun number**: 346.

**Remarks**: Sharp did not mention the number of specimens examined. One specimen labeled as “var” [handwritten] was not considered a syntype because it did not have “Ind.
typ" written on the card mount in Sharp’s hand. In order to stabilize this name, a
lectotype and five paralectotypes are here designated from the material of Bitoma
rugosa.

**Type material examined:** Lectotype (BMNH): card-mounted, “Bitoma rugosa Type N.
Zeal’d D.S. [written at base of card in Sharp’s hand] // Type [round label with red border]
// Sharp Coll. 1905-313.” Paralectotypes (BMNH): 2, individually mounted on separate
cards and pins, with identical labels, “Bitoma rugosa Ind. typ. N. Zeald [written at base of
card mount in Sharp’s hand] // Sharp Coll. 1905-313.” Paralectotypes (BMNH): 3,
individually mounted on separate cards and pins, with identical labels, “Bitoma rugosa
1905-313.”

**Bitoma scita** Broun, 1886

(Figs. 79–80)


**Type locality:** Whangarata, near Tuakau.

**Broun number:** 1596.

**Remarks:** Broun based this species on a single specimen.

**Type material examined:** Holotype (BMNH): card-mounted, “Type [round label with
red border] // 1596. [in Broun’s hand] // Whangarata // New Zealand. [red underline]
Broun Coll. Brit. Mus. 1922-482. // Bitoma scita - [in Broun’s hand]”.

**Bitoma serraticula** Sharp, 1886

162

**Type locality:** New Zealand.

**Broun number:** 1929.

**Remarks:** Sharp based this species on a single specimen.

**Type material examined:** Holotype (BMNH): card-mounted, “Bitoma serraticula Type D.S. New Zealand. Murray [written at base of card in Sharp’s hand] // Type [round label with red border] // Sharp Coll. 1905-313. // BMNH(E) #651701”.

**Bitoma vicina** Sharp, 1876

(Figs. 84–86)


**Type locality:** Tairua.

**Broun number:** 344.

**Remarks:** Sharp did not mention the number of specimens examined. In order to stabilize this name, a lectotype and two paralectotypes are **here designated** from the material of **Bitoma vicina**. There are five additional specimens, one singleton and two pairs card-mounted on separate pins (one pair with right specimen mounted venter-up, with pin head removed) that bear only “Sharp Coll. 1905-313” labels. These appear to be
on the same card and pin type as the lectotype and paralectotypes and may be part of a split-up series. These specimens are not regarded as syntypes, however, due to lack of information.


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**CHORASUS** Sharp, 1882

*Chorasus* Sharp, 1882: 79. Type species: *Chorasus subcaecus* Sharp, 1882, fixed by monotypy.

*Vitiacus* Broun, 1893b: 1087. Type species: *Vitiacus costatus* Broun, 1893, fixed by monotypy. Synonymized with *Chorasus* Sharp by Ślipiński and Lawrence 1997: 368.

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*Chorasus beckae*, NEW NAME

*(Figs. 87–88)*

*Chorasus beckae*, replacement name for *Chorasus subcaecus* (Broun, 1921a: 528; as *Vitiacus*), preoccupied by *Chorasus subcaecus* Sharp, 1882: 80.

**Chorasus subcaecus** (Broun): Implied combination based on synonymy of *Vitiacus* with *Chorasus* in Ślipiński and Lawrence 1997: 368.

**Type locality:** Hollyford.

**Broun number:** 4051.

**Remarks:** Broun based this species on a single specimen collected on 20 February, 1914.

**Etymology:** The specific epithet of the replacement name honors Becky Freeman for her support during the preparation of this work.


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**Chorasus costatus** (Broun, 1893)

(Figs. 89–90)


*Chorasus costatus*: Ślipiński and Lawrence 1997: 368, based on synonymy of *Vitiacus* with *Chorasus* (p. 368). Maddison 2010: 426.

**Type locality:** Moeraki.

**Broun number:** 1937.

**Remarks:** Broun based this species on a single specimen.


*Chorasus costicollis* (Broun, 1893)

(Figs. 91–92)


*Chorasus costicollis*: Implied combination based on synonymy of *Vitiacus* with *Chorasus* in Ślipiński and Lawrence 1997: 368.

*Chorasus costicollis*: Maddison 2010: 426.

**Type locality**: Capleston.

**Broun number**: 2501.

**Remarks**: Broun based this species on a single specimen.


*Chorasus incertus* (Broun, 1895)

(Figs. 93–94)


*Chorasus incertus*: Implied combination based on synonymy of *Vitiacus* with *Chorasus* in Ślipiński and Lawrence 1997: 368.

*Chorasus incertus*: Maddison 2010: 426.
Type locality: Mount Te Aroha.

Broun number: 2774 (as given in Broun 1921a: 530; May 1967: 178).

Remarks: Broun mentioned that he based this species on two specimens collected in March, 1894. Broun (1895: 195) originally listed this taxon as a varietal form of \textit{V. costatus} to be treated further when more material of both forms became available. Hetschko (1930: 48) also listed it as a variety of \textit{Vitiacus costatus} Broun. However, \textit{V. incertus} was listed as a distinct species in later works (e.g. May 1967), thus we regard this species as distinct and not a varietal form. In order to stabilize this name, a lectotype and paralectotype are here designated from the material of \textit{Vitiacus incertus}.


\textit{Chorasus lateralis} (Broun, 1921)

(Figs. 95–96)


Type locality: Erua.
**Broun number**: 4056.

**Remarks**: Broun based this species on a single specimen collected in January, 1909. A duplicate specimen was located in the MNHN Broun Collection, but we do not recognize this as a syntype since it lacked Broun’s handwritten “4056.” and Broun (1921a: 531) indicated only having examined a single specimen.


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**Chorasus posticalis** (Broun, 1921)

(Figs. 97–98)


*Chorasus posticalis*: Implied combination based on synonymy of *Vitiacus* with *Chorasus* in Ślipiński and Lawrence 1997: 368.

*Chorasus posticalis*: Maddison 2010: 426.

**Type locality**: Hollyford.

**Broun number**: 4052.

**Remarks**: Broun based this species on a single specimen collected on 20 February, 1914.


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**Chorasus purus** (Broun, 1921)

(Figs. 99–100)

Chorasus purus: Implied combination based on synonymy of Vitiacus with Chorasus in Ślipiński and Lawrence 1997: 368.

Chorasus purus: Maddison 2010: 426.

Type locality: Hollyford.

Broun number: 4053.

Remarks: Broun based this species on a single specimen collected on 16 February, 1914.


Chorasus setarius (Broun, 1921)

(Figs. 101–102)


Chorasus setarius: Implied combination based on synonymy of Vitiacus with Chorasus in Ślipiński and Lawrence 1997: 368.


Type locality: Erua, near Waimarino.

Broun number: 4055.

Remarks: Broun mentioned that he based this species on two specimens collected in January, 1909 and 1910. Only one of the two specimens matching the date and locality was located BMNH Broun collection. In order to stabilize this name, a lectotype is here designated from the material of Vitiacus setarius.

*Chorasus subcaecus* Sharp, 1882

(Figs. 103–105)


*Chorasus subcoecus*: Hetschko 1930: 59. Incorrect subsequent spelling, not available.

**Type locality:** Greymouth.

**Broun number:** 1943.

**Remarks:** Sharp did not mention the number of specimens examined. In order to stabilize this name, a lectotype and eight paralectotypes are here designated from the material of *Chorasus subcaecus*. There are an additional six specimens in the BMNH that appear to be on the same card and pin type as the syntypic series. While it is possible these specimens are also part of the syntypic series, we do not regard them as such due to the discrepancy in label data (e.g., one specimen was dated 1885).


*Chorasus suturalis* (Broun, 1921)

(Figs. 106–107)


*Chorasus suturalis*: Implied combination based on synonymy of *Vitiacus* with *Chorasus* in Ślipiński and Lawrence 1997: 368.

*Chorasus suturalis*: Maddison 2010: 426.

**Type locality:** Mount Owen.

**Broun number:** 4054.

**Remarks:** Broun based this species on a single specimen collected on 27 December, 1914.

Mus. 1922-482. // M\(^{1}\) Owen. 27.12.1914. [in Broun’s hand] // Vitiacus suturalis [in
Broun’s hand]”.

**CICONISSUS** Broun, 1893

*Ciconissus* Broun, 1893a: 185. Type species: *Ciconissus granifer* Broun, 1893, by
monotypy.

*Caanthus* Champion, 1894: 378. Type species: *Caanthus gibbicollis* Champion, 1894, by
monotypy. Synonymized with *Ciconissus* Broun by Ślipiński and Lawrence 1997:
372.

**Ciconissus granifer** Broun, 1893

(***Figs. 108–109**)


**Type locality**: Mount Pirongia.

**Broun number**: 2773.

**Remarks**: Broun mentioned that he based this species on seven specimens collected in
December, 1892. Three specimens in the BMNH and one in the NZAC matching this
data were located. In order to stabilize this name, a lectotype and three paralectotypes are
here designated from the material of *Ciconissus granifer.*

**EPISTRANUS** Sharp, 1877

*Epistrophus* Sharp, 1876: 22 [nec Kirsch, 1868]. Type species: *Epistrophus lawsoni* Sharp, 1876, fixed by monotypy.

*Epistranus* Sharp, 1877c: 395. Replacement name for *Epistrophus* Sharp, 1876.

Remarks: The genus was originally described by Sharp as *Epistrophus* (1876: 22). In 1877, Sharp re-printed his 1876 paper and replaced the name *Epistrophus* with *Epistranus* (1877c: 395) followed by a later paper (Sharp 1878: 36) re-stating this replacement name on account of being preoccupied by *Epistrophus* Kirsch, 1868. Ivie and Ślipiński (1990: 11) incorrectly attributed this replacement to Sharp 1878: 36 (not Sharp, 1877c: 395).

*Epistranus fulvus* Reitter, 1880

Type locality: Greymouth.

Broun number: 3083.

Remarks: Reitter did not mention the number of specimens examined. In order to stabilize this name, a lectotype and five paralectotypes are here designated from the material of Epistranus fulvus.


Epistranus hirtalis Broun, 1893
(Figs. 112–113)


**Type locality:** Mount Pirongia.

**Broun number:** 2772.

**Remarks:** Broun (1893) did not designate a unique species number for this species that he based on two specimens from Pirongia collected in December, 1892. We located two specimens in the BMNH, though the second specimen lacks the locality label, both specimens are considered syntypes. In order to stabilize this name, a lectotype and paralectotype are here designated from the material of *Epistranus hirtalis*.


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*Epistranus humeralis* Broun, 1880

(Figs. 114–115)


**Type locality:** Tairua.

**Broun number:** 363.
Remarks: Broun based this species on a single specimen.


Epistranus lawsoni (Sharp, 1876)

(Figs. 116–118)

Epistrophus lawsoni Sharp, 1876: 22.

Epistranus lawsoni Sharp 1877c: 395 (reprinted, with corrections, from Sharp 1876).


Type locality: Auckland.

Broun number: 362.

Remarks: Sharp based this species on a single specimen “sent from Auckland by Mr. T. Lawson…” which is labeled as a type by Sharp, but also bears a (presumably) erroneous Greymouth label.


176
**Epistranus optabilis** Broun, 1893

*(Figs. 119–120)*


**Type locality:** Moeraki.

**Broun number:** 2357.

**Remarks:** Broun mentioned that he based this species on two specimens. These were located in the BMNH Broun collection, mounted on the same card. In order to stabilize this name, a lectotype and paralectotype are here designated from the material of *Epistranus optabilis.*


**Epistranus parvus** Broun, 1886

*(Figs. 121–122)*


**Type locality:** near Howick.

**Broun number:** 1712.
Remarks: Broun did not mention the number of specimens examined. In order to stabilize this name, the single specimen of *Epistranus parvus* in the BMNH Broun collection is here designated as the lectotype.


*Epistranus sharpi* Reitter, 1880

(Figs. 123–124)


**Type locality:** Greymouth.

**Broun number:** 3082.

Remarks: Reitter did not mention the number of specimens examined. In order to stabilize this name, a lectotype and eight paralectotypes are here designated from the material of *Epistranus sharpi*.

Paralectotype (MNHN): 1, card-mounted [card with three black lines near base, middle line thicker], “Epistranus sharpi Reitter PARALECTOTYPE design. By R. LESCHEN 2009 [blue label]”.

*Epistranus valens* Broun, 1881

(Figs. 125–126)


**Type locality:** Mount Manaia [Whangarei Heads].

**Broun number:** 1168.

**Remarks:** Broun based this species on a single specimen missing one antenna.


**GLENENTELA** Broun, 1893

*Glenentela* Broun, 1893b: 1089. Type species: *Glenentela serrata* Broun, 1893, fixed by monotypy.
Glenentela costata Broun, 1921

(Figs. 127–128)


Type locality: Glenhope.

Broun number: 4050.

Remarks: Broun mentioned that he based this species on four specimens collected on 18 July, 1915. Three specimens in the BMNH and two in the NZAC matching this date were located. We assume Broun mis-reported the number of specimens before him. In order to stabilize this name, a lectotype and four paralectotypes are here designated from the material of Glenentela costata.


180
**Glenentela serrata Broun, 1893**

*(Figs. 129–130)*


**Type locality:** Howick.

**Broun number:** 1940.

**Remarks:** Broun did not mention the number of specimens examined. In order to stabilize this name, a lectotype is **here designated** from the single specimen of *Glenentela serrata* in the BMNH Broun collection.


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**HETERARGUS** Sharp, 1886

*Heterargus* Sharp, 1886: 384. Type species: *Heterargus rudis* Sharp, 1886, fixed by monotypy.


**Heterargus angulifer** (Broun, 1914)

(Figs. 131–132)


*Heterargus angulifer*: Implied combination based on synonymy of *Gathocles* with *Heterargus* in Ślipiński and Lawrence 1997: 385.


**Type locality**: McClennan’s Bush, near Methven [Mount Hutt also given in original description].

**Broun number**: 3547.

**Remarks**: Broun mentioned that he based this species on 12 specimens collected at Mount Hutt in April, 1912, which is the same locality as McLennan’s Bush. Ten specimens in the BMNH, MNHN, and NZAC with the same date ranges were located. There is one specimen in the NZAC labeled as “3547 var.” from McClennans Bush, which we do not consider a syntype. In order to stabilize this name, a lectotype and nine paralectotypes are here designated from the material of *Gathocles angulifer*. Broun’s determination label on the lectotype reads “Heterargus angulifer,” but the name given in the original description is *Gathocles angulifer*.


183
**Heterargus crassus** (Broun, 1881) NEW COMBINATION

(Figs. 133–134)


Heterargus crassus: Implied combination based on synonymy of Protarphius with Heterargus in Ślipiński and Lawrence 1997: 385.

**Type locality**: Parua.

**Broun number**: 1167.

**Remarks**: Broun mentioned that he based this species on two specimens. In order to stabilize this name, a lectotype and paralectotype are here designated from the material of Ablabus crassus.


**Heterargus decorus** (Broun, 1914)

(Figs. 135–136)

**Heterargus decorus**: Implied combination based on synonymy of *Protarphius* with *Heterargus* in Ślipiński and Lawrence 1997: 385.

**Heterargus decorus**: Maddison 2010: 426.

**Type locality**: Great Barrier Island.

**Broun number**: 3407.

**Remarks**: Broun mentioned that he based this species on two specimens collected in March, 1911. In order to stabilize this name, a lectotype and paralectotype are here designated from the material of *Protarphius decorus*.


**Heterargus fuscus** (Broun, 1923)

(Figs. 137–138)


**Heterargus fuscus**: Implied combination based on synonymy of *Gathocles* with *Heterargus* in Ślipiński and Lawrence, 1997: 385.

**Heterargus fuscus**: Maddison 2010: 426.

**Type locality**: Mount Dick, near Kingston.

**Broun number**: 4281.
Remarks: Broun did not mention the number of specimens examined, but stated they were collected on 17 March, 1914. In order to stabilize this name, a lectotype and two paralectotypes are here designated from the material of *Gathocles fuscus*.


**Heterargus grossanus** (Broun, 1886) NEW COMBINATION

(Figs. 139–140)


*Gathocles grossanus*: transferred from *Coxelus* by Broun 1893b: 1087.

*Heterargus grossanus*: Implied combination based on synonymy of *Gathocles* with *Heterargus* in Ślipiński and Lawrence 1997: 385.

**Type locality:** Dunedin.

**Broun number:** 1662.

Remarks: Broun did not mention the number of specimens examined. We located one specimen in the BMNH matching his description, though there was an additional specimen in the BMNH with a printed “Otago” label, a printed “Purakanui” label, and a
handwritten “Gathocles grossanus” determination label. This specimen is not regarded as being part of the syntypic series due to the difference in locality with the original description. In order to stabilize this name, a lectotype is here designated from the material of Coxelus grossanus.


**Heterargus indentatus (Broun, 1893)**

(Figs. 141–142)


**Type locality:** Taranaki, near Stratford.

**Broun number:** 2769.

**Remarks:** Broun mentioned that he based this species on two specimens. In order to stabilize this name, a lectotype and paralectotype are here designated from the material of *Protarphius indentatus*.

Heterargus interruptus (Broun, 1923)

(Figs. 143–144)


Heterargus interruptus: Implied combination based on synonymy of Gathocles with Heterargus in Ślipiński and Lawrence 1997: 385.


Type locality: Wellington.

Broun number: 4282.

Remarks: Even though this species was described by Broun under the name “Gathocles interruptus” in the original description, both specimens carry a “Glenentela interrupta” determination label and were located under Glenentela and above the “interruptus” tag in the BMNH Broun collection. Broun did not mention the number of specimens examined, but stated they were collected on 24 April, 1916. In order to stabilize this name, a lectotype and two paralectotypes are here designated from the material of Gathocles interruptus.

Heterargus nodosus (Broun, 1893)

(Figs. 145–146)


Type locality: Moeraki.

Broun number: 1936.

Remarks: Broun based this species on a single specimen. There is an additional specimen in the BMNH that matches the information given in the original description bearing the following label data: “1936. [in Broun’s hand] // Moeraki [in Broun’s hand] // New Zealand. [red underline] Broun Coll. Brit. Mus. 1922-482. // Gathocles nodosus [in Broun’s hand]”. Upon comparison, both specimens appeared to be of the same species. It is impossible to determine which the one specimen Broun had before him was. Therefore, we chose to recognize as the holotype the cleaner of the two specimens. Additionally, the handwritten determination label of the holotype has a period following the name, which was common on Broun’s type specimens.


189
Heterargus obliquicostatus (Broun, 1909)

(Figs. 147–148)


Type locality: Otara, Southland.

Broun number: 2767 (as given in May 1967: 178).

Remarks: Broun did not mention the number of specimens examined. Two specimens in the NZAC matching the locality were located. Three specimens in the BMNH matching the locality were located, but one is labeled as a variety and not considered a syntype. This varietal specimen was mentioned in the description as having fewer antennal segments (one side has a few funicle segments fused, but the 2-segmented club exists for both sides). In order to stabilize this name, a lectotype and four paralectotypes are here designated from the material of Gathocles obliquicostatus.

name abbreviated or perhaps label was cut] [in Broun’s hand]”. Paralectotype (BMNH):


**Heterargus pallens (Broun, 1914)**

(Figs. 149–150)


*Protarphius palleus*: Hudson 1923: 369. Incorrect subsequent spelling, not available.

*Heterargus pallens*: Implied combination based on synonymy of *Protarphius* with *Heterargus* in Ślipiński and Lawrence 1997: 385.


**Type locality**: McClennan’s Bush, near Methven.

**Broun number**: 3548.

**Remarks**: Broun did not mention the number of specimens examined, but stated they were collected in April, 1912. In order to stabilize this name, a lectotype and eight paralectotypes are **here designated** from the material of *Protarphius pallens*.

**Type material examined**: Lectotype (BMNH): card-mounted, “Type [round label with red border] // 3548. [in Broun’s hand] // M3C1ennans. 23.4.1912. [in Broun’s hand] //
Heterargus parallelus Broun, 1914

(Figs. 151–152)


Type locality: Hump Ridge, near Invercargill.

Broun number: 3546.
Remarks: Broun did not mention the number of specimens examined, but stated they were collected in February, 1912. In order to stabilize this name, a lectotype and three paralectotypes are here designated from the material of *Heterargus parallelus*.


*Heterargus posticalis* (Broun, 1909)

(Figs. 153–154)


*Heterargus posticalis*: Implied combination based on synonymy of *Protarphius* with *Heterargus* in Ślipiński and Lawrence 1997: 385.


**Type locality:** Otara, Southland.

**Broun number:** 2771 (as given in May 1967: 178).
Remarks: Broun did not mention the number of specimens examined. In order to stabilize this name, a lectotype is here designated from the material of Heterargus posticalis.


**Heterargus rudis** Sharp, 1886

(Figs. 155–157)


Type locality: Greymouth.

Broun number: 1935.

Remarks: Sharp did not mention the number of specimens examined. In order to stabilize this name, a lectotype and eight paralectotypes are here designated from the material of *Heterargus rudis*.


Paralectotype (BMNH): mounted on same card as lectotype, right specimen is a

**Heterargus ruficornis** (Broun, 1893)

(Figs. 158–159)


**Type locality:** Mount Pirongia.

**Broun number:** 2768.

**Remarks:** Broun mentioned that he based this species on two specimens collected in December, 1892. In order to stabilize this name, a lectotype and paralectotype are here designated from the material of *Protarphius ruficornis*. 

195

**Heterargus serricollis** Broun, 1893

(Figs. 160–161)


Type locality: Capleston.

Broun number: 2500.

Remarks: Broun based this species on a single specimen.


**Heterargus subaequus** Broun, 1914

(Figs. 162–163)


Type locality: Hakapoua, Southland.
**Broun number:** 3406.

**Remarks:** Broun based this species on a single specimen collected on 1 March, 1911. There was an additional specimen in the BMNH that bears a “Hakapoua, Southland” label (in Broun’s hand), but this was not considered a syntype because the specimen lacked a Broun identification label.


**Heterargus tricavus** (Broun, 1909)

*(Figs. 164–165)*


**Heterargus tricavus:** Implied combination based on synonymy of *Protarphius* with *Heterargus* in Ślipiński and Lawrence 1997: 385.

**Heterargus tricavus:** Maddison 2010: 426.

**Type locality:** Broken River, Canterbury.

**Broun number:** 2770 (as given in May 1967: 178).

**Remarks:** Broun did not mention the number of specimens examined. In order to stabilize this name, a lectotype and two paralectotypes are here designated from the material of *Protarphius tricavus*.


**LASCONOTUS** Erichson, 1845

*Lasconotus* Erichson, 1845: 258. Type species: *Lasconotus complex* LeConte, 1859, by subsequent monotypy.


*Lasconotus gracilis* (Sharp, 1876)
(Figs. 166–168)


**Type locality**: Auckland.

**Broun number**: 365.

**Remarks**: Sharp based this species on a single specimen.


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*NORIX* Broun, 1893

*Norix* Broun, 1893b: 1090. Type species: *Norix crassus* Broun, 1893, fixed by monotypy.

*Norix crassus* Broun, 1893

(Figs. 169–170)

**Type locality:** Mokohinou Island.

**Broun number:** 1941.

**Remarks:** Broun based this species on a single specimen missing a leg.


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**NOTOCOXELUS** Ślipiński and Lawrence, 1997

*Notocoxelus* Ślipiński and Lawrence, 1997: 404. Type species: *Coxelus helmsi* Reitter, 1880, fixed by monotypy.

**Remarks:** Sharp remarked on the affinities of the New Zealand *Coxelus* (= *Notocoxelus*) with that of the European *Coxelus*, suggesting it was near enough to not require a separate genus. However, Ślipiński and Lawrence (1997: 404) erected the genus *Notocoxelus* for the New Zealand members of the genus *Coxelus*, but neglected to formally designate all New Zealand species as new combinations under *Notocoxelus* (Adam Ślipiński, pers. comm.). Below we formally combine these names for the New Zealand *Coxelus*. 
Notocoxelus bicavus (Broun, 1909) NEW COMBINATION

(Figs. 171–172)


Notocoxelus bicavus: Implied combination based on the erection of the genus Notocoxelus (Ślipiński and Lawrence, 1997: 404).

Type locality: Invercargill.

Broun number: 2766 (as given in May 1967: 178).

Remarks: Broun based this species on a single specimen.


Notocoxelus chalmeri (Broun, 1886) NEW COMBINATION

(Figs. 173–174)


Notocoxelus chalmeri: Implied combination based on the erection of the genus Notocoxelus (Ślipiński and Lawrence, 1997: 404).

Type locality: Purakanui, on the coast north of Dunedin [Otago Region].

Broun number: 1711.
Remarks: Broun did not mention the number of specimens examined. In order to stabilize this name, a lectotype is here designated from the material of *Coxelus chalmeri*.


*Notocoxelus clarus* (Broun, 1882) NEW COMBINATION

(Figs. 175–176)


*Notocoxelus clarus*: Implied combination based on the erection of the genus *Notocoxelus* (Ślipiński and Lawrence, 1997: 404).

**Type locality:** Parua.

**Broun number:** 1357.

**Remarks:** Broun based this species on a single specimen.


*Notocoxelus dubius* (Sharp, 1876) NEW COMBINATION

(Figs. 177–179)

Notocoxelus dubius: Implied combination based on the erection of the genus Notocoxelus (Ślipiński and Lawrence, 1997: 404).

Type locality: Auckland and Tairua.

Broun number: 350.

Remarks: Sharp did not mention the number of specimens examined sent to him “…from Auckland and Tairua by Mr. Lawson and Captain Broun.” In the BMNH, there is one specimen from Auckland with “Ind. typ.” another specimen with “N Zeald” and “type” written at the base of the cards, both of which bear “Greymouth, New Zealand, Helms” labels, probably attached in error. There are a number of other specimens in the BMNH from Greymouth with Sharp’s handwriting at the base of the card-mount, but we do not regard these as part of the syntypic series due to the discrepancy in type locality. In order to stabilize this name, a lectotype and paralectotype are here designated from the material of Coxelus dubius.


Notocoxelus elongatus (Broun, 1909) NEW COMBINATION
Notocoxelus elongatus: Implied combination based on the erection of the genus Notocoxelus (Ślipiński and Lawrence, 1997: 404).

**Type locality:** Broken River.

**Broun number:** 2764 (as given in Broun 1914b: 178; May 1967: 178).

**Remarks:** Broun mentioned that he based this species on three specimens. In order to stabilize this name, a lectotype and two paralectotypes are here designated from the material of Coxelus elongatus.


**Notocoxelus graniceps** (Broun, 1893) NEW COMBINATION

*(Figs. 182–183)*

Notocoxelus graniceps: Implied combination based on the erection of the genus

Notocoxelus (Ślipiński and Lawrence, 1997: 404).

Type locality: Moeraki.

Broun number: 2356.

Remarks: Broun mentioned that he based this species on three specimens from Moeraki, but only two specimens in the BMNH specimens are labeled Otago or Moeraki. In order to stabilize this name, a lectotype and paralectotype are here designated from the material of Coxelus graniceps.


Notocoxelus helmsi (Reitter, 1880)

(Figs. 184–185)


Type locality: Greymouth.

Broun number: 3084.
Remarks: Reitter did not mention the number of specimens examined. In order to stabilize this name, a lectotype and 13 paralectotypes are here designated from the material of *Coxelus helmsi*.


Notocoxelus instabilis (Broun, 1914) NEW COMBINATION
(Figs. 186–187)


Notocoxelus instabilis: Implied combination based on the erection of the genus Notocoxelus (Ślipiński and Lawrence, 1997: 404).

Type locality: McClennan’s Bush, near Methven [Pudding Hill also given in original description].

Broun number: 3545.

Remarks: Broun mentioned that he based this species on “about twenty specimens” from McClennan’s Bush and Pudding Hill during April and May, 1912, but only five specimens in the BMNH and six specimens in the NZAC matching this data were located. In order to stabilize this name, a lectotype and ten paralectotypes are here designated from the material of Coxelus instabilis.

Broun’s hand]”. Paralectotype (BMNH): card-mounted venter-up, “3545 [in Broun’s
4.5.1912. [in Broun’s hand] // Coxelas instabilis [in Broun’s hand]”. Paralectotype
instabilis [in Broun’s hand]”. Paralectotypes (NZAC): 2, individually mounted on
separate cards and pins, with identical labels, “Methven. Canterbury. [in Brookes’ hand]
Collection // A.E. Brookes Collection”. Paralectotype (NZAC): card-mounted venter-up,
[blue label] // T. Broun Collection // A.E. Brookes Collection”.

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**Notocoxelus longulus** (Broun, 1893) NEW COMBINATION

(Figs. 188–189)


*Notocoxelus longulus*: Implied combination based on the erection of the genus *Notocoxelus* (Ślipiński and Lawrence, 1997: 404).

**Type locality**: Moeraki.

**Broun number**: 1934.

**Remarks**: Broun mentioned that he based this species on three specimens. In order to stabilize this name, a lectotype and two paralectotypes are here designated from the material of *Coxelus longulus*.


*Notocoxelus mucronatus* (Broun, 1911) NEW COMBINATION

(Figs. 190–191)

Notocoxelus mucronatus: Implied combination based on the erection of the genus Notocoxelus (Ślipiński and Lawrence, 1997: 404).

Type locality: Pitt Island.

Broun number: This species was listed as number 61 in the paper, but this is not a “Broun number” in the standard sense.

Remarks: Broun did not mention the number of specimens examined. In order to stabilize this name, a lectotype and seven paralectotypes are here designated from the material of Coxelus mucronatus.


**Notocoxelus oculator (Broun, 1893) NEW COMBINATION**

(Figs. 192–193)


*Notocoxelus oculator*: Implied combination based on the erection of the genus *Notocoxelus* (Ślipiński and Lawrence, 1997: 404).

**Type locality**: Moeraki.

**Broun number**: 2354.

**Remarks**: Broun based this species on a single specimen.


**Notocoxelus ovicollis (Broun, 1893) NEW COMBINATION**

(Figs. 194–195)

Notocoxelus ovicollis: Implied combination based on the erection of the genus Notocoxelus (Ślipiński and Lawrence, 1997: 404).

**Type locality:** Moeraki [Otago Region].

**Broun number:** 1933.

**Remarks:** Broun based this species on a single specimen.


Notocoxelus picicornis (Broun, 1893) NEW COMBINATION

(Figs. 196–197)


Notocoxelus picicornis: Implied combination based on the erection of the genus Notocoxelus (Ślipiński and Lawrence, 1997: 404).

**Type locality:** Moeraki.

**Broun number:** 2355.

**Remarks:** Broun based this species on a single specimen.


Notocoxelus posticalis (Broun, 1893) NEW COMBINATION

(Figs. 198–199)

Notocoxelus posticalis: Implied combination based on the erection of the genus Notocoxelus (Ślipiński and Lawrence, 1997: 404).

**Type locality:** Moeraki.

**Broun number:** 1932.

**Remarks:** Broun based this species on a single specimen.

**Type material examined:** Holotype (BMNH): card-mounted, “Type [round label with red border] // 1932. [in Broun’s hand] // Otago [topside, in Broun’s hand] oerak [underside, in Broun’s hand; label was cut and the “M” in “Moeraki” was inadvertently cut off] // New Zealand. [red underline] Broun Coll. Brit. Mus. 1922-482. // Coxelus posticalis [in Broun’s hand]”.

Notocoxelus punctatus (Broun, 1910) NEW COMBINATION

(Figs. 200–201)


Notocoxelus punctatus: Implied combination based on the erection of the genus Notocoxelus (Ślipiński and Lawrence, 1997: 404).

**Type locality:** Sunday Island.

**Broun number:** This specimen was not given a number by Broun.

**Remarks:** Broun based this species on a single specimen. In the Broun Collection Kermadecs Island drawer at the BMNH, there is a label stating “Transferred to Auckland Institute and Museum, New Zealand, 30/10/1969. ref. Trustee’s Meeting Oct.23.69”. This refers to the holotype in the AMNZ.

*Notocoxelus regularis* (Broun, 1893) NEW COMBINATION

(Figs. 202–203)


*Notocoxelus regularis*: Implied combination based on the erection of the genus *Notocoxelus* (Ślipiński and Lawrence, 1997: 404).

**Type locality:** Ashburton.

**Broun number:** 2499.

**Remarks:** Broun mentioned that he based this species on two specimens from Ashburton. Two specimens labeled “Canterbury” with “Ashburton” hand-written underneath were located in the BMNH. In order to stabilize this name, a lectotype and paralectotype are here designated from the material of *Coxelus regularis*.


**Notocoxelus robustus** (Broun, 1880) NEW COMBINATION

(Figs. 204–205)


*Notocoxelus robustus*: Implied combination based on the erection of the genus *Notocoxelus* (Ślipiński and Lawrence, 1997: 404).

**Type locality**: Mount Manaia [Whangarei Heads].

**Broun number**: 352.

**Remarks**: Broun based this species on a single specimen.


**Notocoxelus rufus** (Broun, 1893) NEW COMBINATION

(Figs. 206–207)


*Notocoxelus rufus*: Implied combination based on the erection of the genus *Notocoxelus* (Ślipiński and Lawrence, 1997: 404).

**Type locality**: Taieri, Otago.
Broun number: 1931.

Remarks: Broun based this species on a single specimen.


Notocoxelus similis (Sharp, 1876) NEW COMBINATION
(Figs. 208–210)


Notocoxelus similis: Implied combination based on the erection of the genus Notocoxelus (Ślipiński and Lawrence, 1997: 404).

Type locality: Auckland.

Broun number: 351.

Remarks: Sharp did not mention the number of specimens examined. In order to stabilize this name, a lectotype and paralectotype are here designated from the material of Coxelus similis.

**Notocoxelus thoracicus** (Broun, 1895) NEW COMBINATION

(Figs. 211–212)


**Notocoxelus thoracicus**: Implied combination based on the erection of the genus *Notocoxelus* (Ślipiński and Lawrence, 1997: 404).

**Type locality**: Wellington.

**Broun number**: 2763 (as given in May 1967: 178).

**Remarks**: Broun did not mention the number of specimens examined. In order to stabilize this name, a lectotype and paralectotype are here designated from the material of *Coxelus thoracicus*. There is an additional specimen (card-mounted venter-up) in the BMNH Broun collection that matches the type locality, but we do not consider this to be a syntype because Broun’s determination label identifies it as a variety of *C. thoracicus*. Additionally, the locality label is handwritten rather than typed, as is the case with the lectotype (BMNH) and paralectotype (MNHN).


**Notocoxelus variegatus** (Broun, 1909) NEW COMBINATION

(Figs. 213–214)

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**Notocoxelus variegatus**: Implied combination based on the erection of the genus **Notocoxelus** (Ślipiński and Lawrence, 1997: 404).

**Type locality**: Invercargill.

**Broun number**: 2765 (as given in May 1967: 178).

**Remarks**: Broun based this species on a single specimen.


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**Notocoxelus xanthonyx** (Broun, 1910) **NEW COMBINATION**

**(Figs. 215–216)**


**Notocoxelus xanthonyx**: Implied combination based on the erection of the genus **Notocoxelus** (Ślipiński and Lawrence, 1997: 404).

**Type locality**: Raoul Island [Sunday Island].

**Broun number**: This specimen was not given a number by Broun.

**Remarks**: Broun based this species on a single specimen.


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**Pristoderus** Hope, 1840

*Pristoderus* Hope, 1840: 145. Type species: *Dermestes scaber* Fabricius, 1775, by original designation.


*Pristiderus* Agassiz, 1846: 135. Incorrect subsequent spelling, not available.

*Enarsus* Pascoe, 1866: 444. Type species: *Enarsus bakewellii* Pascoe, 1866, fixed by monotypy. Synonymized with *Pristoderus* Hope by Ślipiński and Lawrence 1997: 406.


Remarks: The genus Pristoderus was removed from synonymy and recognized as valid by Ivie and Ślipiński (1990: 9), stating: “This senior synonym of Ulonotus cannot be suppressed, and is the proper name of the genus currently known as Ulonotus.” Pascoe (1876: 51) stated that Fabricius’ Dermestes scaber is congeneric with White’s Pristoderus antarcticus and Erichson’s Ulonotus was probably based on one of these two species, although Erichson did not formally describe any species when he erected the genus. Sharp (1876: 17) stated that the name Pristoderus Hope “may be with advantage dropped into oblivion” due to lack of characters provided by Hope for the genus.

Pristoderus aberrans (Broun, 1880)

(Figs. 217–218)


Recyntus aberrans: Hetschko 1930: 56.


Type locality: Tairua, Whangarei Heads.

Broun number: 338.
Remarks: Broun mentioned that he based this species on three specimens, two from Tairua and one from Whangarei Heads, but only one matching these localities was located. Broun remarked that he sent material of this species to Sharp, who informed him it was not *U. lawsoni*. It is possible the other two syntypes are amongst Sharp’s material at the BMNH. In order to stabilize this name, a lectotype is here designated from the material of *Ulonotus aberrans.*


*Pristoderus acuminatus* (Broun, 1880)

(Figs. 219–220)

*Tarphiomimus acuminatus* Broun, 1880: 183.


*Pristoderus acuminatus*: Implied combination based on synonymy of *Dryptops* with *Pristoderus* in Ślipiński and Lawrence 1997: 406.


Type locality: Tairua.

Broun number: 325.

Remarks: Broun based this species on a single specimen. Broun (1880: 183) stated that this species might be more closely allied to *Ulonotus* due to the structure of the tarsi (lacking a lobed first tarsomere, as is found in *Tarphiomimus*). Broun (1882: 293) later
moved the species to his newly-described genus *Drytops*. *Drytops* was subsequently synonymized with *Pristoderus* by Ślipiński and Lawrence (1997). Interestingly, Broun mentions this species in his description of *Allobitoma*, referring to it as *Tarphiomimus acuminatus* (probably disregarding his previous transfer to *Drytops*), stating that the species “will no doubt be placed in another genus apart from *Tarphiomimus*” (Broun 1921a: 527).


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*Pristoderus aemulus* (Broun, 1923)

(Figs. 221–222)


*Pristoderus aemulus*: Implied combination based on *Ulonotus* as a junior synonym of *Pristoderus* in Ivie and Ślipiński 1990: 9.


**Type locality:** Belgrove.

**Broun number:** 4280.

**Remarks:** Broun based this species on a single specimen collected on 10 December, 1914.

**Pristoderus affinis** (Broun, 1923)

(Figs. 223–224)


**Pristoderus affinis**: Implied combination based on *Ulonotus* as a junior synonym of *Pristoderus* in Ivie and Ślipiński 1990: 9.

**Pristoderus affinis**: Maddison 2010: 426.

**Type locality**: Martinborough.

**Broun number**: 4279.

**Remarks**: Broun based this species on a single specimen collected from Martinboro on 25 August, 1918. We could not locate a specimen matching this date. A single specimen in the BMNH Broun collection was located that matches the locality in Broun’s description of the species. We assume this specimen is the holotype.


**Pristoderus antarcticus** (White, 1846)

(Figs. 225–226)


**Boleotophagus antarcticus**: White 1846 pl. 1, fig. 12. *Lapsus calami*.


**Type locality**: Port Nicholson, New Zealand.

**Broun number**: 331.

**Remarks**: White did not mention the number of specimens examined of _Bolitophagus antarcticus_. In order to stabilize this name, a lectotype and two paralectotypes are here designated from the material of _Bolitophagus antarcticus_.


**Pristoderus asper** (Sharp, 1876)

(Figs. 227–229)


Type locality: Tairua.

Broun number: 335.

Remarks: Sharp based this species on a single specimen.


Pristoderus atratus (Broun, 1880)

(Figs. 230–231)


Recyntus atratus: Hetschko 1930: 56.

Pristoderus atratus: Implied combination based on Ulonotus as a junior synonym of

Pristoderus in Ivie and Ślipiński 1990: 9.


Type locality: Tairua.

Broun number: 339.

Remarks: Broun based this species on a single specimen.


Pristoderus bakewellii (Pascoe, 1866)

(Figs. 232–233)


*Pristoderus bakewellii*: Ślipiński and Lawrence 1997: 407, based on synonymy of *Enarsus* with *Pristoderus* (p. 406).


**Type locality**: New Zealand.

**Broun number**: 355.

**Remarks**: Pascoe did not mention the number of specimens examined. In order to stabilize this name, a lectotype and paralectotype are here designated from the material of *Enarsus bakewellii*.

**Type material examined**: Lectotype (BMNH): minuten-pinned into card, “Type [round label with red border] // New Zealand [green elliptical label, in Pasoe’s hand] // Enarsus Bakewellii type Pasc. [in Pascoe’s hand] // Pascoe Coll. 93-60 // BMNH(E) #651713”.


*Pristoderus brouni* (Sharp, 1876)
(Figs. 234–236)


*Pristoderus brouni*: Implied combination based on *Ulonotus* as a junior synonym of

*Pristoderus* in Ivie and Ślipiński 1990: 9.


**Type locality**: Tairua.

**Broun number**: 333.

**Remarks**: Sharp mentioned that he based this species on two specimens. In order to stabilize this name, a lectotype and paralectotype are here designated from the material of *Ulonotus brouni*.


(*Pristoderus carus* (Broun, 1886))

(Figs. 237–238)


*Pristoderus carus*: Implied combination based on *Ulonotus* as a junior synonym of

*Pristoderus* in Ivie and Ślipiński 1990: 9.

Type locality: Purakanui, near Dunedin.

Broun number: 1706.

Remarks: Broun based this species on a single specimen.


**Pristoderus cinereus** (Broun, 1886)

(Figs. 239–240)


**Pristoderus cinereus**: Implied combination based on *Ulonotus* as a junior synonym of *Pristoderus* in Ivie and Ślipiński 1990: 9.

**Pristoderus cinereus**: Maddison 2010: 426.

Type locality: Mount Egmont.

Broun number: 1709.

Remarks: Broun did not mention the number of specimens examined. In order to stabilize this name, the single specimen of *Ulonotus cinereus* in the BMNH Broun collection is here designated as the lectotype.


**Pristoderus contractifrons** (Broun, 1880)

(Figs. 241–242)

Hetschko 1930: 36.

*Pristoderus contractifrons*: Implied combination based on synonymy of *Enarsus* with

*Pristoderus* in Ślipiński and Lawrence 1997: 406.


**Type locality**: Tairua.

**Broun number**: 358.

**Remarks**: Broun based this species on a single specimen.


*Pristoderus cucullatus* (Sharp, 1886)

(Figs. 243–245)


*Pristoderus cucullatus*: Implied combination based on synonymy of *Enarsus* with

*Pristoderus* in Ślipiński and Lawrence 1997: 406.


**Type locality**: Greymouth.

**Broun number**: 1939.

**Remarks**: Sharp did not mention the number of specimens examined (listed as “Helms, No. 280” in the original description). Sharp stated that Mr. Helms sent him two
specimens initially, then additional specimens at a later date, which we also regard as syntypes. In order to stabilize this name, a lectotype and seven paralectotypes are here designated from the material of *Enarsus cucullatus*.


*Pristoderus discalis* (Broun, 1921)

(Figs. 246–247)

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Pristoderus discalis: Implied combination based on *Ulonotus* as a junior synonym of *Pristoderus* in Ivie and Ślipiński 1990: 9.


**Type locality**: Routeburn, northwest of Lake Wakatipu.

**Broun number**: 4047.

**Remarks**: Broun based this species on a single specimen with a broken tibia collected on 11 February, 1914. This specimen was located in the BMNH beside a similar, fully intact specimen collected on 16 February, 1914.


*Pristoderus discedens* (Sharp, 1877)

(Figs. 248–250)


**Type locality**: West Coast.

**Broun number**: 332.

**Remarks**: Sharp did not mention the number of specimens examined. In order to stabilize this name, a lectotype and paralectotype are here designated from the material of *Ulonotus discedens*. Since the paralectotype bears no labels other than the one listed
below, it can be assumed this specimen is in the same series as the lectotype. Moreover, the pin and card are of the same stock and style.


**Pristoderus dissimilis** (Sharp, 1886)

*(Figs. 251–253)*


*Pristoderus dissimilis*: Implied combination based on *Ulonotus* as a junior synonym of *Pristoderus* in Ivie and Ślipiński 1990: 9.


**Type locality:** Bealey [Greymouth and Picton also given in original description].

**Broun number:** 1926.

**Remarks:** Sharp did not mention the number of specimens examined but stated he was sent “an example from Captain Broun (with the No. 109 attached),” which “was found in numbers at Bealey and Picton by Helms,” and is conspecific with a specimen that Reitter sent “some time ago from Greymouth….” In order to stabilize this name, a lectotype and 15 paralectotypes are **here designated** from the material of *Ulonotus dissimilis*.

**Pristoderus dorsalis (Broun, 1882)**

(Figs. 254–255)


**Type locality:** on the Waitakere Range.

**Broun number:** 1354.
Remarks: Broun based this species on a single specimen.


**Pristoderus exigus** (Broun, 1882)

(Figs. 256–257)


*Pristoderus exigus*: Implied combination based on *Ulonotus* as a junior synonym of *Pristoderus* in Ivie and Ślipiński 1990: 9.


Type locality: Parua Bay [near Whangarei Harbour].

Broun number: 1356.

Remarks: Broun based this species on a single specimen. This species description was re-printed in Part III of Broun’s New Zealand Coleoptera (1886: 765).


**Pristoderus fulvus** (Broun, 1893)

(Figs. 258–259)

**Pristoderus fulvus**: Implied combination based on *Ulodon* as a junior synonym of *Pristoderus* in Ivie and Ślipiński 1990: 9.

**Pristoderus fulvus**: Maddison 2010: 426.

**Type locality**: Moeraki.

**Broun number**: 1925.

**Remarks**: Broun based this species on a single specimen. We located one specimen in the BMNH Broun collection with a “1925” Broun number and identification label (but lacking a locality label), which we assume to be the holotype. Broun’s determination label on the lectotype reads “Ulodon fulvous,” but the name given in the original description is *Ulodon fulvus*.


**Pristoderus fuscatus** (Broun, 1886)

(Figs. 260–261)


**Pristoderus fuscatus**: Implied combination based on *Ulodon* as a junior synonym of *Pristoderus* in Ivie and Ślipiński 1990: 9.

**Pristoderus fuscatus**: Maddison 2010: 426.

**Type locality**: Mount Egmont.
**Broun number:** 1707.

**Remarks:** Broun did not mention the number of specimens examined. In order to stabilize this name, the single specimen of *Ulonotus fuscatus* in the BMNH Broun collection is here designated as the lectotype.


*Pristoderus insignis* (Broun, 1880)

*(Figs. 262–263)*

*Ulonotus insignis* Broun, 1880: 191.


*Pristoderus insignis*: Implied combination based on synonymy of *Recynthus* with *Pristoderus* in Ślipiński and Lawrence 1997: 406.


**Type locality:** Mount Manaia [Whangarei Heads].

**Broun number:** 341.

**Remarks:** Broun (1880: 191) mentioned that he based this species on two specimens while several others with different body proportions were listed as varieties. We located one specimen labeled “Mount Manaia” which we designate as the lectotype, and another with a similar “341” label which we designate as the paralectotype. Two additional specimens (card-mounted venter-up) were located and may be the varietal specimens Broun mentioned. In order to stabilize this name, a lectotype and paralectotype are here
designated from the material of *Ulonotus insignis*. Broun’s determination label on the lectotype reads “Recyntus insignis,” but the name given in the original description is *Ulonotus insignis*.


**Pristoderus integratus** (Broun, 1886)

*(Figs. 264–265)*


*Pristoderus integratus*: Implied combination based on *Ulonotus* as a junior synonym of *Pristoderus* in Ivie and Ślipiński 1990: 9.


**Type locality:** Purakanui, Otago.

**Broun number:** 1710.

**Remarks:** Broun did not explicitly mention the number of specimens examined; however, the wording was ambiguous and he referred to “a small example” from Purakanui and provided a single length measurement. Only one specimen matching this data was located in the BMNH Broun collection, therefore we assume Broun based this species on a single specimen.

*Pristoderus isostictus* (Broun, 1886)

(Figs. 266–267)


*Pristoderus isostictus*: Implied combination based on *Ulonotus* as a junior synonym of *Pristoderus* in Ivie and Ślipiński 1990: 9.


**Type locality:** Paparoa, near Howick.

**Broun number:** 1661.

**Remarks:** Broun did not mention the number of specimens examined. In order to stabilize this name, the single specimen of *Ulonotus isostictus* in the BMNU Broun collection is here designated as the lectotype. Broun’s determination label on the lectotype reads “Notoulus isostictus,” but the name given in the original description is *Ulonotus isostictus*.


*Pristoderus lawsoni* (Wollaston, 1873)

(Figs. 268–269)


*Pristoderus lawsoni*: Implied combination based on *Ulonotus* as a junior synonym of *Pristoderus* in Ivie and Ślipiński 1990: 9.


**Type locality**: Auckland.

**Broun number**: 337.

**Remarks**: Wollaston did not mention the number of specimens examined. Sharp (1876: 18) moved this species to the genus *Ulonotus*. Ivie and Ślipiński (1990: 9) also designated this species as the type species for the genus *Tarphiomimetes* Wollaston. In order to stabilize this name, a lectotype is here designated from a single specimen we believe is the type of *Tarphiomimetes lawsoni*.


*Pristoderus philpotti* (Broun, 1914)

(Figs. 270–271)


*Pristoderus philpotti*: Implied combination based on *Ulonotus* as a junior synonym of

*Pristoderus* in Ivie and Ślipiński 1990: 9.


**Type locality**: Tisbury, Southland.
Broun number: 3404.

Remarks: We assume Broun based this species on two specimens because he mentioned a “second (damaged) specimen…” in the description. In order to stabilize this name, a lectotype and paralectotype are here designated from the material of *Ulonotus philpotti*.


**Pristoderus plagiatus** (Broun, 1911)

(Figs. 272–273)


**Pristoderus plagiatus**: Implied combination based on *Ulonotus* as a junior synonym of *Pristoderus* in Ivie and Ślipiński 1990: 9.


Type locality: Pitt Island.

Broun number: This species was listed as number 60 in the paper, but this is not a “Broun number” in the standard sense.

Remarks: Broun did not mention the number of specimens examined. Four specimens in the BMNH and one in the NZAC matching the locality were located. One of these specimens (BMNH) is labeled as a variant, which we do not consider a syntype. In order
to stabilize this name, a lectotype and three paralectotypes are here designated from the material of *Ulonotus plagiatus*.


**Pristoderus planiceps** (Broun, 1915)

(Figs. 274–275)


*Pristoderus planiceps*: Implied combination based on *Ulonotus* as a junior synonym of *Pristoderus* in Ivie and Ślipiński 1990: 9.


**Type locality**: Longwood Range, Southland.

**Broun number**: 3740.

**Remarks**: Broun based this species on a single specimen collected in January, 1913.

*Pristoderus probus* (Broun, 1893)

(Figs. 276–277)


*Pristoderus probus*: Implied combination based on synonymy of *Enarsus* with *Pristoderus* in Ślipiński and Lawrence 1997: 406.

*Pristoderus probus*: Maddison 2010: 426.

Type locality: Taieri.

Broun number: 1938.

Remarks: Broun did not mention the number of specimens examined. In order to stabilize this name, a lectotype and paralectotype are here designated from the material of *Enarsus probus*.


*Pristoderus proprius* (Broun, 1914)

(Figs. 278–279)

**Pristoderus proprius**: Implied combination based on *Ulonotus* as a junior synonym of *Pristoderus* in Ivie and Ślipiński 1990: 9.


**Type locality**: Rakaia Gorge, near Methven.

**Broun number**: 3541.

**Remarks**: Broun based this species on a single specimen collected on 5 June, 1912.


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**Pristoderus punctatus** *(Broun, 1886)*

*(Figs. 280–281)*


*Pristoderus punctatus*: Implied combination based on *Ulonotus* as a junior synonym of *Pristoderus* in Ivie and Ślipiński 1990: 9.


**Type locality**: Woodhill.

**Broun number**: 1595.

**Remarks**: Broun based this species on a single specimen.

**Pristoderus reitteri** (Sharp, 1882)

(Figs. 282–284)

*Acosmetus reitteri* Sharp, 1882: 80.


*Pristoderus reitteri*: Implied combination based on synonymy of *Recyntus* with

*Pristoderus* in Ślipiński and Lawrence 1997: 406.


**Type locality**: Greymouth.

**Broun number**: 4284.

**Remarks**: Sharp did not mention the number of specimens examined. In order to stabilize this name, a lectotype and 11 paralectotypes are here designated from the material of *Acosmetus reitteri*. Reitter (1880c: 173) lists “Syncalus Reitteri Sharp. n. sp.” without description and most likely refers to the species *Acosmetus reitteri*, soon-after described by Sharp (1882), who noted that “This very remarkable insect I first received from Mr. Reitter, of Vienna, and, supposing it might go into the genus *Syncalus*,

proposed to call it *Syncalus Reitteri*. I find, however, it departs much from *Syncalus*…and I have therefore called it *Acosmetus Reitteri*…” Several specimens in the BMNH lacking handwritten labels by Sharp were not considered syntypes.


Pristoderus rudis (Sharp, 1877)

(Figs. 285–287)


**Type locality:** Christchurch.

**Broun number:** 357.

**Remarks:** Sharp did not mention the number of specimens examined; however, we located three specimens with the same card and pin stock, though the minutens pins varied in placement through the specimen. In order to stabilize this name, a lectotype and two paralectotypes are **here designated** from the material of *Enarsus rudis*.


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**Pristoderus rufescens** *(Broun, 1886)*

(Figs. 288–289)


**Pristoderus rufescens:** Implied combination based on *Ulonotus* as a junior synonym of *Pristoderus* in Ivie and Ślipiński 1990: 9.

**Pristoderus rufescens:** Maddison 2010: 426.

**Type locality:** Purakanui, Otago.

**Broun number:** 1708.
Remarks: Broun did not mention the number of specimens examined. In order to stabilize this name, a lectotype is here designated from the single specimen of *Ulonotus rufescens* in the BMNH Broun collection.


### *Pristoderus salebrosus* (Broun, 1880)

(Figs. 290–291)

*Ulonotus salebrosus* Broun, 1880: 192.


*Pristoderus salebrosus*: Implied combination based on synonymy of *Recyntus* with *Pristoderus* in Ślipiński and Lawrence 1997: 406.


**Type locality:** Tairua.

**Broun number:** 342.

Remarks: Broun mentioned that he based this species on two specimens, both of which were located in the BMNH and the MNHN. In order to stabilize this name, a lectotype and paralectotype are here designated from the material of *Ulonotus salebrosus*. Broun’s determination label on the lectotype reads “Recyntus salebrosus,” but the name given in the original description is *Ulonotus salebrosus*.

**Type material examined:** Lectotype (BMNH): card-mounted, “Type [round label with red border] // 342. [green label] // Tairua [in Broun’s hand] // New Zealand. [red

Pristoderus scaber (Fabricius, 1775)

(Figs. 292–296)


Zimsen 1964: 77. Ivie and Ślipiński 1990: 9


Bolitophagus anguliferus Blanchard, 1853: 167, pl. 11, fig. 3. Gerstaecker 1855: 177.


Incorrect subsequent spelling, not available.


**Remarks:** Fabricius did not mention the number of specimens examined of *Dermestes scaber*, but a specimen in the Banks Collection at the BMNH was listed as the holotype by Radford (1981: 188). Blanchard did not mention the number of specimens examined of *Bolitophagus anguliferus*. Sharp based *Ulonotus integer* on a single specimen.


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**Pristoderus tuberculatus** (Broun, 1880)

(Figs. 297–298)

*Ulonotus tuberculatus* Broun, 1880: 191.


Type locality: Tairua.

Broun number: 340.

Remarks: Broun based this species on a single specimen.


Pristoderus undosus (Broun, 1882)

(Figs. 299–300)


Pristoderus undosus: Implied combination based on synonymy of Drytops with

Pristoderus in Ślipiński and Lawrence 1997: 406.


Type locality: Outram [Taieri, Otago Region].

Broun number: 1355.

Remarks: Broun mentioned that he based this species on two specimens, one having been returned to Sydney W. Fulton. No specimens were located in the BMNH bearing an “Outram” locality label, but two were located with a “Taieri” label (more or less the same locality as Outram), one of which bears a handwritten determination label. A third specimen is presumably in the Otago Museum (OM), Dunedin, which is noted as a
holotype by Harris (2007). This specimen was not confirmed by us due to restricted loaning policy by the OM, and is not considered a syntype until it can be examined. In order to stabilize this name, a lectotype is here designated from the material of *Drytops undosus*.


*Pristoderus uropterus* (Broun, 1912)

(Figs. 301–302)


*Pristoderus uropterus*: Implied combination based on *Ulonotus* as a junior synonym of *Pristoderus* in Ivie and Ślipiński 1990: 9.


**Type locality:** Wairiri, Kaikoura.

**Broun number:** 3222.

**Remarks:** Broun based this species on a single specimen.


*Pristoderus viridipictus* (Wollaston, 1873)
(Figs. 303–305)


(reprinted from Sharp 1876).

*Tarphiomimetes viridipicta*: Sharp 1877b: 268. Incorrect subsequent spelling, not available.


**Type locality**: Auckland.

**Broun number**: 334.

**Remarks**: Wollaston mentioned that he based this species on two specimens (listed as “exponents”). In order to stabilize this name, a lectotype is here designated from the material of *Tarphiomimetes viridipicta*.


*Pristoderus wakefieldi* (Sharp, 1877)

(Figs. 306–308)


Type locality: Peel Forest.

Broun number: 356.

Remarks: Sharp did not mention the number of specimens examined, but stated they were collected in March, 1874. In order to stabilize this name, a lectotype is here designated from the material of Enarsus wakefieldi. Three additional specimens associated with the lectotype were located in the BMNH, but due to incorrect locality information (“Oxford”) and lack of Sharp handwriting on the card, we do not regard these as syntypes.

Type material examined: Lectotype (BMNH): card-mounted, “Enarsus Wakefieldi Type D.S. New Zealand. [written at base of card in Sharp’s hand] // Type [round label with red border] // Sharp Coll. 1905-313. // BMNH(E) #651714”.

Pristoderus wallacei (Broun, 1912)

(Figs. 309–310)


Type locality: Wairiri, Seaward Kaikoura Range.

Broun number: 3223.
Remarks: Broun did not mention the number of specimens examined. Only four specimens were present in the BMNH, three that match the locality, one of which bears an additional “Moeraki” label. There are five specimens in the NZAC (three individually mounted on separate cards and pins, two pointed on separate cards on the same pins, one venter-up) with determination labels in Broun’s hand and “Syntype” labels in J.C. Watt’s hand. We do not regard these as syntypes because they lack locality labels. In order to stabilize this name, a lectotype and three paralectotypes are here designated from the material of *Ulonotus wallacei*.


**Rytinotus** Broun, 1880

*Rytinotus* Broun, 1880: 204. Type species: *Rytinotus squamulosus* Broun, 1880, fixed by monotypy.

Rhytidonotus: Kirby 1882: 44. Incorrect subsequent spelling, not available.

Edalus Broun, 1886: 834. Unjustified replacement name based on incorrect concept of homonymy.


**Remarks:** Broun described the genus with an original spelling of *Rytinotus* (1880: 204). Later, Broun (1886: 834) gave *Edalus* as a replacement name based on the similarity of his original *Rytinotus* to the genus *Rytinota*. This was an unjustified action based on an incorrect concept of homonymy. For a full discussion of the *Rytinotus* genus-group names, spellings and their usage, see Emberson 2000.

*Rytinotus squamulosus* Broun, 1880

(Figs. 311–312)

Rhytinotus squamulosus: Waterhouse 1881: plate 42. Incorrect subsequent spelling, not available.


**Type locality:** Hunua Range, Auckland [Wairoa District].

**Broun number:** 364.

**Remarks:** Broun based this species on a single specimen. No specimens in the BMNH are labeled from the Wairoa district, but one from “Hunua Range” was located and is assumed to be the holotype. Broun’s determination label on the holotype reads “Rhytidinotus squamulosus,” but the name given in the original description is Rytinotus squamulosus.


**SYNCALUS** Sharp, 1876

Syncalus Sharp, 1876: 20. Type species: Syncalus hystrix Sharp, 1876, designated by Ivie and Ślipiński 1990: 12.

**Remarks:** Sharp (1976:20–21) erected this genus and stated its affinities with and differences from *Tarphius*, suggesting that morphology would indicate members of the two genera probably share similar habits. Broun (1880: 197) erected *Acosmetus* to include members that appeared to be intermediate between *Coxelus* (=*Notocoxelus*) and *Syncalus*, while Sharp (1882: 81) considered *Acosmetus* to be a distinct genus.

**Syncalus explanatus** Broun, 1912

*(Figs. 313–314)*


**Type locality:** Akatarawa, near Wellington.

**Broun number:** 3220.

**Remarks:** Broun based this species on a single specimen.


**Syncalus granulatus** (Broun, 1880)

*(Figs. 315–316)*

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Syncalus granulatus: IMPLIED combination based on synonymy of Acosmetus with Syncalus in Ślipiński and Lawrence 1997: 412.


**Type locality**: Parua, near Whangarei Harbour.

**Broun number**: 354.

**Remarks**: Broun based this species on a single specimen.


**Syncalus hystrix** Sharp, 1876

(Figs. 317–319)


**Type locality**: Tairua?

**Broun number**: 361.

**Remarks**: Sharp based this species on a single specimen sent by Broun. Although no locality was explicitly given in the description, it is likely the specimen was from Tairua, as Sharp received specimens of other species from Tairua from Broun (listed in descriptions in same paper).

Syncalus munroi Broun, 1893

(Figs. 320–321)


Type locality: Hunua Range, Clevedon.

Broun number: 2502.

Remarks: Broun mentioned that he based this species on three specimens, although only two were located in the BMNH Broun collection. There are two additional specimens (not regarded as syntypes) in the Broun collection with a “2502” label, but are from differing localities and are on different card types. There are also four specimens in the NZAC with labels in Brookes’ hand that match the localities (two card-mounted venter-up). Because Broun mentioned only three specimens, we are electing to not regard the NZAC and additional BMNH specimens as syntypes, as two were located in the BMNH with appropriate Broun labels. In order to stabilize this name, a lectotype and paralectotype are here designated from the material of Syncalus munroi.


**Syncalus oblongus** (Broun, 1880)

(Figs. 322–323)


*Syncalus oblongus*: Combination by Broun 1923: 686. Ślipiński and Lawrence 1997: 414 (note that this was listed as a new combination, but the earlier combination by Broun was apparently missed). Maddison 2010: 426.

**Type locality**: Whangarei Heads.

**Broun number**: 353.

**Remarks**: Broun did not mention the number of specimens examined. One specimen of *Syncalus oblongus* in the BMNH Broun collection bears a correct Broun number label and determination label, which we regard as the lectotype (here designated).


**Syncalus optatus** Sharp, 1876

(Figs. 324–326)

**Type locality:** Auckland.

**Broun number:** 359.

**Remarks:** Sharp based this species on a single “mutilated” specimen.

**Type material examined:** *Holotype* (BMNH): card-mounted [missing tarsomeres on the prolegs and right meso- and metalegs], “Syncalus optatus Type N. Zeal’d. D.S. [written at base of card in Sharp’s hand] // Type [round label with red border] // Sharp Coll. 1905-313.”

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**Syncalus piciceps** Broun, 1893

*(Figs. 327–328)*


**Type locality:** Wellington.

**Broun number:** 1942.

**Remarks:** Broun based this species on a single specimen.


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**Syncalus politus** Broun, 1880

*(Figs. 329–330)*

**Type locality:** Tairua.

**Broun number:** 360.

**Remarks:** Broun based this species on a single specimen.


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**Syncalus solidus** Broun, 1923

(Figs. 331–332)


**Type locality:** Tairua [Hunua Range, Waitakere, and Pakarau also given in original description].

**Broun number:** 4283.

**Remarks:** Broun did not mention the number of specimens examined. We located a specimen with a printed “Tairua” label which we regard as the lectotype and five specimens (three with a handwritten “Waitakere” label and two with a handwritten “Pakarau” label) which we regard as paralectotypes. No specimens were located, however, that are explicitly labeled from the Hunua Ranges. In order to stabilize this name, a lectotype and five paralectotypes are here designated from the material of **Syncalus solidus**.


**TARPHIOMIMUS** Wollaston, 1873

*Tarphiomimus* Wollaston, 1873: 12. Type species: *Tarphiomimus indentatus* Wollaston, 1873, fixed by monotypy.


*Taphiomimus*: Sharp and Muir 1912: fig. 93. Incorrect subsequent spelling, not available.

**Tarphiomimus indentatus** Wollaston, 1873

*(Figs. 333–334)*


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Taphiomimus indentatus: Sharp and Muir 1912: pl. 57, fig. 93. Incorrect subsequent spelling, not available.


Broun 1880: 183.

Ectomida laceratus: Hetschko 1930: 35 (listed as a jr. synonym of Tarphiomimus indentatus). Incorrect subsequent spelling, not available.


Remarks: Sharp (1876:18) stated that Pascoe’s Ectomida lacerata is identical with Wollaston’s Tarphiomimus indentatus based on the descriptions and correspondence with Pascoe. Broun (1880: 183) also stated that this species agrees with Pascoe’s Ectomida lacerata, placed within the Heteromera, but Wollaston’s Tarphiomimus indentatus has priority due to date of publication. Pascoe did not mention the number of specimens examined of Ectomida lacerata and the type is apparently lost, as we could not locate specimens in the BMNH, MNHN, or NZAC. Wollaston did not mention the number of specimens examined of Tarphiomimus indentatus, though we examined seven with labels
from Lawson. One of these bears a determination label in Wollaston’s handwriting, and this specimen is designated as the lectotype. In order to stabilize this name, a lectotype and six paralectotypes are here designated from the material of *Tarphiomimus indentatus*. There is a specimen in the BMNH with a “Co-Type” label [round label with yellow border] that we do not consider a syntype due the the lack of Wollaston labels.


*Ectomida lacerata* Pascoe: type material not examined.

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**Tarphiomimus tuberculatus** Broun, 1912

(Figs. 335–336)


**Type locality:** Mount Greenland, near Ross.

**Broun number:** 3221.
Remarks: Broun did not mention the number of specimens examined. Only two specimens were located in the BMNH Broun collection. In order to stabilize this name, a lectotype and paralectotype are here designated from the material of *Tarphiomimus tuberculatus*.


*Tarphiomimus wollastoni* Sharp, 1882

(Figs. 337–339)


Type locality: Greymouth.

Broun number: 1924.

Remarks: Sharp did not mention the number of specimens examined. In order to stabilize this name, a lectotype and 13 paralectotypes are here designated from the material of *Tarphiomimus wollastoni*.

Type material examined: Lectotype (BMNH): mounted on same card as 3 paralectotypes, left-most specimen is the lectotype, “Tarphiomimus Wollastoni Types D.S. Greymouth. Helms. 1881. [written at base of card in Sharp’s hand] // Type [round

Subfamily ZOPHERINAE Solier, 1834: 505.

Tribe PYCNOMERINI Erichson, 1845: 290. Type genus: Pycnomerus Erichson, 1842.

PYCNOMERODES Broun, 1886

**Pycnomerodes peregrinus** Broun, 1886

(Figs. 340–341)


**Type locality:** near Howick.

**Broun number:** 1715.

**Remarks:** Broun did not mention how many specimens he “cut out from a log near Howick.” Two specimens were located in the BMNH, one from Waitakere (affixed with a BMNH type label) and one from Paparoa. We regard the Paparoa specimen as the lectotype, because “Paparoa” is an old-use name for Howick. In order to stabilize this name, a lectotype is here designated from the material of *Pycnomerodes peregrinus*.


**PYCNOMERUS** Erichson, 1842

*Pycnomorphus* Motschulsky, 1858: 139. Type species: *Colydium haematodes* Fabricius, 1801, fixed by monotypy. Synonymized with *Pycnomerus* Erichson by Ślipiński and Lawrence 1999: 30.


**Remarks:** Broun (1893b: 1094) listed the species *Pycnomerus pubescens* in the comparative section for *P. sinuatus*, but this name is probably a manuscript name as no specimens bearing this name were found in collections or in the literature.

Hetschko (1930: 65) listed *Penthelispa aequicolle* Reitter, 1878 from “Neu-Seeland” which is an error, as this species was described from “Portorico.” It should be noted that *Pycnomerus aequicollis* (attributed to Reitter, although author and year were
not in parentheses) was listed in Maddison (2010: 426) as occurring in New Zealand, a recapitulation from Hetschko (1930).

**Pycnomerus angulatus** Broun, 1893

(Figs. 342–343)


_Type locality_: Maketu, Hunua Range.

_Broun number_: 2503.

**Remarks:** Broun based this species on a single specimen.


**Pycnomerus arboreus** Broun, 1886

(Figs. 344–345)


_Type locality_: near Howick.

_Broun number_: 1663.

**Remarks:** Broun did not mention the number of specimens examined. In order to stabilize this name, a lectotype is _here designated_ from the material of *Pycnomerus arboreus*.

Pycnomerus arcuatus Broun, 1914

(Figs. 346–347)


Type locality: Broken River, Canterbury.

Broun number: 3408.

Remarks: Broun based this species on a single specimen.


Pycnomerus basalis Broun, 1882

(Figs. 348–349)


Type locality: Parua Bay [near Whangarei Harbour].

Broun number: 1359.
Remarks: Broun did not mention the number of specimens examined. In order to stabilize this name, a lectotype is here designated from the material of *Pycnomerus basalis*.


*Pycnomerus caecus* Broun, 1886

(Figs. 350–351)


*Pycnomerus coecus*: Hetschko 1930: 61. Incorrect subsequent spelling, not available.

**Type locality:** Dunedin [Otago Region].

**Broun number:** 1599.

Remarks: Broun based this species on a single specimen.


*Pycnomerus candidus* Broun, 1912

(Figs. 352–353)


Maddison 2010: 426.

**Type locality:** Greymouth.
Broun number: 3227.

Remarks: Broun based this species on a single specimen.


**Pycnomerus carinellus** Broun, 1886

(Figs. 354–355)


Type locality: Woodhill (Kaipara Railway).

Broun number: 1598.

Remarks: Broun based this species on a single specimen.


**Pycnomerus cognatus** Broun, 1886

(Figs. 356–357)


Type locality: near Howick.

Broun number: 1714.
Remarks: Broun did not mention the number of specimens examined. We regard the Paparoa specimen as the lectotype, because “Paparoa” is an old-use name for Howick. In order to stabilize this name, a lectotype is here designated from the material of *Pycnomerus cognatus*.


*Pycnomerus depressiusculus* (White, 1846)  
(Figs. 358–363)

*Lyctus depressiusculus* White, 1846: 18.


*Penthelispa sophorae*: Reitter 1880: 175.


*Pycnomerus sophorae* Sharp in Reitter 1880a: 508.


**Remarks**: White did not mention the number of specimens examined of *Lyctus depressiusculus*, though we located two specimens in the BMNH card-mounted together (the left specimen is the lectotype). Sharp did not mention the number of specimens examined of *Pycnomerus sophorae* from Tairua sent from Broun, and there are six specimens in the BMNH labeled by Sharp as types mixed in with specimens of *P. depressiusculus*.

We were unable to locate types of Reitter’s (1878: 124) *Penthelispa acutangulum* and these are presumed lost. Based on the title of Reitter’s (1878: 113) paper, type(s) should be deposited in Berlin, though types were not located in the Hungarian Natural History Museum (Otto Merkl, pers. comm) or the Museum für Naturkunde, Berlin (Bernd Jaeger and Manfred Uhlig, pers. comm.).

In order to stabilize these names, a lectotype and paralectotype are **here designated** from the material of *Lyctus depressiusculus* and a lectotype and five paralectotypes are **here designated** from the material of *Pycnomerus sophorae*.

**Type material examined**: *Lyctus depressiusculus* White: **Lectotype** (BMNH): mounted on same card as paralectotype, left specimen is the lectotype, “Type [round label with red border] // Port Nicholson N Zealand [green label, handwritten] // 67. 18- [round label, handwritten] // Lyctus depressiusculus White Zool. Ereb & Terror [in White’s hand]”.

**Paralectotype** (BMNH): mounted on same card as lectotype, right specimen is a paralectotype, labels same as lectotype. *Pycnomerus sophorae* Sharp: **Lectotype** (BMNH): card-mounted, “Pycnomerus sophorae Type N. Zeal[^d]. D.S. [written at base of
card in Sharp’s hand] // Type [round label with red border] // Sharp Coll. 1905-313.”


*Paralectotypes* (BMNH): 3, individually mounted on separate cards and pins, with the following labels on each: “Pycnomerus sophorae Ind. typ. N. Zeal\(^d\) DS. [written at base of card in Sharp’s hand] // Sharp Coll. 1905-313.” *Penthelispa acutangulum* Reitter:

Type material not examined.

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**Pycnomerus ellipticus** Broun, 1880

*(Figs. 364–365)*


**Type locality**: Tairua.

**Broun number**: 372.

**Remarks**: Broun based this species on a single specimen.


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**Pycnomerus elongellus** Broun, 1893

*(Figs. 366–367)*

**Type locality:** Mount Arthur.

**Remarks:** Broun based this species on a single specimen.

**Broun number:** 2505.


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**Pycnomerus frontalis** Broun, 1893

(Figs. 368–369)


**Type locality:** Howick.

**Broun number:** 2504.

**Remarks:** Broun based this species on a single specimen.


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**Pycnomerus helmsi** Sharp, 1886

(Figs. 370–372)

**Type locality:** Greymouth.

**Broun number:** 1948.

**Remarks:** Sharp mentioned three specimens (listed as “No. 291, Helms” in the original description), and only one of these could be reliably identified as a syntype. There are four additional specimens (one specimen on one card and three specimens on another) which were labeled by Sharp but do not bear the handwritten word “type” at the base of the card. In order to stabilize this name, a lectotype is here designated from the material of *Pycnemerus helmsi*.


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*Pycnemerus hirtus* Broun, 1886

*(Figs. 373–374)*


**Type locality:** Whangarata.

**Broun number:** 1600.

**Remarks:** Broun based this species on a single specimen.

*Pycnomerus impressus* Broun, 1893

(Figs. 375–376)


**Type locality**: Hermitage, Mount Cook.

**Broun number**: 1946.

**Remarks**: Broun did not mention the number of specimens examined. In order to stabilize this name, a lectotype is here designated from the material of *Pycnomerus impressus*.


*Pycnomerus lateralis* Broun, 1886

(Figs. 377–378)


**Type locality**: Tuakau.

**Broun number**: 1601.
Remarks: Broun based this species on a single specimen.


_Pycnomerus latitans_ Sharp, 1886

(Figs. 379–381)


Type locality: Greymouth.

Broun number: 1950.

Remarks: Sharp did not mention the number of specimens examined. We located five specimens which we consider syntypes, including two pairs on separate cards with “1883” and “1885” handwritten on the cards, respectively. Four specimens (two pairs on separate cards) are labeled as variants and are not considered syntypes. In order to stabilize this name, a lectotype and four paralectotypes are here designated from the material of _Pycnomerus latitans_.


Pycnomerus longipes Broun, 1893

(Figs. 382–383)


Type locality: Otago.

Broun number: 2506.

Remarks: Broun based this species on a single specimen.


Pycnomerus longulus Sharp, 1886

(Figs. 384–386)

**Type locality:** Picton [Greymouth and Kumara also given in original description].

**Broun number:** 1947.

**Remarks:** Sharp did not mention the number of specimens examined. There were several specimens in the BMNH, and we considered six to be syntypes, not including specimens hand-labeled by Sharp as variants. In order to stabilize this name, a lectotype and five paralectotypes are here designated from the material of *Pycnomerus longulus*.


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**Pycnomerus marginalis** Broun, 1893

(Figs. 387–388)


**Type locality:** Boatman’s [Bay].

**Broun number:** 1944.
Remarks: Broun based this species on a single specimen.


**Pycnomerus mediocris** Broun, 1911
(Figs. 389–390)


Type locality: Pitt Island.

Broun number: This species was listed as number 62 in the paper, but this is not a “Broun number” in the standard sense.

Remarks: Broun did not mention the number of specimens examined. There are five specimens in the BMNH Chatham Islands Broun Collection and one in the NZAC. There is an additional specimen in the NZAC that lacks the “62.” label, which we do not consider a syntype. In order to stabilize this name, a lectotype and five paralectotypes are here designated from the material of *Pycnomerus mediocris*.


Pycnomerus mediocrus Broun, 1911 [in J.C Watt’s hand]”.

**Pycnomerus minor** Sharp, 1876

(Figs. 391–393)


Maddison 2010: 426.

*Penthelispa minor*: Reitter 1880c: 175.

**Type locality**: Tairua?

**Broun number**: 371.

**Remarks**: Sharp did not mention the number of specimens examined. Although no locality was explicitly given in the description, it is likely the specimen was from Tairua, as Sharp received specimens of other species from Tairua from Broun (listed in descriptions in same paper).

Three specimens labeled as types were located in the BMNH. Two card-mounted specimens labeled as “Northland” were also in the BMNH, but these are not considered as syntypes because the card-stock differs from the presumed syntypes. In order to
stabilize this name, a lectotype and two paralectotypes are here designated from the material of Pycnomerus minor.


*Pycnomerus nitiventris* Broun, 1903

(Figs. 394–395)


*Pycnomerus nitidocularis* Hetschko 1930: 63. Incorrect subsequent spelling, not available.


**Type locality:** Westport.

**Broun number:** 2780 (as given in May 1967: 178).

**Remarks:** Broun mentioned two specimens from Walker’s collection, which we assume are the two specimens in the BMNH Broun collection labeled from Westport. In order to stabilize this name, a lectotype and paralectotype are here designated from the material of *Pycnomerus nitiventris*.

**Type material examined:** Lectotype (BMNH): card-mounted, “Type [round label with red border] // 2780. [in Broun’s hand] // Westport. [in Broun’s hand] // New Zealand. [red

*Pycnmerus ocularius* Broun, 1914

(Figs. 396–397)


**Type locality:** Mount Te Aroha.

**Broun number:** 3409.

**Remarks:** Broun mentioned that he based this species on three specimens collected in November, 1910. Three pins bearing only two specimens with labels matching this data were located in the BMNH Broun collection, though one specimen has come off the card and was not found in the drawer (this pin has all of the same labels as the lectotype, but no type label). In order to stabilize this name, a lectotype and paralectotype are here designated from the material of *Pycnmerus ocularius*.

Pycnomerus parvulus Broun, 1921

(Figs. 398–399)


Maddison 2010: 426.

Type locality: Karekare, west coast, near Auckland.

Broun number: 4182.

Remarks: Broun based this species on a single specimen collected on 23 February, 1916.

One specimen, lacking a BMNH type label, bears a “Kerikeri” label (an alternate spelling of Karekare, which is located on the west coast of Auckland in the Waitakere ranges).

We regard this specimen as the holotype.


Pycnomerus reversus Broun, 1912

(Figs. 400–401)


Maddison 2010: 426.

Type locality: Greymouth.

Broun number: 3226.

Remarks: Broun mentioned that he based this species on three specimens sent from Lewis. One specimen was found loose in the drawer and was subsequently re-glued by us to the appropriate elongate card. In order to stabilize this name, a lectotype and two paralectotypes are here designated from the material of Pycnomerus reversus.

**Pycnomerus rufescens** Broun, 1882

(Figs. 402–403)


Type locality: Parua Bay [near Whangarei Harbour].

Broun number: 1358.

Remarks: Broun based this species on a single specimen.


**Pycnomerus ruficollis** Broun, 1909

(Figs. 404–405)

**Type locality:** Broken River, Canterbury.

**Broun number:** 2782 (as given in May 1967: 178).

**Remarks:** Broun did not mention the number of specimens examined, although he mentions a “good series” with some specimens that are a “little larger and darker” in color than “the type.” Four specimens were located in the BMNH Broun collection. In order to stabilize this name, a lectotype and 3 paralectotypes are here designated from the material of *Pycnemerus ruficollis*.


**Pycnemerus simplex** Broun, 1880

(Figs. 406–407)


**Type locality:** Mount Manaia [Whangarei Heads].

289
Broun number: 370.

Remarks: Broun based this species on a single specimen.


Pycnomerus simulans Sharp, 1876
(Figs. 408–410)


Penthelispa simulans: Reitter 1880c: 175.

Type locality: Tairua

Broun number: 369.

Remarks: Sharp did not mention the number of specimens examined. None of the other specimens labeled by Sharp as Pycnomerus simulans matched the type locality (as most were labeled from localities in the South Island), therefore, we decided to recognize two specimens without specific geographic data as syntypes. In order to stabilize this name, a lectotype and paralectotype are here designated from the material of Pycnomerus simulans.

Type material examined: Lectotype (BMNH): mounted on same card as paralectotype, left specimen is the lectotype, “Pycnomerus simulans Type N. Zeal[4]. D.S. [written at base of card in Sharp’s hand] // Type [round label with red border] // Sharp Coll. 1905-313.”
Paralectotype (BMNH): mounted on same card as lectotype, right specimen is a paralectotype, labels same as lectotype.

_Pycnomerus sinuatus_ Broun, 1893

(Figs. 411–412)


**Type locality:** Midhirst, near Mount Egmont.

**Broun number:** 1945.

**Remarks:** Broun did not mention the number of specimens examined. Two specimens were located in the BMNH Broun collection that matched this locality, and one was labeled as a variety. In order to stabilize this name, a lectotype is here designated from the material of *Pycnomerus sinuatus*.


_Pycnomerus sulcatissimus_ (Reitter, 1880)

(Figs. 413–417)


*Pycnomerus sulcatissimus:* Maddison 2010: 426 (attributed to Reitter, although author and year were not in parentheses).

Type locality: Penthelispa sulcatissima Reitter: assumed to be Greymouth, as Reitter received specimens from Helms, who collected extensively in Greymouth. Pycnomerus sulcatissimus Sharp: Greymouth.


Remarks: The nomenclatural history of this species is complex. Reitter first described this species (1880b: 5) under the genus Penthelispa. Sharp (1886: 389) later describes the species Pycnomerus sulcatissimus, at the end of the description stating: “I have retained for this species the trivial name under whith it has been distributed by Herr Reitter.” It is apparent Sharp was unaware of Reitter’s earlier description, and, using material sent to him from Reitter, described the species under Pycnomerus. Sharp elected to not recognize the genus Penthelispa, as he stated (1876: 25): “Pascoe and Leconte have proposed to distinguish the Pycnomeri with distinctly 11-jointed antennae by the name of Penthelispa. Erichson, who pointed out this character [in his 1845 description of Pycnomerini], considered it unnecessary to make distinct generic names for the two forms; and the present species indicates the correctness of his judgement; for the antennae are just intermediate in structure between the two forms.” The genera Pycnomerus and Penthelispa were later synonymized by Sharp 1894: 474 (missed by Hetschko 1930); thus, Pycnomerus sulcatissimus Sharp is rendered a subjective synonym, as well as a secondary homonym, of Pycnomerus sulcatissimus (Reitter). Hetschko
(1930) listed both species under their respective genera. Reitter did not mention the number of specimens examined of *Penthelispa sulcatissima*. Sharp did not mention the number of specimens examined of *Pycnomerus sulcatissimus*. We considered all specimens not given as variants as syntypes. In order to stabilize these names, a lectotype and eight paralectotypes are here designated from the material of *Penthelispa sulcatissima* Reitter and a lectotype and four paralectotypes are here designated from the material of *Pycnomerus sulcatissimus* Sharp.

**Type material examined:** *Penthelispa sulcatissima* Reitter: *Lectotype* (MNHN): card-mounted, “TYP. REITTER // New Zealand Helms sulcatissima m. [in Reitter’s hand] // Penthelispa sulcatissima Rt TYPE Slip. 85 [green label, in S.A. Ślipiński’s hand]”.

**Paralectotypes** (MNHN): 5, individually mounted on separate cards and pins [card with three black lines near base, middle line thicker], with identical labels, “Now. Zeeland Helms Reitter. [label bordered with thin black line]”. *Paralectotype* (MNHN): card-mounted [card with three black lines near base, middle line thicker], lacking labels, but on with same card and pin type as lectotypes and other paralectotypes. *Paralectotype* (MNHN): card-mounted [card with three black lines near base, middle line thicker], “EX. COLL. REITTER”.


_Pycnomerus suteri_ Broun, 1909

(Figs. 418–419)


_Type locality:_ The Hermitage, Mount Cook.

_Broun number:_ 2781 (as given in May 1967: 178).

_Remarks:_ Broun based this species on a single specimen.


_Pycnomerus tenuiculus_ Broun, 1914

(Figs. 420–421)

Type locality: McClenann’s Bush, near Methven.

Broun number: 3549.

Remarks: Broun based this species on a single specimen collected on 23 April, 1912.


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CHAPTER 3

*Phylogenetic Analysis of the Ironclad and Cylindrical Bark Beetles of the World*

*(Coleoptera: Tenebrionoidea: Zopheridae).*


Appendix H contains the figures 1a–2d for Chapter 3 and is available as a supplementary file via LoboVault. See PDF titled “Appendix_H_Figures_Chapter3”.

**Abstract.** We infer the first phylogenetic hypothesis for Zopheridae Solier, 1834 (Coleoptera: Tenebrionoidea). Portions of three genes (28S rDNA, cytochrome c oxidase I and histone III) were analyzed. One hundred eighty three zopherid species were included, representing 2/2 subfamilies, 15/15 tribes, and more than half of the currently recognized genera. Twelve outgroup taxa from eight other families of Tenebrionoidea were included. Parsimony and partitioned Bayesian analyses were performed on the combined data set. In both phylogenetic analyses, Zopheridae was not recovered as monophyletic. The subfamily Zopherinae was not recovered as monophyletic in both analyses, and the subfamily Corticariinae was recovered as monophyletic only in the Bayesian analysis.
Introduction:

Zopheridae are cosmopolitan, small, litter-dwelling or subcortical beetles that exhibit tremendous morphological diversity. Members of the Zopheridae are thought to include both economically beneficial and harmful insects, as several genera (Colydium, Aulonium, Nematidium) are predaceous as both larvae and adults of destructive wood-boring insects, while others have been documented to transmit crop-destroying fungi (Ivie 2002a, b, c; Ślipiński and Lawrence 1997). Thus, studies of the taxonomy and natural history of the group is of economic relevance and has exhibited strong funding potential (e.g. USDA, see Lord et al. 2011). As proposed by Ślipiński and Lawrence (1999), Zopheridae (sensu novo) contains three previously separate families: the ironclad beetles (Zopheridae=Zopherinae s.n.), the monommatid beetles (Monommatidae=Zopherinae s.n.), and the cylindrical bark beetles (Colydiidae=Colydiinae s.n.) (for classification history of the groups, see Ślipiński and Ivie, 1990: 2–4). As currently constituted, Zopheridae contains nearly 180 genera, 15 tribes, and over 1,700 species, of which a disproportionate species diversity (nearly half) is restricted to the Australo-Pacific Region (Ślipiński and Lawrence 2010). Other large radiations and high levels of endemism (notably on islands or other isolated southern hemisphere landmasses) occur in Madagascar (13/35 endemic genera containing 90/100 endemic species), the Macronesian Islands (63 endemic species), and the Austral Region
(~28 genera, hundreds of endemic species) (Dajoz 1980; Ślipiński and Lawrence 1997; Amorim et al. 2012). The majority of the Zopheridae inhabiting these localities have profound morphological innovations such as loss of some major mouthparts, eye reduction and wing loss, traits that presumably decrease vagility resulting in low likelihood of long-distance dispersal. Due to high levels of diversity and endemism and niche specialization across a broad range of habitats, Zopheridae are ideal for investigating biogeographic patterns of paleoendemism, neoendemism, speciation, and ecological diversification throughout the Austral Region, as well as globally. However, before any interdisciplinary studies can be conducted, a phylogeny of the group is critically needed.

Despite their relative diversity and decent amounts of taxonomic attention by previous workers, the monophyly of the family is still strongly questioned. Seemingly few characters unite the groups included in Zopheridae, often making identification of its members quite difficult. In reference to the identification of North American Coleoptera, Ivie (2002a: 445) states: “However if it has 4-4-4 tarsi and doesn’t fit somewhere else, try this family.” Only two comprehensive catalogues to these groups exist: Hetschko (1930) and Ivie and Ślipiński (1990). Hetschko’s catalogue validated the assertion of the group as a “wastebasket taxon” (Lawrence 1980: 305), as his concept of the family was later shown to contain members from ~85 genera across 14 other families of Coleoptera not currently recognized as Zopheridae (Ivie and Ślipiński 1990: 16-18). Ivie and Ślipiński’s catalogue rectified many issues on the generic level, but higher-level groups remained problematic.
The first major work to progress the taxonomy of this family was Ślipiński and Lawrence (1997) which addressed the subfamily Colydiinae of the Australo-Pacific region and provided the first-ever key, diagnoses, and definitions to the genera of this surprisingly diverse subset. They defined each of the nine tribes, revealing a reliance on geographic distribution and characters that demonstrate high degrees of variability as the defining features of these groups (e.g. antennal segmentation, procoxal closure, tarsomere shape). Ślipiński and Lawrence stated (1997: 344) “The internal classification of the Colydiinae presents serious problems and suffers from inadequate analysis…most of these taxa are based on a few relatively superficial characters, and a cladistics analysis of the entire subfamily will probably lead to further reduction.” In reference to the mega-diverse tribe Synchitini, they stated “It is probably that of the above tribes at least Acropini and Colydiini will also be included here.” As is the case with many of the major works on the group, the generic concepts were well-addressed, but their higher-level relationships remained murky.

A later work by Ślipiński and Lawrence (1999) provided the most comprehensive analysis of the family and its constituents via a cladistic analysis based on 59 adult and larval morphological characters across 37 tenebrionoid taxa. Their analysis consisted of 5/9 colydiine tribes, 6/6 zopherine tribes, and representatives of 5 tenebrionoid families as outgroups. Results of their analyses led to the combination of the three previously-recognized families under a larger Zopheridae (Zopheridae, Monommatidae, Colydiidae). Their analyses provided a few morphological characters as potential synapomorphies for Zopheridae \textit{sensu novo}, notably character #12, #30, and #39. Unfortunately, these characters were either mis-scored (#39, most likely due to poor taxon sampling) or are
homoplasious when additional tenebrionoid groups are included (#12, #30). Their analyses recovered the family Ulodidae as sister to Zopheridae sensu novo, but the sampling lacked several other notable tenebrionoid families and only contained eight exemplars from the diverse colydiine subfamily. As a consequence, the monophyly of this heterogeneous family is still in question and higher-level relationships within the group remain tentative, likely due to the limited choice of in-group and out-group taxa as well as possible incorrect morphological character scoring (Lawrence 1980; Ivie 2002a, b, c; Ślipiński and Lawrence 1997, Ślipiński and Lawrence 2010). The monophyly of Zopheridae sensu novo has not been recovered in some molecular analyses (i.e. Hunt et al. 2007, Kanda in prep.) but has been recovered in one subsequent morphological analysis (with addition of Trichtenotomidae; Lawrence et al. 2011), although both these studies were severely limited by weak taxonomic sampling within the group. Ivie (2002) reviewed the zopherids for North America, but elected to retain separation under the previously-recognized family-group names.

Lower-level phylogenies within Zopheridae are practically non-existent, with the only exception being a cladistic analysis of Zopherini based on 32 adult morphological characters scored for nearly all species of Zopherini (Foley and Ivie 2008). Although the taxonomic sampling within the tribe was strong, Zopherini was assumed monophyletic, thus rendering many of the internal relationships insignificant if the tribe is actually para/polyphyletic. It is apparent that, although considerable attention had been paid to this somewhat small beetle group, the status of the higher-level classification of the family and member tribes are still in flux. In order to provide nomenclatural and taxonomic stability, the classification of Zopheridae (and higher Tenebrionoidea) need to
be re-addressed. After this task is satisfactorily achieved, larger questions about the biogeography, natural history, and evolution of the group can be rigorously examined.

**Objective**

The objective of this study is to construct the first comprehensive molecular phylogeny of worldwide Zopheridae based on a representation of 15/15 tribes and over half of world genera, with particular emphasis on testing the monophyly of Zopheridae within the superfamily. A greater knowledge of the taxonomy and phylogeny of a difficult and diverse taxon will provide a suitable foundation for future studies investigating biogeographic hypotheses as well as the evolution and impact of several key morphological innovations throughout the family. In addition, the construction of this phylogeny has potential to elucidate higher-level coleopteran relationships of the superfamily Tenebrionoidea.

**Materials and Methods**

**Taxon Sampling**

_Ingroup:_ In an effort to achieve comprehensive taxonomic coverage of Zopheridae on a worldwide scale, we accumulated large numbers of specimens from numerous localities around the world, including dense samples from critically important localities in the Palaearctic (USA, Denmark, Canaries, Japan), Neotropics (Panama, Costa Rica, French Guyana, Peru, Venezuela, Bolivia, Chile), Madagascar, continental Africa (Cameroon, South Africa, Zambia), Southeast Asia (PNG, Sarawak) and the Southwest Pacific (Fiji, New Caledonia, New Zealand). These analyses included 184
ingroup taxa representing both subfamilies, 15/15 tribes and ~90 genera, representing ~57% generic coverage (Table 1). Within the subfamily Zopherinae, the following generic sampling was achieved: 2/3 Latometini, 1/16 Monommatini, 1/1 Phellopsini, 3/4 Pycnomerini, 1/2 Usechini, and 4/9 Zopherini, representing ~34% generic coverage within the subfamily. Within the subfamily Colydiini, the following generic sampling was achieved: 2/4 Acropini, 2/2 Adimerini, 4/4 Colydiini, 4/6 Gempylodini, 1/1 Nematidiini, 1/3 Orthocerini, 1/1 Rhagoderini, 1/1 Rhopalocerini, and 62/~120 Synchitini (+ ~6 n.gen. or gen. undet.), representing nearly 55% generic coverage within the subfamily.

**Outgroup:** Also included in the analyses were 12 outgroup taxa representing eight of the other 28 tenebrionid families: Archaeocrypticidae, Oedemeridae, Melandryidae, Mycetophagidae, Mycteridae, Tenebrionidae, Tetratomidae, and Ulodidae (Table 1). This selection was based on examining several previous works to determine the more closely related tenebrionid families (e.g. Hunt et al. 2007; Lawrence et al. 2011). K. Kanda (Ph.D. candidate, Oregon State University) is currently conducting analyses of 4-6 loci across a comprehensive sampling of all beetle families within the superfamily Tenebrionoidea (in prep., 114 taxa across 28/28 Tenebrionoid families + outgroups from Cucujoidea). K. Kanda corroborated our outgroup selection based on the relatedness of those taxa to Zopheridae in his preliminary analyses and generously supplied DNA aliquots and partial sequence data for 11/12 outgroups. The topologies were rooted to KK180 Mycterus sp. (Mycteridae). We feel this is a strong taxonomic sampling and should serve to adequately address the monophyly of the family, subfamilies and tribes of Zopheridae worldwide.
Several taxa were not identified below the generic level due to the poor state of taxonomy in those groups and a great number of expected undescribed species. Primary voucher specimens and DNA extraction vouchers were deposited in the Museum of Southwestern Biology Division of Arthropods (MSBA) at the University of New Mexico (majority) and the Oregon State University Tissue collection (OSUIC) (some outgroups). Sequences were submitted to GenBank (accession numbers ####-####).

**Data Sampling**

DNA was extracted using Qiagen (Valencia, California, USA) DNEasy kit for animal tissues. The abdomen was removed prior to extraction, and the remainder of the specimen was placed in buffer. After incubation, each specimen was removed from the buffer, rinsed, and retained as a primary voucher specimen. Three genes were amplified and sequenced: 28S ribosomal DNA (28S), cytochrome c oxidase I (COI), and histone III (H3).

DNA fragments were amplified using PCR with TaKaRa Ex Taq (Takara Bio Inc., Otsu, Shiga, Japan) on an Eppendorf Mastercycler ep gradient S Thermal Cycler (Eppendorf, Hamburg, Germany) and visualized by gel electrophoresis. PCR purification was done using ExoSAP-IT (USB-Affymetrix, Cleveland, OH, USA) and cyclesequenced using ABI Prism Big Dye v3.1 (Fairfax, VA, USA) with the same primers used for amplification. Sequencing reaction products were purified using Sephadex G-50 Fine (GE Healthcare, Uppsala, Sweden) and sequenced with an ABI 3130xl Genetic Analyzer (Molecular Biology Facility, University of New Mexico). All gene regions were sequenced in both directions. PCR product yield, specificity and
contamination were monitored using gel electrophoresis. Data editing and contig assembly was performed in Geneious® version 6.1.6 (created by Biomatters Ltd., available from http://www.geneious.com). All sequences were BLASTed against published GenBank sequences to detect possible contamination.

**Gene Selection**

We identified three mitochondrial and nuclear genes we think are appropriate for providing resolving signal at multiple levels within Zopheridae.

**28S rRNA (28S):** (~2200bp). This marker has become nearly universal in higher phylogenetics in insects. Despite challenges with alignment, it has considerable utility because it exhibits variation suitable for providing signal at multiple levels within phylogenetic reconstruction. We sequenced a partial ~1,000bp region that has previously proven successful in New Zealand Zopheridae (Buckley and Leschen, 2013).

**Cytochrome c oxidase I (COI):** (~1500bp). This gene has been used for phylogenetic analysis of numerous coleopteran groups. Primers for this gene have already been optimized to work across the Zopheridae (Marske et al. 2011; Buckley & Leschen, 2013) (for utility, see: Sandoval et al., 1998; Koulianos, 1999; Reyes et al., 1999; Ribera et al., 2001a; Ribera et al., 2001b; Klass et al., 2003; Miller et al., 2007; Miller and Edgerly, 2008). We sequenced a partial ~770bp region that has previously proven successful in New Zealand Zopheridae (Buckley and Leschen, 2013).

**Histone III (H3):** (328bp). This nuclear protein coding gene often exhibits considerable third position variation in Coleoptera (Bergsten and Miller, 2007; Miller et
al., 2007). This level of variation is often not suitable for higher level phylogenetics, but it makes it highly suitable for species- and population-level analysis.

**Analytical Methods**

**Alignment:** Alignment of COI and H3 was performed in Geneious® based on conservation of the codon reading frame. Alignment of 28S was done using Muscle (Edgar, 2004) under the default settings (max 16 iterations) as implemented in Geneious®. Gaps were treated as missing data. The individual loci datasets were exported from Geneious® as NEXUS files. An Incongruence Length Difference test (ILD, Farris et al. 1994) was performed in WinClada (Nixon, 2002) and revealed no significant incongruence between the datasets (p=0.1667). Therefore, the datasets were concatenated in Geneious® and exported as a NEXUS file. The combined dataset produced an alignment with 2,068 bases. Completeness of data for each taxon is provided in Table 1. Overall, sequence data from three loci for all taxa was as follows: 28S: 86% of taxa; COI 79% of taxa, H3 68% of taxa.

**Parsimony:** A combined parsimony analysis was performed in TNT v.1.1 (Goloboff et al. 2007) as implemented by WinClada with commands set to the following: Ratchet: 10,000 iterations per rep, perturbation 10% up- and down-weight; Drift: 50 iterations per rep; Tree Fusion: 5 round of fusion; 1000 total trees held, and TBR-Max. Bootstrap values were calculated in NONA as implemented by WinClada using 1,000 replications, 10 search reps (mults), one starting tree per rep, “don’t do max*(TBR)” and saving the consensus of each replication.
Bayesian: Optimal partitioning strategies and models of evolution for the dataset were calculated in PartitionFinder v.1.1.1 (Lanfear et al. 2012) under the following commands: branchlengths = linked; models of evolution = beast; modelselection = BIC; scheme = greedy; datablocks = charset 28S=1-969; charset COI_pos1=970-1740\3; charset COI_pos2=971-1740\3; charset COI_pos3=972-1740\3; charset H3_pos1=1742-2068\3; charset H3_pos2=1743-2068\3; charset H3_pos3=1741-2068\3. The optimal partitioning strategy and models of evolution recovered were as follows: by gene, by separate codon position (7 partitions); partition 1 = 28S under SYM+I+G; partition 2 = COI pos. 1 under GTR+I+G; partition 3 = COI pos. 2 under GTR+I+G; partition 4 = COI pos. 3 under GTR+I+G; partition 5 = H3 pos. 3 under SYM+I+G; partition 6 = H3 pos. 1 under GTR+I+G; partition 7 = H3 pos. 2 under K80+I. Bayesian analyses were conducted using BEAST v.1.7.5 (Drummond et al. 2012). A BEAST xml file NEXUS file of the combined data was generated in BEAUti v.1.7.5 (Drummond et al. 2012) under a lognormal relaxed clock with the tree prior set to Yule Process. Four separate Bayesian runs were run through use of the CIPRES Science Gateway ver. 3.1 (Miller et al., 2010), each run for 10 x 10⁷ generations, sampling every 1000 generations. The log files were then analyzed in Tracer v1.4.1 (Rambaut and Drummond, 2007) to determine an acceptable burn-in. To conserve estimation, the log files and tree files for each run, respectively, were combined with a removed burn-in per run of 8% generations and thinned under a lower sampling frequency (every 20,000 generations) in LogCombiner v.1.7.5 (Drummond et al. 2012). The combined log file was then analyzed in Tracer for acceptable stationarity and ESS values. The sampled trees in the combined tree file were summarized in TreeAnnotator v.1.7.5 (Drummond et al. 2012) onto a single “target” tree.
This tree was analyzed, rooted, and set to display posterior probabilities in FigTree v.1.3.1 (Rambaut 2006-2009).

*Imaging and Tree Figures*

Color habitus images were captured using a Visionary Digital™ Passport and BK Plus imaging systems (www.visionarydigital.com), equipped with a Canon 40D or 7D DSLR camera. Image stacks were montaged in Zerene Stacker v.1.04 (Zerene Systems LLC, Richland, WA, USA). Images were edited in Adobe Photoshop CS5 v.12.0.4. Trees were digitally rendered in Adobe Illustrator CS5, v.15.0.2 (Adobe Systems, Inc., San Jose, CA, USA).

*Results*

The parsimony ratchet analyses resulted in 130 most parsimonious trees (L=21,580, Ci=9, Ri=37). The consensus tree (L=21,980, Ci=9, Ri=36) is displayed in Fig. 1. Low consistency and retention index values indicate considerable homoplasy in the data.

The results of the parsimony and Bayesian analyses differed greatly in higher-level topology, although the results at the tribal and genus-group levels were congruent in many important aspects (Figs. 1, 2b-d). Zopheridae *sensu lato* was recovered as polyphyletic with respect to several outgroup taxa in both the parsimony and Bayesian topologies. Within Zopheridae, the subfamily Colydiinae was recovered as monophyletic in the Bayesian topology, but paraphyletic with respect to several zopherine taxa and tenebrionoid outgroups in the parsimony topology. The subfamily Zopherinae was
recovered as polyphyletic with respect to several colydiine taxa and tenebrionoid outgroups in the parsimony topology and paraphyletic with respect only to Tetratomidae in the Bayesian topology. Both topologies were very weakly supported at internal nodes and more better supported at the terminal nodes.

Bayesian Topology
Family-group: Within the outgroup taxa, the family Tenebrionidae was recovered as polyphyletic. Two tenebrionids within the tribe Cnemeplatiini were included in this analysis due to previous doubts about family-group placement (K. Kanda, pers. comm.). These two taxa were recovered within a larger clade containing exemplars from Mycetophagidae and Archaeocrypticidae with strong support (pp = 0.87), suggesting a re-evaluation of the larger Tenebrionoidea (and specifically Tenebrionidae) is needed. Zopheridae was not recovered as monophyletic, rendered polyphyletic by several tenebrionoid outgroup families (Oedemeridae, Tenebrionidae, Tetratomidae). The support for this grouping, however, was very weak (posterior probability, pp = 0.2, denoted by a red circle in Fig. 2a).

Subfamily-groups (Fig. 2a): The subfamily Zopherinae was not recovered as monophyletic, rendered paraphyletic with respect to Tetratomidae. The inclusion of Tetratomidae within Zopherinae was weakly supported (0.3 pp for entire “Zopherinae” clade), but its inclusion was marginally better supported within two internal zopherine clades (pp = 0.62 and 0.47, respectively, yellow highlighted region in Fig. 2a, b). The subfamily Colydiinae was recovered as monophyletic, although with weak support (pp = 0.25).
Within the subfamily Zopherinae, the tribes Monommatini, Latometini, Phellopsini, Usechini, and Pycnomerini were recovered as monophyletic with pp = 1 (Fig. 2b). The tribe Zopherini was rendered polyphyletic with respect to the remaining zopherine tribes. All included zopherine genera were recovered as monophyletic, and several interesting relationships were found. Zopherinae is composed of two major clades (although with weak support: pp = 0.4). In clade 1, the tribe Monommatini was shown to be sister to the *Verodes* + *Phloeodes* portion of Zopherini with marginally high support (pp = 0.76). This clade is sister to the Tetratomidae+??Zopheridae n.gen clade, although only with moderate support (pp = 0.62). Phellopsini was recovered sister to Usechini with high support (pp = 0.98), and together formed the sister clade to Latometini (pp = 0.88). In clade 2 (pp = 0.34), Pycnomerini was recovered as sister to the rest of Zopherini. The Gondwanan genus *Pycnomerodes* was recovered as sister to the Australian *Docalis*, and together they were sister to the cosmopolitan *Pycnomerus*.

Within the subfamily Colydiinae, the following tribes were recovered as monophyletic: Adimerini (pp = 0.89), Rhagoderini (pp = 1), Acropini (pp = 0.93), Nematidiini (pp = 0.98), Orthocerini and Rhopalocerini. The following tribes were recovered as polyphyletic: Gempylodini, Colydiinae, and Synchitini. The only included member of the tribe Orthocerini (*Orthocerus clavicornis*) was recovered as sister to the synchitine genus *Paryphus* with strong support (pp = 1). The gempylodine *Pseudendestes australis* was recovered outside the remaining genera within the tribe, rendering Gempylodini polyphyletic. Nematidiini was recovered as sister to a clade containing the single representative of the monogeneric tribe Rhopalocerini (*Rhopalocerus rondanii*)
and several genera within the tribe Synchitini. Interestingly, these synchitine genera form a separate group on the basis of morphological characters as well, all members having a reduced first tarsomere (apparently 3-3-3 tarsal formula), and a mid-lateral secretory pore present on the pronotum (“3-3-3” clade, Fig. 2d). A number of the colydiine genera with morphological apomorphies clustered together. Adimerini (whose members bear a distinctly lobed first tarsomere) was recovered as sister to the stalk-eyed Acrocin (Plagiope+Acropis) + the Chilean member of new, presumably Gondwanan genus (“Ślipińskius”), and this clade was recovered as sister to the enigmatic North American Rhagoderini. The nominal tribe of the subfamily, Colydiini, was recovered as polyphyletic. Two of the four genera within Colydiini (Anarmostes and Colydiium) grouped together with decent support (pp = 0.72), but the remaining two genera, although grouping together with weak support (Pseudaulonium and Aulonium, pp = 0.11) were nested within a clade of Synchitini.

**Taxa of interest:** There were a few notable relationships among taxa of interest. Among the first group of Synchitini, a clade of presumably Gondwanan groups was nested within a greater sampling of synchitine genera (upper green highlighted portion – Fig. 2d). The genera Notocoxelus, Isotarphius, and “Coxelus” from Chile all share morphological similarities. In studies of the New Zealand members, it has been suggested that the Australian Namunaria, New Zealand Notocoxelus and Chilean Coxelus all constitute a single Gondwanan genus (NPL, T. Buckley, and R.A.B. Leschen, in prep). Interestingly, the monotypic genus Isotarphius was recovered nested within this clade, and the larger clade does not appear to be closely related to many of the remaining New Zealand and Australian zopherids (lower green highlighted portion, Fig. 2d). This large clade of
strictly Australian and New Zealand zopherids is moderately well-supported (pp = 0.67), but it is apparent from the relationships recovered that the generic relationships need to be re-evaluated (e.g. Pristoderus, Ablabus, Bitoma “NEW”). A denser sampling of taxa from the Australo-Pacific was intentional 1) due to the zopherid diversity in the region (see Introduction) and 2) due to on-going work by NPL, T. Buckley and R.A.B. Leschen. The results from this phylogeny support a strong radiation of zopherids throughout the region.

Parsimony Topology

Due to the extremely poor resolution of the parsimony tree, only a brief summary of the findings will be given. Clades or relationships congruent with the Bayesian topology will be mentioned below. See discussion for remarks on parsimony performance.

Family- / Subfamily-groups (Fig. 1): Within the outgroup taxa, the family Tenebrionidae was recovered as polyphyletic. As in the Bayesian topology, members of the tribe Cnemeplatiini grouped together, but separately from the remaining tenebrionids. Unlike the Bayesian topology in which nearly all outgroups were at or very near the base of the rooted tree, the parsimony analyses resulted in a tenebrionoid (col172: Tanylypa morio) and an oedemerid (KK175: Copidita quadrimalata) nested within clades of zopherines, as well as two members of Tenebrionidae forming a clade sister to the greater Colydiinae. Unlike the Bayesian topology, a clade of “basal” colydiines was recovered sister to a clade of tenebrionoid outgroups. This arrangement was weakly supported and may be an
artifact of missing data, as morphology would indicate the subfamily Zopherinae should hold this position (as in Bayesian topology).

**Tribal and Genus-groups:** Within the subfamily Zopherinae, the tribes Monommatini, Latometini, Phellopsini, Usechini, and Pycnomerini were recovered as monophyletic (bootsraps: Latometini = 88; Usechini = 100) (Fig. 1). The tribe Zopherini was rendered paraphyletic with respect to Oedemeridae and the presumably new genus (Ngen160 – groups with Tetratomidae in Bayesian topology). As in the Bayesian results, Phellopsini was recovered as the sister to Usechini with relatively high support (bootstrap = 63), although this group was not recovered as sister to Latometini. Similar again to the Bayesian results, a *Phloeodes + Verodes* Zopherini clade was separate from the *Zopherosis + Zopherus* Zopherini clade. Pycnomerini was recovered as sister to the rest of Zopherini. Interestingly, the zopherine tribe Pycnomerini was recovered as monophyletic, but nested well within the Colydiinae. Within the subfamily Colydiinae, the following tribes were recovered as monophyletic: Adimerini, Rhagoderini (bootstrap = 55), Acropini (bootstrap = 81), Nematidiini, Orthocerini and Rhopalocerini. The following tribes were recovered as polyphyletic: Gempylodini, Colydiinae, and Synchitini. As in the Bayesian topology, the tribe Orthocerini (*Orthocerus clavicornis*) was recovered sister to the synchitine genus *Paryphus*, although with weak support. The gempylodine *Endestes* sp. Bolivia grouped with Rhopalocerini, and *Pseudendestes australis* was once again recovered outside the remaining genera within the tribe, rendering Gempylodini polyphyletic. Nematidiini was recovered within a basal clade of Colydiinae, sister to several members of the tribe Synchitini. As in the Bayesian analyses, a number of the colydiine genera with morphological apomorphies clustered together. Adimerini was
again recovered as sister to the stalk-eyed Acropini (*Plagiope*+*Acropis*), although the placement of this clade differed than in the Bayesian topology. The nominal tribe of the subfamily, Colydiini, was recovered as polyphyletic. Two of the four genera within Colydiini (*Anarmostes* and *Colydium*) grouped together, but the remaining two genera were recovered elsewhere throughout the subfamily.

**Taxa of interest:** As with the Bayesian topology, several relationships among taxa of interest were elucidated. Among the larger group of Synchitini, the clade of presumably Gondwanan groups was again nested within a greater sampling of synchitine genera (although with weak support), but also includes of a species of *Lascotonus* from Malaysia. Again, this clade does not appear to be closely related to many of the remaining New Zealand and Australian zopherids. A large clade of strictly Australian and New Zealand zopherids is present, and it is again apparent from the relationships recovered that the generic relationships need to be re-evaluated. Interestingly, this clade was recovered sister to the Rhopalocerinin, although with weak support. A clade of the “3-3-3-like tarsi” was recovered, although not sister to Rhopalocerini as in the Bayesian topology. The consensus parsimony cladogram resulted in an unresolved polytomy of the “*Bitoma*” groups, the enigmatic gempylodine *Pseudendestes australis*, and several other synchitine and colydiine taxa. This polytomy was recovered as sister to the *Anarmostes+Colydium* clade.

**Discussion**
**Taxonomic Implications – Family-group Relationships**

Both topologies suggest a non-monophyletic Zopheridae. In order for the classification of Tenebrionoidea to be consistent with these findings, Zopheridae *sensu lato* will need to be divided into family groupings more similar to previously-held concepts (*e.g.* as reviewed in Ślipiński and Lawrence, 1999). This would include a resurrection of the family-groups Colydiidae and Zopheridae, although the previously-recognized family-group Monommatidae would continue to be retained as a tribe within Zopheridae. In order to address the polyphyly of the subfamily Zopherinae, A) the tenebrionoid family Tetratomidae would need to be subsumed within a larger Zopheridae *sensu novo* (in reference to the Bayesian topology), or B) further family-group level divisions would need to be made, elevating various clades within the subfamily to family-group status (*e.g.* Tetratomidae + Monommatidae + [Verodes+Phloeodes]). If the Bayesian topology is accepted, the monophyletic subfamily Colydiinae would be returned to family-group status as the former Colydiidae. If the Parsimony topology is accepted, the definitions of families and subfamilies across the Tenebrionoidea will need to be re-evaluated to reflect monophyletic clades.

**Taxonomic Implications – Tribal-group Relationships**

**Zopherinae:** The zopherine-tribal relationships recovered in this analysis are incongruent with those put forth by Ślipiński and Lawrence (1999) based on morphology alone; however, many of the larger findings of that study are supported (1999: 8). Similar results included recovering the expanded Pycnomerini within Zopherini, more or less two major clades of Zopheridae including a clade of the true zopherines, a monophyletic Usechini,
and a monophyletic Latometini within Zopheridae. In our analyses, however, the tribe Phellopsini was not recovered as the sister group to Monommatini. Within the tribe Zopherini, our results are also incongruent with those recovered in a morphological analysis presented by Foley and Ivie (2008), but this is likely due to the lack of other zopherine tribes and assumed monophyly of Zopherini in that analysis. In both Foley and Ivie (2008) and this work, however, Verodes was recovered sister to Phloeodes and Zopherosis as sister to Zopherus. In order to remedy these discrepancies, the tribal classification will need to be re-addressed through the inclusion of additional molecular markers, taxa, and morphological characters.

Colydiinae: Little work has been done to address the tribal relationships of the Colydiinae in any rigorous fashion, and the analyses conducted by Ślipiński and Ivie (1999) simply did not include a large enough taxon sampling of this diverse subfamily to draw any appreciable comparisons. In both our Bayesian and Parsimony analyses, the tribes Adimerini, Rhagoderini, Acropini, Nematidiini, Orthocerini and Rhopalocerini were recovered as monophyletic. The tribes Colydiini and Synchitini were recovered as polyphyletic, although this is not unexpected. Morphological investigations of members of these tribes have yet to result in any concrete characters for delimiting the majority of the currently-recognized groups and appear to be based on variable and/or apomorphic characters (e.g. Orthocerini, Rhopalocerini). If results from current analyses stand, the entire tribal classification system will need to be eliminated in favor of a “supertribe” as suggested by previous zopherid workers (M. Ivie, S.A. Ślipiński, R.A.B. Leschen, pers. comm.). It is possible the tribe Nematidiini and an expanded Adimerini
(Acropini+Adimerini) could be recognized, although this is dependent on placement within the greater Colydiinae.

Taxonomic Implications – Genus-group Relationships

It is apparent from several clades recovered throughout both analyses that the genus-group definitions are also in critical need of revision. Several genera (e.g. Synchita, Ablabus, Pristoderus, Bitoma, Namunaria) were recovered as para- or polyphyletic, although this comes as little surprise due to the fragmentary nature of alpha-level work within the group worldwide. A continued effort will be made to address the fauna of the Australo-Pacific region, as this zopherid subset shows promise for addressing previously-held hypotheses of southern hemisphere biogeography. Both analyses recovered a large clade of strictly Australian and New Zealand members, and the relationships between and within these genera will continue to be investigated via additional taxonomic sampling.

Topology Incongruence

As previously mentioned, there was significant incongruence in the Bayesian and Parsimony topologies. Missing data is a possible explanation for the shortcomings of the parsimony analyses, and gaps in data and sampling need to be filled prior to the acceptance of a preferred topology. It is also possible long-branch attraction is plaguing the parsimony analyses. Another explanation is that considerable homoplasy exists within the group, thus leading to poorly-resolved and poorly-supported topologies under a parsimony framework.
Future Directions - Increased Taxonomic and Molecular Sampling

In addition to the loci used in this study, we will continue to explore possible new markers being used in Coleoptera including other mitochondrial and nuclear genes, relying on the foundational work of Wild and Maddison (2008) and ongoing work on beetles and other groups of insects by Miller (e.g. Lord et al., 2010; Miller et al. 2007, 2008) for primers and amplification and sequencing protocols. We hope some of these markers will aid in resolving the deeper divergences and provide more stability along the backbone of the tree. In addition, an effort will be made to obtain more exemplars of the smaller tribes throughout the family, allowing for a more accurate test of monophyly and sister-group relationships. Partitioned Bremer analyses on the data will be conducted to provide more insight on how the data is performing under parsimony, and problematic taxa will continue to be diagnosed. In addition, fossil calibrations will be implemented in Bayesian analyses in order to estimate lineage divergence times.

Conclusions

Although these analyses are a positive step in the direction towards a revised classification of Zopheridae, few concrete, actionable results were obtained. This phylogeny succeeded in confirming the fears of previous zopherid workers, demonstrating a messy and quite unresolved clustering of tenebrionoids. Encouragingly, the loci and taxa sampled for these analyses provided decent resolution at the more terminal nodes. While this begins to aid in the resolution of genus-group relationships and point out more glaring problems in our current tribal classifications, the poor resolution of the internal nodes needs to be remedied. Once accomplished, taxonomic
alterations may be made to provide a more concrete definition of the included groups. As it stands, Zopheridae and the groups therein are still heavily under question, and this is complicated further by the highly convergent morphology within the Tenebrionoidea. It is our hope that additional molecular markers and taxon sampling can continue to aid in the resolution of this enigmatic group of LBBs (little brown beetles).

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### Table 1. Taxon Sampling and Gene Coverage for the Molecular Phylogeny of Zopheridae.

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CHAPTER 4

Novel Microscopy Techniques Reveal Multiple Evolutionary Origins of Metal Incorporation into Mandibles of the Megadiverse Beetles (Coleoptera).


Appendix I contains the figures 1–17 for Chapter 4 and is available as a supplementary file via LoboVault. See PDF titled “Appendix_I_Figures_Chapter4”. Appendix J contains the supplementary ESEM-EDS mandibular scans and is available as a supplementary file via LoboVault. See PDF titled “Appendix_J_EDS_Chapter4”.

Abstract

It is well-documented that invertebrates incorporate various elements into their cuticle for reinforcement and wear resistance. High concentrations of heavy metals and halogens have previously been detected in a variety of invertebrate morphological structures. While numerous studies have investigated the types and locations of cuticular metals in assorted taxa, few have robustly investigated patterns of incorporation across a single order of diverse organisms within a phylogenetic framework. In doing so, potential evolutionary patterns of heavy metal incorporation can be revealed and may provide predictive ability to infer natural histories and phylogenetic relationships. Using a novel
combination of microscopy instrumentation and analytical techniques, here we demonstrate the ability to rapidly and inexpensively visualize and analyze elemental incorporation and composition. Utilizing these techniques, we investigated metal incorporation within the mandibles of 117 taxa across the megadiverse order Coleoptera. Several lineages were found to incorporate zinc or manganese into various locations on the mandibular surface. To test for phylogenetic signal and evolutionary correlation between presence/absence of metals and adult mandibular use, we constructed a phylogeny under a Bayesian framework from a subsampling of a pre-existing dataset (Hunt et al. 2007), performed discrete statistical analyses on character evolution via BayesTraits Discrete (Pagel et al. 2004), and performed ancestral state reconstructions under both Parsimony and Bayesian frameworks via Mesquite (Maddison and Maddison 2011) and BayesTraits Multistate (Pagel et al. 2004). Resultant patterns of metal incorporation were strongly correlated with adult mandibular use and appear to have originated several times throughout Coleoptera. Additionally, the location and types of cuticular metals are demonstrated to be potentially valuable characters for taxonomic diagnoses. The utility of this instrumentation and analysis has broad-reaching impacts to the fields of material sciences, insect physiology, and systematics.

**Introduction**

The mandibles, ovipositors, tarsal claws, and mouth hooks of various invertebrates are structures that frequently contain significant amounts of heavy metals and halogens such as zinc, manganese, iron, copper, bromine, and chlorine (Figs. 1-10, Birkendal et al. 2006, Bone et al. 1993, Edwards et al. 1993, Hillerton and Vincent 1982,
Hillerton et al. 1984, Lichtenegger et al. 2003, Schofield and Lefevre 1987, Quicke et al. 1998, Vincent and Wegst 2004). It has been demonstrated that the incorporation of these metals provides significant improvements in overall hardness and wear and fracture resistance (Fontaine et al. 1991, Morgan et al. 2003, Schöberl and Jäger 2006, for review of mandibular wear, see Chapman, 1995). While numerous studies have been conducted to identify the presence, types and locations of cuticular metals in particular groups of arthropods (Edwards et al. 1993, Fawke et al. 1997, Cribb et al. 2008a,b), few have focused on and sampled densely within any one major group. One possible reason for the lack of expansive research in this important area of invertebrate physiology lies in the methods and instrumentation currently employed. Some techniques presently being used to investigate cuticular metals such as Scanning Transmission Ion Microscopy (STIM), Proton Induce X-ray Emission (PIXE, e.g. Yoshiura et al. 2002), and Mass Spectrometry are quantitatively very accurate but are costly to run, require high levels of expertise and necessitate an irreparable alteration of specimens. Other techniques (environmental SEM, X-ray EDS), although more qualitative than quantitative, are becoming more readily available and are more easily accessible to a larger portion of the scientific community. Except for a few recent works (Schofield et al. 2001, 2002, 2003; Cribb et al. 2005, 2008a,b), the use and knowledge of this type of instrumentation has seemingly been restricted to physicists, insect physiologists and material scientists. Herein we describe a particular instrumentation set-up for the rapid and efficient qualitative analysis of cuticular elemental incorporation. We used this analytical combination to conduct a broad-scale survey of the incorporation of heavy metals in to the mandibles of adults across the order Coleoptera in order to investigate the prevalence and patterns of cuticular
metals and examine possible correlations between metal incorporation and adult mandibular use.

**Objectives**

The objectives of this study are as follows:

1) Utilize cost-effective and time-efficient Scanning Electron Microscopy methods to reveal the presence/absence and types of metal incorporation in arthropod cuticle.

2) Conduct a broad survey across the megadiverse order Coleoptera to investigate the prevalence and patterns of metal incorporation in beetle mandibles.

3) Examine possible correlations between metal incorporation and adult mandibular use.

4) Determine the potential for new taxonomic characters.

**Methods**

**Mandibular Metal Analysis**

*Taxon Sampling-Metal Analysis:* The beetles (Coleoptera) comprise arguably the most diverse group of organisms on the planet, with an estimated 350,000 described species that occupy a broad array of habitats and ecological niches. In an attempt to decipher patterns of elemental incorporation, mandibles from 117 beetle taxa representing 4/4 suborders, 16/16 superfamilies, and over 25% of all known beetle families were analyzed for the presence/absence, types, and location of mandibular metals, with an emphasis on groups of economic importance (e.g. Curculionidae, Anobiidae) and/or exhibiting diverse adult food preferences and mandibular use (e.g. members of superfamily Cucuoidea).
**Specimen Preparation:** Adult beetle specimens were obtained from the University of Georgia Collection of Arthropods (Athens, GA) (majority), Museum of Southwestern Biology Division of Arthropods (MSBA) at the University of New Mexico), and several individuals (see acknowledgements). Each specimen was assigned a unique voucher number (e.g. NPL2009A12). Specimens were relaxed in warmed distilled water, cleaned via ultrasonication in dilute soapy water, and the mandibles were disarticulated from the head with fine tools. Mandibles were then submerged in 95% ethanol and left to dry. To allow for X-ray EDS analysis of the samples, the mandibles were not sputter coated. After drying, the mandibles were positioned on 260µm carbon conductive tabs (PELCO image tabs, TM, Ted Pella Inc., selected for increased thickness, high purity, and repositionable) placed on standard SEM stubs (12 mm aluminum). Two pairs of mandibles per species were mounted per tab, with right and left mandibles mounted dorsal and ventral surfaces up, respectively. Mandibular preparations and the remainder of the specimens are deposited as voucher specimens in the Museum of Southwestern Biology Division of Arthropods (MSBA) at the University of New Mexico.

**Scanning Electron Microscopy:** A traditional sample preparation for non-environmental SEM would include sputter-coating the sample with gold. This type of preparation is permanent, may damage the specimen, and is unsuitable for rare or delicate specimens. Sputter-coated samples also do not allow for elemental analysis of the specimen. Therefore, analysis and imaging was performed using a Zeiss JEOL 1450EP Variable Pressure Environmental Scanning Electron Microscope (ESEM) at the University of Georgia Center for Ultrastructural Research. A backscatter detector was used to generate the SEM images. Elemental analysis of the samples was conducted.

*Energy-Dispersive X-ray Spectroscopy:* The X-rays generated during SEM imaging were used to determine the elemental composition of the mandibles at the base and the apex. The beam excites electrons within inner shells of the sample (mandibles) causing electrons to be ejected from their orbitals. The empty electron holes are filled by higher-energy electrons from outer orbitals. The change in energy is released in the form of an X-ray. The emitted X-rays are collected and analyzed by an energy dispersive spectrometer (EDS). Elemental composition is determined based on the energy levels of the resulting X-rays from the region being exposed to the electron beam. Energy spectrum readouts (units in KeV) show peaks, the locations of which correspond to specific elements. By analyzing the peaks present and relative strength, it is possible to assess the elements present in the analyzed sample. Unlike more quantitative methods (STIM, PIXE), this type of analysis reveals incorporation only at the cuticular surface and is not appropriate for quantitative determination of amounts or percent composition throughout the mandible.

**Phylogenetic Context**

To date, the most robust phylogeny of the order Coleoptera is provided in Hunt et al. (2007) based on molecular data of three genes (16S ribosomal DNA, 18S ribosomal DNA, cytochrome c oxidase I) for an extensive taxonomic sampling of the group. In order to develop a phylogenetic framework to test character evolution across taxa, a
representative phylogeny is needed. Therefore, molecular data for a taxonomic subset from Hunt et al.’s data (2007) was obtained to construct a representative phylogeny.

**Taxon Sampling.** In order to produce a data matrix with high levels of phylogenetic congruence to the taxa analyzed for mandibular metals, members of Hunt et al.’s (2007) 1,880-taxon matrix were selected in order to achieve the highest taxonomic similarity. In many cases, the exemplars analyzed for metals were represented by the identical species in Hunt’s dataset. When a one-to-one correlation was not possible, taxa were selected that were most closely related (according to current classifications) rather than completeness of gene coverage from Hunt et al.’s (2007) dataset. We feel this approach allows for the most accurate prediction of mandibular metal correlation on a resultant phylogeny of known taxa. It is possible the taxonomy of the groups selected may change or continue to be resolved, thus rendering some of our correlated selections inaccurate. While this cannot be predicted, every effort was made to follow current taxonomic classifications across the groups analyzed.

**Data Sampling.** Sequences of available loci of 86 taxa from Hunt et al.’s 2007 paper were downloaded from GenBank (GenBank accession numbers and data NEXUS files also available from the article supplementary material) via Geneious® version 6.1.6 (created by Biomatters Ltd., available from [http://www.geneious.com](http://www.geneious.com)). Sequence contig assembly was performed in Geneious®.

**Analytical Methods**

**Alignment:** Alignment of COI was performed in Geneious® based on conservation of the codon reading frame. Alignments of 16S and 28S were done using
Muscle (Edgar, 2004) under the default settings (max 16 iterations) as implemented in Geneious®. Gaps were treated as missing data. The individual loci datasets were exported from Geneious® as NEXUS files. An Incongruence Length Difference test (ILD, Farris et al. 1994) was performed in WinClada (Nixon, 2002) and revealed no significant incongruence between the datasets (p=0.1667). Therefore, the datasets were concatenated in Geneious® and exported as a NEXUS file. The combined dataset produced an alignment with 5,322 bases. Completeness of data for each taxon is provided in Table 2.

**Bayesian:** Optimal partitioning strategies and models of evolution for the dataset were calculated in PartitionFinder v.1.1.1 (Lanfear et al. 2012) under the following commands: branchlengths = linked; models of evolution = beast; modelselection = BIC; scheme = greedy; datablocks = charset 18S = 1-2788; charset 16S=2789-3704; charset COI_pos1=3705-5322\3; charset COI_pos2=3706-5322\3; charset COI_pos3=3707-5322\3. The optimal partitioning strategy and models of evolution recovered were as follows: by gene, by separate codon position (5 partitions); partition 1 = 18S under GTR+I+G; partition 2 = 16S under GTR+I+G; partition 3 = COI pos. 1 under GTR+I+G; partition 4 = COI pos. 2 under GTR+I+G; partition 5 = COI pos. 3 under TrN+I+G. Bayesian analyses were conducted using BEAST v.1.7.5 (Drummond et al. 2012). A BEAST xml file NEXUS file of the combined data was generated in BEAUti v.1.7.5 (Drummond et al. 2012) under a lognormal relaxed clock with the tree prior set to Yule Process. Four separate Bayesian runs were run through use of the CIPRES Science Gateway ver. 3.1 (Miller et al., 2010), each run for 5 x 10^7 generations, sampling every 1000 generations. The log files were then analyzed in Tracer v1.4.1 (Rambaut and
Drummond, 2007) to determine an acceptable burn-in. To conserve estimation, the log files and tree files for each run, respectively, were combined with a removed burn-in per run of 4% generations and thinned under a lower sampling frequency (every 10,000 generations) in LogCombiner v.1.7.5 (Drummond et al. 2012). The combined log file was then analyzed in Tracer for acceptable stationarity and ESS values. The sampled trees in the combined tree file were summarized in TreeAnnotator v.1.7.5 (Drummond et al. 2012) onto a single “target” tree. This tree was analyzed, rooted, and set to display posterior probabilities in FigTree v.1.3.1 (Rambaut 2006-2009).

Imaging and Tree Figures

Trees were digitally rendered in Adobe Illustrator CS5, v.15.0.2 (Adobe Systems, Inc., San Jose, CA, USA).

Correlations of Metals Presence with Adult Mandibular Use

In order to test for phylogenetic correlation of the presence/absence of mandibular metals and/or mandibular use, the 86 taxon representative sampling was scored for two binary characters (char. #1 = mandibular metal presence; char. #2 = adult mandibular use) or for one composite multistate character (mandibular metal presence + mandibular use; see schemes and scoring below). Primary references on Coleoptera were surveyed to develop a character scoring for adult mandibular use (Arnett and Thomas 2001, Arnett et al. 2002, Beutel et al. 2005, Crowson 1981, Hunt et al. 2007, Lawrence and Britton 1991, Lawrence and Newton 1992, Lawrence et al. 1999, Lawrence et al. 2011, Leschen et al. 2010). An effort was made to make conservative scorings, as the mandibular use of many
adult beetle groups is still either unknown or assumed. Character #1 was scored as: 0 = no mandibular metals present, 1 = mandibular metals present. We scored adult mandibular use (Char. 2) as “soft” use, “moderate” use, “hard” use, or some combination thereof. We broadly define these use categories as follows: SOFT (score = 0): fungivory, herbivory (primarily leaves and soft tissues), algivory, saprophagy, detritovory; MODERATE (score = 1): scavengery/predation (primarily invertebrate cuticle), xylophagy (soft wood), fungivory (bracket fungi); HARD (score = 2): xylophagy (hard wood, incl. boring, girdling), herbivory (incl. seminivory, nucivory, granivory); - = polymorphic / unknown. If habits were in question, the higher use value was selected (e.g. favoring harder).

In order to test for correlation among the two discrete binary characters (metal presence and mandibular use), we implemented a Likelihood Ratio Test on our resultant phylogeny using BayesTraits Discrete (Pagel et al. 2004) under a Maximum Likelihood analysis. To convert from a multistate mandibular use character (soft = 1, moderate = 2, hard = 3) to a binary character, we combined states as follows: Scheme 1 = multistate scorings of 0 and 1 converted to a binary scoring of 0, and a multistate scoring of 2 converted to a binary scoring of 1); Scheme 2 = multistate scorings of 0 converted to a binary scoring of 0, and multistate scorings of 1 and 2 converted to a binary scoring of 1). BayesTraits Discrete was run under both independent and dependent character settings under scheme 1 and scheme 2 utilizing a Maximum Likelihood framework. No restrictions were placed on the model of character evolution for either the dependent or independent character analyses. Results of discrete analyses of char. #1 and #2 demonstrated significant correlation between mandibular metal presence and mandibular
use under both scoring schemes (see results). Therefore, additional analyses could be run utilizing BayesTraits Multistate (Pagel et al. 2004) to reconstruct ancestral states under a Maximum Likelihood framework. To run multistate analyses, scorings from characters #1 and #2 were merged into a single, multistate character. This effectively linked presence/absence of metals and mandibular use. Thus, the composite character scoring under the two schemes for our data is as follows:

**BayesTraits Multistate Analyses**

**Scheme 1 – composite character produced from of individual chars. #1 and #2**

(chars #1 and #2 converted to binary as above)

0 = char. #1: 0, char. #2: 0, no metals, “soft” use

1 = char. #1: 0, char. #2: 1, no metals, “medium” to “hard” use

2 = char. #1: 1, char. #2: 0, metals present, “soft” use

3 = char. #1: 1, char. #2: 1, metals present, “medium” to “hard” use

**Scheme 2 – composite character produced from of individual chars. #1 and #2**

(chars #1 and #2 converted to binary as above)

0 = char. #1: 0, char. #2: 0, no metals, “soft” to “medium” use

1 = char. #1: 0, char. #2: 1, no metals, “hard” use

2 = char. #1: 1, char. #2: 1, metals present, “heavy” use

3 = char. #1: 1, char. #2: 0, metals present, “soft” to “medium” use

NOTE: Under scheme 2, no taxa were scored for state 3.
BayesTraits Multistate was run utilizing a Maximum Likelihood framework. No restrictions were placed on transitions/transversions between character states (model of character evolution, e.g. shifts from one state to any other equally as likely). Scheme 1 resulted in a 12-rate model (0-1,0-2,0-3,1-0,1-2,1-3,2-1,2-3,3-0,3-1,3-2), and scheme 2 resulted in a 6-rate model (0-1, 0-2, 1-0, 1-2, 2-0, 2-1).

Ancestral State Reconstructions

Reconstructions of ancestral states were carried out under both Parsimony and Maximum Likelihood frameworks in Mesquite v. 2.75 (Maddison and Maddison 2011) and BayesTraits Multistate (Pagel et al. 2004). Ancestral state reconstructions on the Bayesian topology were calculated under a Parsimony framework in Mesquite for the following: presence/absence of mandibular metals (Fig. 12 – single character, no mandibular use included), Multistate Scheme 1 (Fig. 14 – single multistate character of composite presence/absence of metals + mandibular use), and Multistate Scheme 2 (Fig. 15 – single multistate character of composite presence/absence of metals + mandibular use). Ancestral state reconstructions on the Bayesian topology were calculated under a Likelihood framework in Mesquite for the following: presence/absence of mandibular metals (Fig. 13 – single character, no mandibular use included), Multistate Scheme 1 (Fig. 16 – single multistate character of composite presence/absence of metals + mandibular use), and Multistate Scheme 2 (Fig. 17 – single multistate character of composite presence/absence of metals + mandibular use). Note: With the exception of the initial Bayesian topology (Fig. 11), the taxa presented on the resultant topologies (Figs. 12-17) are not the taxa pulled from Hunt et al.’s dataset, but rather are the “taxonomic
correlates” analyzed for mandibular metals (for full list, see Table 2). In Figures 13 and 16–17, likelihoods were reported as proportional, but the graphic of reconstruction does not showing reconstruction proportional to the likelihoods (e.g. higher likelihoods for states depicted by thicker branches).

Results

ESEM / X-Ray EDS Mandible Analysis

ESEM images were captured through the use of the backscatter detector on uncoated samples, yielding high-quality images. In instances where metals were incorporated into the cuticle, these higher density locations appeared much brighter than non-incorporated areas, resulting in a visually striking image (Figs. 1-10). Quantifiable incorporation of heavy metals was found in 13/46 families, 22/68 subfamilies, 42 genera, and 48/117 specimens. While the number of metal-incorporating taxa analyzed is largely dependent on taxon sampling (and may be higher due to increased sampling in certain groups, e.g. Curculionidae), the diversity of families shown to incorporate metals is quite high. Furthermore, there appear to be clear phylogenetic patterns associated with metal incorporation across various beetle lineages. Most notably, the following trends emerged:

1) Three out of four coleopteran suborders lack incorporation of quantifiable concentrations of heavy metals (Archostemata, Myxophaga, Adephaga).

2) Within the suborder Polyphaga, metal incorporation is widespread in Bostrichiformia, Cleroidea, Chrysomeloidea, and Curculionoidea.

3) Within Polyhaga, metal incorporation is conspicuously sparse or absent from Tenebrionoidea, Cucujoidea, and Elateriformia.
4) Metal incorporation is absent in aquatic Coleoptera; incorporation was recovered only in terrestrial groups.

5) Metal incorporation appears to have a phylogenetic correlation; major clades with or without widespread incorporation were recovered.

6) Presence of mandibular metals correlated with adult mandibular use – only taxa utilizing mandibles under “medium” to “hard” scorings displayed instances of incorporation.

Bayesian Phylogenetic Analyses

A consensus Bayesian topology was produced from trees sampled from the posterior distribution (at stationarity) of 86 representative taxa from Hunt et al. (2007) (Fig. 11 - values above nodes indicate posterior probabilities, values below nodes indicate node number). While the higher-level relationships among coleopteran groups recovered from these analyses differed in several aspects from the larger analyses presented in Hunt et al. 2007, our intent was not to replicate their results, but rather to produce a phylogeny with a taxonomic sampling correlating to the taxa analyzed for mandibular metals. This approach allows for the ability to carry out statistical tests of character correlation on a representative phylogeny for scored characters/states.

Correlations of Metals Presence with Adult Mandibular Use

*BayesTraits Discrete Analyses*

**Scheme 1**

Log-likelihood Dependent = -72.5184
Log-likelihood Independent = -81.7029

LR = 2[-72.5184 +81.7029] = 18.369

Chi-squared distribution, w/ 4 degrees of freedom: p-value > 0.001

Result = significant correlation between mandibular metal presence and mandibular use.

**Scheme 2**

Log-likelihood Dependent = -67.6941

Log-likelihood Independent = -81.6452

LR = 2[-67.6941 + 81.6452] = 27.9022

Chi-squared distribution, w/ 4 degrees of freedom: p-value > 0.001

Result = significant correlation between mandibular metal presence and mandibular use.

**Ancestral Character State Reconstructions**

Ancestral state reconstructions on the Bayesian topology under the Parsimony framework for just the presence/absence of metals (Fig. 12) resulted in 11 to 12 instances of the evolution of metal incorporation. The only ambiguous ancestral state reconstruction occurred at the MRCA of Sphindidae–Curculionidae, as the most parsimonious result was either a single evolution and then a loss for *Sphindus americanus*, or two instance of evolution, one at the Anthribidae clade and another at the Curculionidae clade. Ancestral state reconstructions under a Likelihood framework for
just presence/absence of metals recovered (Fig. 13) identical results as under the parsimony framework.

Ancestral state reconstructions under the parsimony framework under a composite multistate character via scheme 1 (Fig. 14) resulted in 10 to 12 instances of the evolution of metal incorporation. The only ambiguous ancestral state reconstructions occurred at the MRCA of Cerambycidae–Nitidulidae and Sphindidae–Curculionidae, respectively. Under this multistate character scoring scheme, additional information about the coevolution of mandibular metals and adult mandibular use can be seen. Green clades represent the presence of mandibular metals and a “soft” mandibular use, whereas black clades represent the presence of mandibular metals and a “moderate” to “hard” mandibular use. Multi-colored clades indicate equally most-parsimonious scorings. There were 3-4 origins of the “presence and soft use” character scoring, with the only ambiguous ancestral state reconstruction at the MRCA node for Anthribidae. All other instances of metal incorporation occurred with a “moderate” to “hard” mandibular use, and a shift to incorporation with “soft” use only occurred 1-2 times (Cleridae: *Enocerus ichneumoneus* and possibly Anthribidae: *Euparius marmoreus*). Ancestral state reconstructions under the Likelihood framework under a composite multistate character via scheme 1 (Fig. 16) recovered identical results as under the Parsimony framework.

Ancestral state reconstructions under the Parsimony framework under a composite multistate character via scheme 2 (Fig. 15) resulted in as few as 3 but as many as 9 instances of the evolution of metal incorporation, but with multiple losses. Black clades represent the presence of mandibular metals and “hard” mandibular use. Green clades represent the absence of mandibular metals and “hard” mandibular use, and white
clades represent the absence of mandibular metals and “soft” to “medium” mandibular use. Multi-colored clades indicate equally most-parsimonious scorings. Ancestral state reconstructions under the Likelihood framework under a composite multistate character via scheme 2 (Fig. 17) recovered similar results as under the Parsimony framework. If the highest likelihood value is accepted, the analysis resulted in 3 instances of the evolution of metal incorporation under scoring scheme 2 (Derodontidae: Derodontus esotericus, Eucnemidae: Isorhipis obliqua, and MRCA of Dermestidae+Silphidae through Curculionidae).

Discussion

The use of this type of ESEM microscopy and X-Ray EDS analysis allows for efficient analysis of the presence/absence of metals and is no more costly than traditional SEM imaging.

*Types of mandibular metals:* Of the taxa with detectable quantities of metals present in the mandibles, the most predominant metals were zinc in association with a chlorine halogen (occurring in 18/21 analyzed subfamilies with metal incorporation). Fewer of the positive taxa contained manganese (2/21 analyzed subfamilies: Dermestidae: Anthreninae; Cerambycidae: Lamiine), usually in much lower concentrations. Aluminum was recovered from Derodontidae, which represents the first documentation of this metal in quantifiable amounts. Another notable result was the recovery of high levels of potassium in Rhysodinae (Adephaga: Carabidae).

*Location of mandibular metal incorporation:* In previous studies, the specific location of metal incorporation in invertebrate mandibles has been mentioned only
secondarily and has yet to be thoroughly investigated. The visually striking images produced by the VP-ESEM + backscatter detector allow for a rapid analysis of specific location of cuticular metals. Out of the 48 specimens analyzed that exhibited appreciable quantities of metals, the majority of incorporation was localized in the mandibular apices (e.g., Anthrenus, Deretaphrus, Figs. 1–2, 3, 6, appendix). In several groups (Trogossitidae, Cleridae, Figs. 7–8, appendix), areas of incorporation extended along the incisal edge of the mandible. In the scolytine weevil (Ips grandicollis, Fig. 4), metal incorporation appears restricted to a small tubercle near the base of the mandible, with the tubercle more than likely serving as a primary grinding surface. Location of incorporation is linked with the mechanical function of the mandible, as the areas of highest abrasion are subjected to the significant mechanical force and are thus more likely to be reinforced. Additional quantitative analyses would undoubtedly reveal metal incorporation in other high-wear areas of the mandibles (e.g. grinding plates, etc.), although in perhaps lower concentrations.

*Sex-specific incorporation:* Many members of the family Cerambycidae (Chrysomeloidea) are wood borers and are a group of major economic importance worldwide. Within this mega-diverse family, members of the tribe Onciderini exhibit a sexually dimorphic girdling behavior in which the females lay eggs in a branch and then girdle the branch, causing structural weakening and eventual detachment of the branch. Males do not girdle. Due to this dimorphism, members of this group were ideal in investigating the presence or absence of sex-specific incorporation of metals into mandibles. A male and female of Oncideres cingulata were analyzed, revealing incorporation of manganese in both sexes. This finding suggests that metals are
incorporated universally in the mandibles of both sexes, lacking differentiation due to sex-specific natural histories.

*Phylogenetic significance:* Only one study has analyzed the presence or absence and types of metals within a phylogenetic framework (Cribb et al. 2008b), demonstrating that high quantities of zinc in the mandibles of one termite family could be used as a phylogenetically and taxonomically informative character. The presence or absence and types of cuticular metals incorporated in beetle mandibles does show strong phylogenetic signal with various clades exhibiting wide-scale incorporation of predominantly one metal (e.g. Polyphaga: Bostrichiformia/Bostrichoidea, Cleroidea, Curculionoidea) or lack of metals entirely (e.g. all Archostemata, Myxophaga, Adephaga except Rhysodines, and Polyphaga: Tenebrionoidea).

*Mandibular Metal Presence Across Coleoptera under a Phylogenetic Context:* It has been previously asserted that relatedness of taxa is the strongest predictor of metal incorporation, not natural histories or habitat (Cribb et al. 2008b). While the evolution of metal incorporation or types of heavy metals and halogens present in various invertebrate structures does seem to be expressed in a phylogenetic framework, our results indicate that mandibular use also plays a critical role in whether or not mandibles are reinforced in adult Coleoptera (see specifically Cucujoidea and Cleroidea). Mandibular use information as follows is given for all taxa that were shown to incorporate appreciable quantities of heavy metals in the mandibular cuticle, as gathered from primary references on Coleoptera (Arnett and Thomas 2001, Arnett et al. 2002, Beutel et al. 2005, Crowson 1981, Hunt et al. 2007, Lawrence and Britton 1991, Lawrence and Newton 1992, Lawrence et al. 1999, Lawrence et al. 2011, Leschen et al. 2010).
Derodontiformia (Derodontidae): The genus Derodontus feeds solely on homobasidiomycete fungi. These types of fungi range from soft to hard.

Bostrichiformia: with the exception of one subfamily of Dermestidae (Dermestinae), all members within the Bostrichiformia analyzed contained metals. This group of beetles is known for their wood-feeding and generally destructive habits, many of which are known as stored product and structural pests. The Bostrichiformia clade exhibits strong phylogenetic signal with metal incorporation.

Dermestidae: stored product pests, scavengers. Interestingly, members analyzed within the subfamily Dermestinae (Dermestes, Thylodrias) contained no metals, whereas the representative of the subfamily Anthreninae (Anthrenus) contained manganese, the only taxon to contain this metal other than a distantly related longhorn beetle (Cerambycidae: Lamiinae: Oncideres cingulata). Anthrenus verbasci is commonly known as the “varied carpet beetle” and are pests of carpets and other similar materials.

Bostrichidae: all members analyzed within the family Bostrichidae contained zinc and chlorine. Bostrichidae usually bore into dead or dying wood, and the taxa analyzed are both members of the subfamily Dinoderinae. The genus Dinoderus is commonly associated with bamboo, and the genus Prostephanus is known to feed on grains.

Ptinidae (=Anobiidae): Members of 5 different subfamilies were found to contain zinc and chlorine. With the exception of a puffball feeder, Caenocara sp. all ptinids contained metals. Most ptinids are stored product pests, and several bore into wood. Members of Dorcatominae are associated with fungi. Some members of Ptininae are wood boring, while others feed on animal matter.
Elateriformia: Eucnemidae: only the subfamily Melasinae within the Eucnemidae exhibited detectable metal incorporation. Eucnemids are associated with dead wood, and it is uncertain whether or not adults feed. The only other elateriform family tested, Phengodidae, did not exhibit metal incorporation.

Lymexyloidea: Lymexylidae are associated with wood and the larvae are wood boring. Their common name, the Ship-timber beetles, alludes to their nature as a structural pest of ship and other timbers. The representative analyzed (Atractocerus sp.) contained detectable quantities of aluminum, the only taxon to exhibit incorporation of this metal in detectable quantities in our analysis. It is possible, however, this result was an analytical artifact and should be re-evaluated.

Cucujoidea: within the large superfamily Cucujoidea, the only family shown to exhibit metal incorporation was Bothrideridae. Within that family, two genera from different subfamilies were analyzed. The genus Deretaphrus (subfamily Bothriderinae) contained significant quantities of zinc and chlorine (Figs. 1-2, appendix), whereas the mycophagous genus Teredomorphus (Bothrideridae: Teredinae) lacked quantifiable amounts of mandibular metals. Members of the subfamily Teredinae (metals absent) are fungivorous as larvae and adults, whereas members of the Bothriderinae (metals present) are thought be predaceous on wood-boring beetles and their larvae as adults.

Cleroidea: One of the more interesting findings of this study was the detection of high levels of zinc and chlorine in the mandibles of the largely predaceous cleroid families Trogossitidae and Cleridae. Within Trogossitidae, two genera were analyzed - the mycophagous Calytis contained no metals, whereas the stored grain pest Tenebroides mauritanicus contained zinc and chlorine. Tenebroides mauritanicus is also known to
bore into wooden barrels. This case suggests a pattern of incorporation not due to incorporation in closely related lineages, but incorporation due to the natural history of the particular group (e.g. predisposition of boring into hard woods and grains as opposed to softer structures). Within the Cleridae, all three genera examined contained zinc and chlorine. The vast majority of clerids are predaceous on wood-boring beetles (including the tested *Thanasimus* and *Enoclerus*). The genus *Necrobia* is a stored product pest.

*Chrysomeloidea:* within this large superfamily, only the bruchine chrysomelids and cerambycids exhibited metal incorporation. The vast majority of chrysomeloids are phytophagous, but members of Bruchine are known as the “bean weevils” and frequently bore into hard seeds and nuts. Members of Cerambycidae bore out of sound wood after eclosion, and some groups girdle tree branches to aid in oviposition.

*Curculionoidea:* This superfamily contains many of the most economically important and destructive wood-boring beetle pests. Within the weevils and related taxa, both the families Anthribidae and Curculionidae were shown to incorporate metals. Most members of the Curculionidae subfamilies Platypodinae and Scolytinae bore into sound wood and then feed on resultant fungal growth. Other curculionids feed on nuts and seeds, but some (e.g. *Curculio*, analyzed, metals not present) feed on softer plant materials such as fruits and leaves). The curcuionoid family Anthribidae (the fungus weevils) commonly feed on polypore and/or pyrenomycete fungi, but some members are presumably phytophagous.

The findings presented here (in addition to Cribb, 2008b) make a strong case for the taxonomic and natural history implications of cuticular metal incorporation. Thus, the incorporation of metals into the mandibles likely has both taxonomic implications,
potentially serving as a character for the separation of natural groups, as well as implications about the natural history of those groups. Based on the correlation of metal incorporation with adult mandibular use, it is expected that other groups of beetles also incorporate metals into their cuticle, e.g. members of subcortical, wood-inhabiting or wood-feeding groups (e.g. Histeridae, Passalidae, rhysodine Carabidae, Buprestidae, Zopheridae, Tenebrionidae, Ciidae, Silvanidae).

Conclusions

There is little doubt a far greater number of beetles incorporate metals into their mandibles in at least trace amounts than is currently documented, however, many of the more quantitative techniques have drawbacks of availability, cost, and time of operation.

Increased hardness and wear resistance of cuticular structures due to metal incorporation most likely plays a critical role in the evolution and natural histories of many invertebrate groups, but relatively little is known about this phenomenon. As of now, few studies have been conducted to investigate the presence and nature of this important physiological state across the vast majority.

From an instrumentation perspective, advances in SEM configurations now allow for an efficient, cost-effective solution for the investigation of the presence of cuticular metals.

Burgeoning areas of research would be to look at the incorporation of metals through both larval and adult life stages, as the natural history of each stage can differ greatly from one another. The bioavailability of metals in the environment and potential
correlations with concentrations and types of metals found in invertebrate cuticles is in need of further investigation.

It can be assumed that metal incorporation across Coleoptera is more pervasive than currently documented and using more sensitive, quantitative techniques will reveal further patterns of cuticular incorporation. However, the qualitative techniques used in this study are excellent indicators of easily-detectable, higher concentrations of metal incorporation on the cuticular surface. Although trace quantities of heavy metals are likely to occur in a great number of additional invertebrate groups, a rapid, cost effective analytical method is an appropriate investigative tool to begin to explore broad-scale patterns of metal incorporation across some of life’s most diverse groups.

Acknowledgements

For the loan of specimens, the authors thank Eugenio H. Nearns (UNM, Albuquerque, New Mexico), Anthony Cognato (MSU, East Lansing, Michigan), Cecil L. Smith (UGCA, Athens, GA), Andy Cline (CDFA, Sacramento, CA). We than Juanita Forrester (Chattahoochee Technical College) and Adriano Giorgi (UGA) for assistance in identification and dissection of Coccinellidae. We thank E.H. Nearns and G.T. Gustafson (UNM) for reviewing early drafts of the manuscript. For discussions, we thank Steve Cameron (ANIC, Canberra, Australia), Mike Ivie (Montana State University), Rich Leschen (NZAC, Auckland, New Zealand), and Tim Lowrey (UNM). We would especially like to thank Chris Witt (UNM) for suggesting and aiding the implementation of many of the phylogenetic methods employed herein.
References


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Table 2. Taxon Sampling for Metals Analysis and Representative Taxa from Hunt et al. 2007.

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References:
Hunt et al. 2007
CONCLUSION

Although a decent amount of previous research has been conducted on the beetle family Zopheridae, a number of critical gaps in our collective knowledge of this economically important group exist. Aspects of identification, classification, and phylogeny need to be addressed with greater rigor, and this was the aim of my individual dissertation chapters.

Accurate identification of zopherid species or even genera is often difficult due to the lack of available resources. IroncladID (Chapter 1) was constructed as an attempt to remedy this issue. IroncladID includes an interactive Key to Genera & Species, Genus Fact Sheets, species diagnoses, and hundreds of images to aid in the identification of Ironclad and Cylindrical Bark Beetles found in North America north of Mexico. Upon completion, the tool was peer reviewed by a number of taxonomic experts and then released for distribution. This tool is currently included in the larger USDA Wood Boring Beetle Resource, a comprehensive resource of identification and screening tools for wood boring beetles of the world (available from: http://wbbresource.org/).

Because of the zopherid hyperdiversity that exists in New Zealand, it is imperative that sound taxonomic work begins with a study of the primary literature and museum specimens. Thus, an illustrated catalogue to the new Zealand Zopheridae was constructed (Chapter 2). For this chapter, we examined nearly all types, photorecorded primary types and associated labels, designate lecto- and paralectotypes, and provide synonymies and replacement names where necessary. The purpose of this paper is to stabilize the nomenclature of the New Zealand species in a critical foundational step before proceeding with revisionary studies.
In order to assess the constitution, monophyly, and relationships within Zopheridae and among other tenebrionoid families, I conducted the first molecular phylogenetic analyses of the family (Chapter 3). Analyses suggest a non-monophyletic Zopheridae. In order for the classification of Tenebrionoidea to be consistent with these findings, Zopheridae *sensu lato* will need to be divided into family groupings more similar to previously-held concepts, including a resurrection of the family-groups Colydiidae and Zopheridae, although the previously-recognized family-group Monommatidae would continue to be retained as a tribe within Zopheridae. Our analyses recovered many of the previously-accepted tribes within the subfamilies Zopherinae and Colydiinae, however, a few of the tribes (*e.g.* Zopherini, Colydiini and Synchitini) were recovered as polyphyletic, although this is not unexpected. Morphological investigations of members of these tribes have yet to result in any concrete characters for delimiting the majority of the currently-recognized groups and appear to be based on variable and/or apomorphic characters (*e.g.* Orthocerini, Rhopalocerini). If results from current analyses stand, the entire tribal classification system will need to be eliminated in favor of a “supertribe” as suggested by previous zopherid workers (M. Ivie, S.A. Ślipiński, R.A.B. Leschen, *pers. comm.*). Although these analyses are a positive step in the direction towards a revised classification of Zopheridae, few concrete, actionable results were obtained. This phylogeny succeeded in confirming the fears of previous zopherid workers, demonstrating a messy and quite unresolved clustering of tenebrionoids. Encouragingly, the loci and taxa sampled for these analyses provided decent resolution at the more terminal nodes. While this begins to aid in the resolution of genus-group relationships and point out more glaring problems in our current tribal classifications, the
poor resolution of the internal nodes needs to be remedied. Once accomplished, taxonomic alterations may be made to provide a more concrete definition of the included groups. As it stands, Zopheridae and the groups therein are still heavily under question, and this is complicated further by the highly convergent morphology within the Tenebrionoidea. It is our hope that additional molecular markers and taxon sampling can continue to aid in the resolution of this enigmatic group of LBBs (little brown beetles).

In Chapter 4, I conducted a broad-scale analysis of metal incorporation across the order Coleoptera using a unique microscopy set-up. From an instrumentation perspective, advances in SEM configurations now allow for an efficient, cost-effective solution for the investigation of the presence of cuticular metals. We demonstrated numerous instances of metal incorporation throughout the order. Resultant patterns of metal incorporation were strongly correlated with adult mandibular use and appear to have originated several times throughout Coleoptera. Additionally, the location and types of cuticular metals are demonstrated to be potentially valuable characters for taxonomic diagnoses. The findings presented here make a strong case for the taxonomic and natural history implications of cuticular metal incorporation. Thus, the incorporation of metals into the mandibles likely has both taxonomic implications, potentially serving as a character for the separation of natural groups, as well as implications about the natural history of those groups.

The over-arching goal of this dissertation was to add to our general knowledge of Coleoptera via a diversity of research questions and methodologies. Foundational studies on the enigmatic beetle family Zopheridae were conducted, and phylogenetic information pertaining to the incorporation of metals as a potential driver for coleopteran diversity
was revealed. This research paves the way for additional investigations on these topics, and it is my sincere hope my work benefits entomology and science as a whole.
APPENDIX A

Lucid3 Key for Chapter 1 – IroncladID.

Available from: http://coleopterasystematics.com/ironcladid/IroncladID-key-portal.html

APPENDIX B

Gallery for Chapter 1 – IroncladID.


APPENDIX C

Morphological Atlas for Chapter 1 – IroncladID.

APPENDIX D

Glossary for Chapter 1 – IroncladID.

The following structures and descriptive terms are found throughout the Ironclad ID resource. The terms below have been defined using the Torre-Bueno Glossary of Entomology (Nichols 1989) and Lawrence et al. (1999, 2010).

**Abdominal process (intercoxal process of abdominal ventrite I):** projection on ventrite 1 which extends anteriorly between metacoxae.

**Abdominal ventrite:** visible ventral abdominal sclerite. Ventrite number does not correspond to true sternite number except in rare cases where sternite 1 is visible. Also called ventrite.

**Acute:** pointed; terminating in or forming less than a right angle.

**Antennae:** paired, segmental appendages, borne one on each side of head, functioning as sense organs and bearing a large number of sensilla.

**Antennal club:** an enlarged portion of the antennal apex, consisting of a variable number of antennomeres (often 3). In an incrassate, antenna the antennomeres gradually enlarge towards to apex, but if there is an abrupt change in length or width at some point, then the antennomeres beyond this are considered to be part of the club.

**Antennal cavity:** a prothoracic cavity for housing the whole antenna or a portion of the antenna (usually the club).

**Antennal insertion:** point of attachment for the antennae, consisting of an opening in the head capsule, sometimes with a reinforced sclerotized ring.

**Antennomere:** antennal segment; including scape, pedicel and flagellomeres.
NOTE: the flagellum is composed of all antennal segments proceeding the scape and pedicel. Any individual antennal segment is commonly called an antennomere.

**Anterior**: in front; before.

**Apex (pl. apices)**: end of any structure distad to the base.

**Apical (apicad)**: an adjective (or adverb) denoting position near or movement toward the apex of a body part. The apex of the head or pronotum is at the anterior end while that of the abdomen or an elytron is at the posterior end; on the legs or antennae, apical and distal are synonymous.

**Arcuate**: arched or bowlike.

**Basal (basad)**: an adjective (or adverb) denoting position near or movement toward the base of a body part. The base of the head or pronotum is at the posterior end while that of the abdomen or an elytron is at the anterior end; on the legs or antennae, basal and proximal are synonymous.

**Bisinuate**: with 2 sinuations or incisions.

**Callosity**: a rather flattened elevation not necessarily harder than the surrounding tissue.

**Canthus (pl. canthi)**: a sclerotized bar encroaching on the eye.

**Carina (pl. carinae)**: an elevated ridge or keel, not necessarily high or acute.

**Clypeus**: the area of the beetle head between the frontoclypeal suture and the labrum, or in the absence of a frontoclypeal suture, the area just behind the labrum and in front of the eyes. Also called the epistoma.

**Concave**: hollowed out; the interior of a sphere as opposed to the outer or convex surface.

**Confluent**: running together.
**Connate:** united at base, or along the entire length; fused.

**Connate ventrites:** ventrites which are immovably united, so that they can not slide over one another as they can when joined by membrane. This may be used as a synonym with fused ventrites, but they are always separated by a groove or line, while fusion sometimes involves the disappearance of any joining line.

**Convex:** the outer curved surface of a segment of a sphere, as opposed to concave.

**Cordate (cordiform):** heart-shaped; triangular, with the corners of the base rounded; not necessarily emarginate at the middle of the base.

**Coxa:** the basal segment of the leg, by means of which it is articulated to the body.

**Denticulate:** set with little teeth or notches.

**Depressed:** flattened down as if pressed.

**Distal (distad):** an adjective (or adverb) denoting position near or at or movement toward the free end of an appendage or that furthest from the body.

**Dorsal (dorsad):** an adjective (or adverb) denoting position near or movement toward the upper side of the body or a body part.

**Elytral declivity:** the downward slope of the elytra, near the apex.

**Elytral suture:** the line formed when two elytra in folded or closed position meet along the midline.

**Elytron (pl. elytra):** the fore wing in Coleoptera, which is more or less uniformly sclerotized and in resting position is longitudinally oriented, usually meeting the opposite elytron along the midline.

**Emarginate:** notched at the margin.
**Epipleuron** (pl. *epipleura*): a lateral, infolded portion of the elytra, which is separated from the elytral disc by a distinct fold or carina and which usually fits against the lateral portions of the abdomen.

**Epipleural fold**: a fold in the elytron which separates the elytral disc from the epipleuron.

**Explanate**: spread out and flattened; applied to a margin.

**Eye facet**: individual parts of the external surface of the compound eye; often convex but sometimes more or less flattened.

**Femur** (pl. *femora*): the third and usually the stoutest segment of the beetle leg, articulated proximally with trochanter (or if the latter is absent, then the coxa) and distally with the tibia.

**Ferrogino-testaceous**: rusty yellow-brown

**Ferrugineous**: rusty red-brown

**Frons**: the area between the eyes and just behind the frontoclypeal suture. In Coleoptera it is not or only rarely separated from the vertex posteriorly.

**Glabrous**: without hairs (setae).

**Heteromeroid** (trochanter type): a type of strongly oblique trochantofemoral attachment with the base of the femur abutting the coxa.

**Hypomeron** (pl. *hypomera*): that portion of the pronotum which is visible from the ventral side; when there is a lateral pronotal carina, this is the portion below that carina (the pronotal disc being above it).

**Impression**: an indentation or depression on a surface.

**In repose**: at rest.
**Interfacetal setae (of eye):** setae arising between adjacent eye facets.

**Interspaces (interval):** the space between two structures or sculptures.

**Interstria (interstice) (of elytra):** the space between two lines, whether striate or punctate.

**Labial palp:** the one- to four-segmented appendage of the insect labium, borne on the palpiger.

**Lateral (laterad):** an adjective (or adverb) denoting position near or movement toward the sides of the body.

**Lateral pronotal carina (pl. carinae):** a sharp lateral edge on the prothorax separating the pronotal disc above and the hypomeron below.

**Macula (pl. maculae):** a spot or mark.

**Maculate:** spotted; with many superficial marks or spots.

**Mandible:** one of the paired lateral biting jaws in beetles, lying just below the labrum and just above the maxillae. The mandible is usually relatively stout and heavily sclerotized, with one or more apical teeth, a basal mola or grinding area, a membranous prostheca distal to the mola and sometimes one or more accessory teeth.

**Matte:** lacking or deprived of luster or gloss.

**Maxillary palp:** one- to seven-segmented appendage of the insect maxilla, carried by the stipes on its outer end, being sensory in function.

**Medial fleck (of flight wings):** binding patch located in the medial field. In Polyphaga this is located in front of MP3+4.

**Median:** on the midline.
Mesal (mesad): an adjective (or adverb) denoting position near or movement toward the midline of the body.

Meso-: prefix referring to a structure forming part of the mesothorax, including mid legs (e.g. mesocoxa, mesepisternum, mesotarsus, mesepisternum).

Mesocoxae: the coxae of the mesothorax.

Mesothorax: the second (middle) segment of the beetle thorax.

Mesotibia: the tibia of the mesoleg.

Meta-: prefix referring to a structure forming part of the metathorax, including hind legs (e.g. metacoxa, metepimeron, metatibia, metaventrite).

Metacoxae: the coxae of the metathorax.

Metathorax: the third (posterior) segment of the beetle thorax.

Metaventrite: ventral plate lying behind and between the mesocoxal cavities and delimited laterally by the metanepisterna.

Nodule: a small knot or swelling.

Oblique: slanting; any direction between perpendicular and horizontal.

Opaque: without any surface luster.

Palpomere: palp segment.

Pedicel: the second segment of the insect antenna, supporting the flagellum.

Piceus: black

Postcoxal process: mesal extension of the posterior part of the propleuron or hypomeron behind the procoxa, which may meet the prosternal process or the opposing postcoxal process, thus closing the procoxal cavity externally.

Posteriad: toward the posterior end.
**Posterior**: hinder or hindmost, opposed to anterior; hind or rear.

**Preapical groove (of abdominal ventrite V)**: a groove located just before the apex of abdominal ventrite V.

**Pro-**: prefix referring to a structure forming part of the prothorax, including fore legs (e.g. procoxa, prosternum, protrochantin, protarsus).

**Procoxae**: the coxae of the prothorax.

**Procoxal cavities**: countersunk prothoracic housing into which the procoxa fits. Formed in part by the prosternum and in part by the propleuron or pronotal hypomeron.

**Procoxal cavities: external closure**: externally closed when the postcoxal processes of the hypomera meet the prostemal process or meet one another.

**Pronotal disc**: the area of the pronotum which is visible dorsally and usually delimited laterally by the two lateral carinae. Contrasted with the paired pronotal hypomera, which extend onto the ventral surface.

**Pronotum**: dorsal portion of the pronotum, lying above the lateral pronotal carinae when these are present.

**Prosternal process**: projection of the mesal portion of the prosternum which extends between the procoxae and may overlap the mesoventrite or fit into the mesoventral cavity.

**Prosternum**: used for the entire ventral plate lying in front of and between the procoxae and between the notosternal or pleurosternal sutures.

**Prothorax**: the first segment of the beetle thorax.

**Protrochantin**: a precoxal sclerite articulating with the procoxa, prosternum and pleuron or sometimes fused to the pleuron or apparently absent.
**Proximal**: that part of an appendage nearest the body, as opposed to distal.

**Pubescence**: short, fine, soft, erect hair or down.

**Pubescent**: downy; clothed with soft, short, fine, loosely set hair.

**Puncture**: a small impression on the cuticle, like that made by a needle.

**Quadrate**: four-sided.

**Recumbent**: lying down; reclining.

**Reniform**: kidney-shaped.

**Rugose**: wrinkled.

**Scabrous**: irregularly and roughly rugose; possessing short, sharp projections or wrinkles.

**Scape**: the first or basal segment of the insect antenna.

**Scutellar Shield**: exposed portion of the mesoscutellum which lies between the bases of the elytra.

**Scutellary striole**: a shortened stria or puncture row lying just laterad of the scutellum but not extending very far posteriorly.

**Scutellum**: posterior portion of mesotergum. Often referring only to that portion of the scutellum which is visible between the bases of the elytra (see Scutellar Shield).

**Secretory pore**: a pore that exudes a glandular secretion.

**Serrate**: sawlike, i.e., with notched edges like the teeth of a saw.

**Serrulate**: finely serrated; with minute teeth or notches.

**Seta (pl. setae)**: a sclerotized, hairlike (or scalelike) projection of cuticula arising from a single trichogen cell and surrounded at the base by a small cuticular ring.

**Sinuate**: wavy, applying specifically to edges and margins.
**Spine:** a multicellular, more or less thornlike process or outgrowth of the cuticle not separated from it by a joint.

**Subantennal groove:** groove or concavity lying below the antennal insertion and housing the base of the antenna. Placed between the eye (if present) and the mandibular articulation, and sometimes extends below or behind the eye.

**Subequal:** similar, but not equal in size, form or length.

**Subgenal ridges:** a pair of sharp longitudinal ridges extending from the maxillary articulations to the posterior region of the head and usually forming the lateral edges of a concavity. The subgenal ridges usually occur in conjunction with a strongly declined head and fit against the procoxae when the head is at rest.

**Sublateral:** just inside the lateral margin.

**Sublateral pronotal carina:** applied to various longitudinal carinae lying mesad of the lateral carinae. These may extend the length of the pronotal disc or be restricted to the posterior angles.

**Tarsal claw:** usually one of two articulated, sclerotized, claw-like processes attached to the apex of the tarsus. These claws and the empodium comprise the pretarsus.

Occasionally, there is a single claw or none at all.

**Tarsal formula:** the number of tarsomeres on the fore, mid, and hind tarsi, respectively.

**Tarsomere:** one of the divisions of the tarsus.

**Tarsus (pl. tarsi):** the fifth segment of the beetle leg, which is articulated proximally with the tibia and distally with the pretarsus; almost always subdivided into two to five tarsomeres.
Temple: the lateral portion of the head between the posterior edge of the eye and an abrupt narrowing of the head to form a posterior neck.

Testaceous: brownish-yellow

Tibia (pl. tibiae): the fourth and often the longest segment of the beetle leg, articulated proximally with the femur and distally with the first tarsomere.

Tibial spur: an articulated, multicellular, spur-like process located at the apex of the tibia; usually paired but occasionally single, and sometimes absent.

Tomentose: covered with a form of pubescence composed of short, matted, woolly hair.

Trochanter: the second segment of the beetle leg, articulated proximally with the coxa and distally with the femur; usually a relatively small sclerite and occasionally highly reduced or absent.

Trochantin: a precoxal sclerite articulating with the coxa, sternum and pleuron or sometimes fused to the pleuron or apparently absent.

Truncate: cut off squarely at the tip.

Tubercle: a small knoblike or rounded protuberance.

Variegated: of several colors in indefinite pattern.

Ventral (ventrad): an adjective (or adverb) denoting position near or movement toward the lower side of the body or a body part.

Vestiture: the general surface covering comprised of cuticular projections, e.g., setae, scales, or spicules.
APPENDIX E

USDA Legal Jargon for Chapter 1 – IroncladID.

Ironclad ID was developed and published by the Center for Plant Health Science and Technology (CPHST) as part of a cooperative agreement with the University of New Mexico (UNM). The tool and fact sheets are available from the following web address (last updated 05 June, 2011): http://coleopterasystematics.com/ironcladid/

The interactive identification key runs as a Lucid3 Java Applet. Please read the Lucid3 system requirements for information regarding operating systems, web browsers, and other software needed to run the key.

This key has been constructed for identifying all genera and species of Ironclad and Cylindrical Bark Beetles known to occur in North America north of Mexico. This key does not include taxa known to occur in Mexico. It is very possible (and likely) additional zopherid taxa have been and will be introduced into or discovered within North America. If you believe you have a specimen that does not properly key to a listed entity, please contact the key author.

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Taxonomy: It should be noted that no taxonomic or nomenclatural changes are proposed in Ironclad ID. We feel that an identification tool is not the appropriate outlet for such changes, and any inconsistencies herein are purely out of error, rather than an explicit taxonomic statement.
Suggested Citation: Lord, N.P, Nearns, E.H., and K.B. Miller. 2011-2013.

Ironclad ID: Tool for Diagnosing Ironclad and Cylindrical Bark Beetles (Coleoptera: Zopheridae) of North America north of Mexico. The University of New Mexico and Center for Plant Health Science and Technology, USDA, APHIS, PPQ.

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APPENDIX F
USDA Official Announcement of Tool Release for Chapter 1 – IroncladID.
Appendix F is available as a supplementary file via LoboVault. See PDF titled “Appendix_F_USDA_Announcement”.

APPENDIX G
Figure Captions and Figures for Chapter 2 – Illustrated Catalogue and Type Designations of the New Zealand Zopheridae (Coleoptera: Tenebrionoidea).
Appendix G is available as a supplementary file via LoboVault. See PDF titled “Appendix_G_Figures_Chapter2”.

APPENDIX H
Appendix H is available as a supplementary file via LoboVault. See PDF titled “Appendix_H_Figures_Chapter3”.

APPENDIX I
Figures for Chapter 4 – Novel Microscopy Techniques Reveal Multiple Evolutionary Origins of Metal Incorporation into Mandibles of the Megadiverse Beetles (Coleoptera).
Appendix I is available as a supplementary file via LoboVault. See PDF titled “Appendix_I_Figures_Chapter4”.

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APPENDIX J

ESEM EDS scans for Chapter 4 – Novel Microscopy Techniques Reveal Multiple Evolutionary Origins of Metal Incorporation into Mandibles of the Megadiverse Beetles (Coleoptera).

Appendix J is available as a supplementary file via LoboVault. See PDF titled “Appendix_J_Figures_Chapter4”.