

TAXONOMY, CLASSIFICATION, RECONSTRUCTED PHYLOGENY,
BIOGEOGRAPHY, AND NATURAL HISTORY OF NEARCTIC SPECIES OF
BRYCHIUS THOMSON (COLEOPTERA: HALIPLIDAE)

By

TONYA MOUSSEAU

A thesis
Submitted to the Faculty of Graduate Studies
In Partial Fulfillment of the Requirements for the Degree of

MASTER OF SCIENCE

Department of Entomology
University of Manitoba
Winnipeg, Manitoba
R3T 2N2

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FACULTY OF GRADUATE STUDIES

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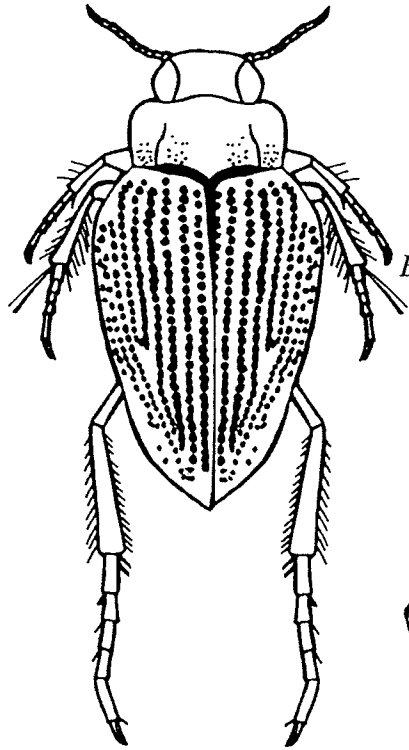
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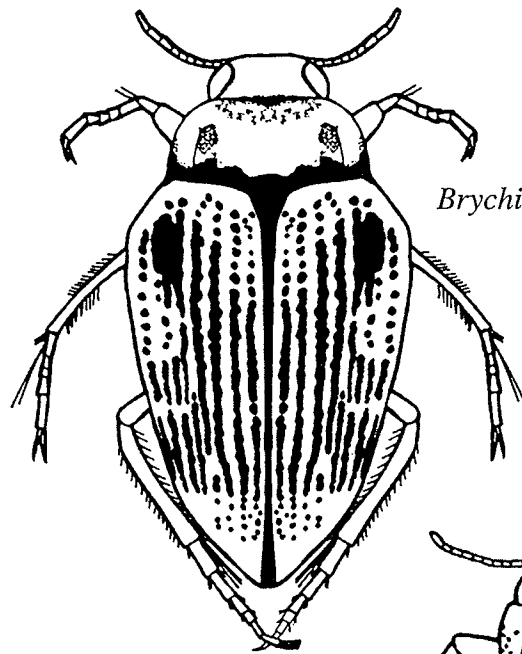
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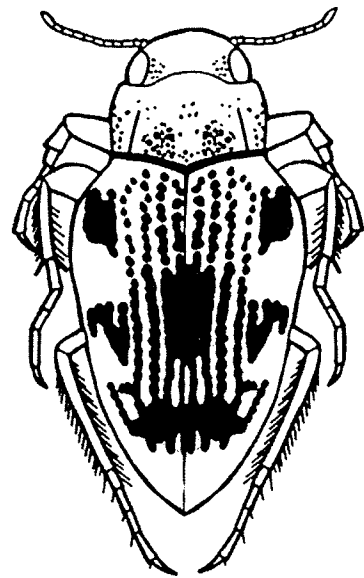
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Brychius hornii Crotch



Brychius hungerfordi Spangler



Brychius pacificus Carr

Frontispiece

Dedicated to my two loving grandfathers,
Bernie Mousseau (Pépère) and William Both (Opa),
who passed away during the time of this research.

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ABSTRACT

Tonya Mousseau, Department of Entomology, University of Manitoba, July 2004.
Taxonomy, classification, reconstructed phylogeny, biogeography, and natural history of
Nearctic species of *Brychius* Thomson (Coleoptera: Haliplidae).

The Nearctic species of *Brychius* Thomson 1859 (Coleoptera: Haliplidae) were revised by examining adult and larval specimens. There are three valid species in North America: *Brychius hornii* Crotch 1873, *Brychius pacificus* Carr 1928, and *Brychius hungerfordi* Spangler 1954. *Brychius albertanus* Carr 1928 is a junior subjective synonym of *Brychius hornii* Crotch 1873. Descriptions of adults and larvae (excluding *B. pacificus*), distribution data, and a key to adults are provided for all Nearctic species. From a reconstructed phylogeny of all species of *Brychius*, *B. hornii* + *B. hungerfordi* is the sister-group to the two European species, *Brychius elevatus* Panzer 1794 + *Brychius glabratus* Villa 1833. *Brychius pacificus* is the basal lineage. Because of limited dispersal capabilities, species of *Brychius* are thought to have arisen and diversified on Laurasia during the Jurassic Period. *Brychius hornii* and *B. hungerfordi* originated in the Tertiary Period before the advent of the Laramide orogeny, ca. 50 to 100 million years ago. Vicariance has played an important role in the present distribution, where species were once widespread in cool mountainous glacial streams, then became restricted to geographically isolated regions with the retreat of the glaciers and the extinction of intervening populations.

A population of *Brychius hornii* 1873 Crotch from the Duck Mountains, Manitoba was observed in the field and laboratory to gain insight into the biology and life history of

this group of crawling water beetles. Notes were made on the habitat, reproduction, pupation, life cycle, and behaviour of this population. The hydrology of a site seems to play an important role in the habitat requirements. Mating behaviour for *B. hornii* was observed in June and, although oviposition was not observed, eggs are thought to be laid in June/July. The larvae of *B. hornii* overwintered in the laboratory, buried in moist sand/soil. Pupation occurred in the laboratory in March with one adult emerging in May. The natural history of all species of *Brychius* is discussed in light of these new findings.

FOREWORD

This thesis is written in paper style. Chapter I contains a general introduction and Chapter II contains a review of pertinent literature necessary for understanding the overall body of research. Individual manuscripts (Chapters III and IV) are prepared for independent submissions to scientific journals. Chapter V contains a general discussion of the research contained herein.

CHAPTER I

GENERAL INTRODUCTION

The Haliplidae are currently classified as having five genera (Lawrence and Newton 1995) and 220 described species worldwide (Vondel 1995). Of these, 68 species occur in North America (Poole and Gentili 1996). The Haliplidae are grouped in the suborder Adephaga but are quite distinct from the other adephagan groups. The Haliplidae are easily recognized by their small size (body length less than 5mm), characteristic shape (body widest across humerus, elytra tapering posteriorly), colouration (lines of darkened punctures marked with various maculations against a light yellow to light reddish-brown colour), and the greatly expanded hind coxae, which is the defining feature of adults of the family. However, systematic studies are lacking on these beetles, perhaps due to their small size (2-5mm), the uniformity of structure, and lack of species-specific characters (Beutel and Ruhna 1990), but more likely because of their low economic importance. The classification, even at the generic level, is far from complete.

The genus *Brychius* was thought to be comprised of four species in the Nearctic Region (Crotch 1873; Carr 1928; Spangler 1954) and two species in the Palaearctic Region (Holmen 1987). There are very few reports of these species in the haliplid literature, and while Zimmermann (1924) produced a world revision, there have been no further attempts at a genus level revision.

The purpose of my thesis was to revise the Nearctic species of *Brychius* by

amending the existing taxonomy and classification, and providing information about the evolutionary history of the species. The objectives of the research were: 1) to determine species status for all known Nearctic populations of *Brychius*, 2) to provide keys for the identification of adults, 3) to reconstruct the phylogeny of the species, 4) to provide an explanation of their distribution and evolution, and 5) to gain information about the aspects of biology and life history of these species.

CHAPTER II

LITERATURE REVIEW

Taxonomic History of Haliplidae

The members of Haliplidae were first described as belonging to a single genus, *Haliphus* Latreille placed in the Hydrocanthares (Latreille 1806). They were later placed as a separate family (Aubé 1836). Currently, the Haliplidae is a unique, separate family (Lawrence & Newton 1995) with five genera: *Peltodytes* Régimbart, 1878, *Haliphus* Latreille, 1806, *Apteraliphus* Chandler, 1943, *Algophilus* Zimmermann, 1924, and *Brychius* Thomson, 1859.

The genus *Peltodytes* consists of 23 species occurring in the Americas, mostly in Canada and the United States (Roughley 2001). In the Nearctic Region, Matheson (1912) and Roberts (1913) produced information on a few species, and Zimmermann (1924) provided a world revision, treating 27 species. Since then, there has been little systematic work on the members of the genus (Young 1961; Satô 1963).

There are 56 species of *Haliphus* known for North and Central America (Roughley 2001). The latest revision of species of *Haliphus* in the Palearctic Region was by Zimmermann (1924). The most recent revision for the Nearctic species was by Wallis (1933). Since these two revisions, there have been many additional descriptions and synonymies of species (Mank 1940; Brigham 1977; Brigham and Sanderson 1972, 1973; Gunderson and Otremba 1988; Wells 1989; Ciegler 2003). Wallis (1933) recognized 41 species; however, there are now approximately 56 species known in North and Central

America (Roughley 2001).

The genus *Haliphus* has been divided into five subgenera: *Haliphus* s. str., *Neohaliphus* Netolitzky, 1911, *Haliplidius* Guignot, 1928, *Liaphlus* Guignot, 1928, and *Paraliaphlus* Wallis, 1933. Even though these subgeneric categories have been used in many important works in the family, they have also caused confusion. For instance, adults of *Haliphus minor* Zimmermann, 1924 and *Haliphus rugosus* Roberts, 1913 are not easily placed into any of the existing subgenera (Wallis 1933). Also, some species, such as *Haliphus laminatus* (Schaller, 1783), have adults that fit into one subgenus and larvae that fit into another (Vondel 1986). Because the present generic subdivision of the family appears paraphyletic, some of the subgenera may likely be raised to genera in the future (Holmen 1987).

Recent taxonomic studies on species of *Haliphus* and *Peltodytes* have tended to be more focused, regional work. These include the Pacific Northwest (Hatch 1953), California (Leech and Chandler 1956), North Dakota (Gordon and Post 1965), Maine (Malcolm 1971), Virginia (Matta 1976), Wisconsin (Hilsenhoff and Brigham 1978), North and South Carolina (Brigham *et al.* 1982), and Minnesota (Gunderson and Otremba 1988).

Apteraliplus and *Algophilus*, consist of a single species each. *Apteraliplus parvulus* Chandler, 1943 is known only from temporary, vernal pools and ponds from California, Oregon, and Washington (Brigham *et al.* 1982; Kitayama 1981; Zack 1991). *Algophilus lathridioides* Zimmermann, 1924 is found only in the Cape Province of South Africa (Zaitsev 1972).

The genus *Brychius* was thought to be comprised of four species in the Nearctic

Region (Crotch 1873; Carr 1928; Spangler 1954) and two species in the Palaearctic Region (Holmen 1987). There are very few reports of these species in the haliplid literature, and while Zimmermann (1924) produced a world revision, there have been no further attempts at a generic revision.

Taxonomic history of species of *Brychius*

Nearctic species

There are four described species of *Brychius* in the Nearctic Region: *Brychius hornii* Crotch, 1873, *Brychius albertanus* Carr, 1928, *Brychius pacificus* Carr, 1928, and *Brychius hungerfordi* Spangler, 1954. There are also accounts in the literature of possible undescribed species (Beutel and Ruhna 1990; Brigham 1978; Brigham *et al.* 1982; Matta 1976); however, these specimens have been examined here and have been determined as *B. hornii*.

Brychius hornii was first described by Crotch in 1873; however, the description is of limited use. This is because Crotch only described the colours of different structures and the placement of punctures, both being highly variable within a species. Matheson (1912) provided a more complete description of the external characters of *B. hornii*.

Throughout the literature and on museum specimen labels, there are numerous accounts of *B. hornii* written as *B. horni*. Zimmermann (1924) was the first to misspell *B. hornii* with one "i" and this is probably the source of the subsequent misspellings.

Brychius albertanus and *B. pacificus* were described by Carr in 1928. In his paper, he included a key to the three described species known at the time and provided a short description of these species. However, as with Crotch's description of *B. hornii*, the

key and descriptions include characters that are variable and difficult to evaluate. Some of these problems stem from Carr only having three specimens of *B. pacificus* to evaluate.

Brychius hungerfordi was described by Spangler in 1954. This description includes drawings of the left paramere and aedeagus, important structures in species determination in the Haliplidae. The larval stage was described by Strand and Spangler (1994), and this is the first description for any larvae of the Nearctic species of *Brychius*.

Palearctic species

According to the most recent authority (Vondel 2003), there are two species of *Brychius* that occur in the Palearctic Region: *Brychius elevatus* Panzer, 1794 and *Brychius glabratus* Villa, 1833. *Brychius elevatus* is found throughout most of Europe and extending east to central Siberia (Holmen 1987). *Brychius glabratus* has only been collected from northern Italy and Sardinia (Zaitsev 1972). Synonyms of *B. elevatus* include: *Brychius cristatus* Sahlberg, 1875; *Brychius rossicus* Semenow, 1898; *Brychius elevatus* ssp. *norvegicus* Münster, 1922; *Brychius elevatus* spp. *intermedius* Müller, 1908; *B. obenbergeri* Říha, 1953.

According to Zaitsev (1972), there are three species of *Brychius* in Europe: *B. elevatus*, *B. cristatus*, and *B. glabratus*. However, he does acknowledge that other authors (Münster 1922; Hellén 1923) consider *B. elevatus* and *B. cristatus* to be the same species. He also considered *B. elevatus* as perhaps consisting of a number of geographical forms (subspecies) which may be connected by transitional forms.

Zaitsev (1972) provided a key to separate adults of *B. elevatus* and *B. cristatus*.

He did not include *B. glabratus* in the key as he stated it has a very narrow distribution.

Brychius cristatus is found in the southern taiga (in the northern and central parts of Russia) and it forms a subspecies (*B. rossicus*), which connects it with *B. elevatus* (Zaitsev 1972).

Pearce (1930) stated that Zimmermann (1924) was correct in separating *Brychius elevatus* and *B. glabratus*, the latter species being distinct and restricted in distribution. Zaitsev (1972) also admitted that adults of *B. elevatus* differed more sharply from those of *B. glabratus* than from *B. cristatus*. I have also examined adult specimens of *B. elevatus* and *B. glabratus* and concur that they appear to be quite distinct based on external structural characters.

Classification of the Hydradeephaga

Coleoptera is comprised of four suborders: Archostemata, Myxophaga, Adephaga and Polyphaga (Lawrence and Newton 1995). The Adephaga and the Polyphaga were divided into suborders in the late 19th century, based on distinct structural differences of the metacoxae (Crowson 1955). Adephagan beetles historically have been divided into two groups (LeConte 1853). The terrestrial adephagan families are often termed the "Geadephaga", while the specialized aquatic families are often termed the "Hydradeephaga" (Holmen 1987). Hydradeephagan beetles are usually characterized by a hydrodynamically-shaped body and fringes of swimming hairs on their middle and hind legs (Crowson 1981).

The evolutionary relationships between the Hydradeephaga have evoked much discussion. Two primary questions gleaned from the literature are: 1) is Hydradeephaga

monophyletic, and 2) was the ancestor of the group aquatic or terrestrial?

The Hydradephaga may be polyphyletic (Figure 1). Bell (1965, 1966, 1967) was the first to propose that the Hydradephaga consists of three independent phyletic lineages of Gyrinidae, Haliplidae and the complex of dytiscoid families (Noteridae, Amphizoidae, Hygrobiidae and Dytiscidae), based on larval and adult structure. Throughout history, there have been numerous hypotheses suggesting the polyphyletic classification of the Hydradephaga (Table 1).

However, it is now thought that with the discovery of Aspidytidae, a new family in the Hydradephaga, the hydradephagan families are monophyletic (Ribera *et al.* 2002) (Figure 2). In this study, Aspidytidae is the sister group to Dytiscidae and Hygrobiidae. A single aquatic origin of the Hydradephaga is strongly supported by both a molecular and structural dataset, with very little conflict between the two.

The Gyrinidae appear to be unique within the Hydradephaga and have highly derived specializations for locomotion on the water surface. If the monophyletic view of the Hydradephaga is followed, Gyrinidae is basal to all other aquatic families (Ribera *et al.* 2002). If the polyphyletic view is followed, Gyrinidae is one of three independent invasions of the aquatic environment (Beutel 1995, 1997) and may be the sister group of the remaining Adephaga (Beutel and Roughley 1988) (Figure 1).

The Haliplidae also have unique structural and habitual characteristics that are completely different from those of Gyrinidae and the other hydradephagan families. The monophyly of the Haliplidae is supported by several synapomorphies. One synapomorphy is that they are the only Hydradephaga to have large metaxacoxal plates. These plates aid in respiration as an air storage space, as well as providing a hydrostatic

function (Hickman 1931a). A second synapomorphy is found in the mandibles of the larvae, which have unique sucking channels specialized for algal feeding (Matheson 1912; Hickman 1931b; Seeger 1971a).

In the past, members of the Haliplidae were thought to have ten-segmented antennae and this character was used to separate them from the rest of the Hydradeephaga. Species of Haliplidae have eleven-segmented antennae. The confusion of the ten segments was brought about by the length of the exposed part of the basal segment, which is very short in adults of haliplid species and very long in other species of Hydradeephaga. Furthermore, Zimmermann (1924) treated the basal bulb of this segment as independent and described the antenna as having twelve parts in the members of the Haliplidae.

Nonetheless, the members of the Haliplidae make up a distinct group of aquatic adephagans. It is debatable whether the members of the Hydradeephaga are a monophyletic or polyphyletic group. The relationships of the Haliplidae to the Adephaga may be clarified after an undescribed adephagan from South America, which has a number of haliplid-like features but lacks the enlarged metacoxal plates characteristic of this group, has been studied (P.J. Spangler, unpublished, in Lawrence and Newton 1995).

Classification of the Haliplidae

A phylogeny of the five genera of Haliplidae was provided by Beutel and Ruhнау (1990). In their interpretation, *Peltodytes* is the sister-group to the remaining taxa and *Brychius* is the sister-group to *Haliphus*, which includes the South African genus *Algophilus* and the Nearctic *Apteraliphus* (Figure 2).

Members of *Peltodytes* are quite different from the remaining genera. The larvae of species of *Peltodytes* breathe by means of long tracheal gills (Jaboulet 1960), whereas the larvae of species of *Brychius* and *Haliphus* breathe by means of microtracheal gills (Seeger 1971a). Microtracheal gills are a significant synapomorphy of Haliplidae, excluding *Peltodytes* (Beutel and Ruhnau 1990). These gills may be an advantage over the long gills of *Peltodytes*, perhaps for movement and concealment from predators. Synapomorphies of species of *Peltodytes* include a narrow, trapezoidal shape of the peristome, shallow maxillary fossae, and metacoxal plates covering all but the last abdominal sternites (Beutel and Ruhnau 1990).

Haliphus is not monophyletic; the genus is defined by pleisiomorphic characters or characters that also apply to other haliplid genera (Beutel and Ruhnau 1990). For example, *Haliphus* should include the South African species, *A. lathridioides* and the Nearctic species, *A. parvulus* (Beutel and Ruhnau 1990). *Algophilus lathridioides* and African species of *Haliphus* (*Liaphlus*) were also grouped together by Zimmermann (1924). A monophyletic group of *Algophilus*, *Apteraliphus*, and the *Haliphus*-subgenus *Liaphlus* is supported by the presence of two posterolateral ridges on the head, the presence of a digitiform appendage on the left paramere, and strong, dilated apodemes of the gonocoxae (Beutel and Ruhnau 1990).

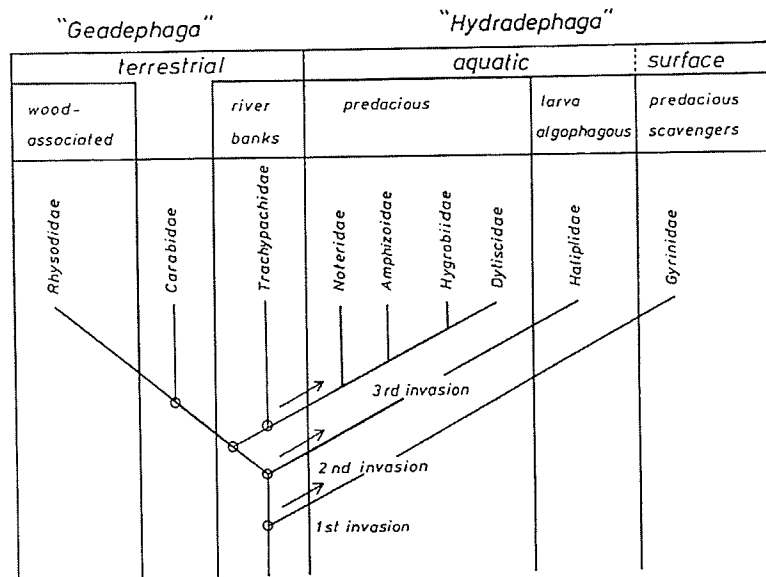
Brychius is a well-founded, monophyletic genus. Synapomorphies of adults of this group include an incision of the terminal abdominal sternite, flat and parallel-sided pronotum, long tarsal claws, and micropores on large areas of the body surface (Beutel and Ruhnau 1990). Synapomorphies of the larvae include mandibles with a truncated, spine-covered lobe, third antennal segment shorter than the second, and the urogomphus

curved at the apex. Members of *Brychius* are found in running water habitats and some of these characters show their adaptiveness to this constantly moving environment.

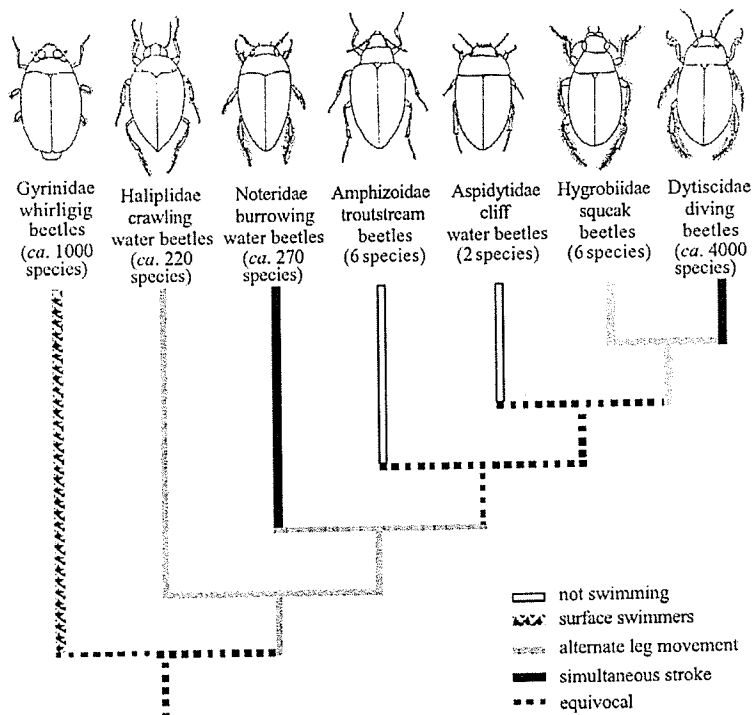
Table 1. The history of evolutionary hypotheses of Hydradephaga

Author	Date	Classification Hypothesis
Crowson	1960	Hydradephaga derived from Geadephaga as a result of a single invasion of the aquatic habitat, Trachypachidae a remnant of the Geadephagan group which gave rise to Hydradephaga.
Bell	1966	Hydradephaga represents three independent phyletic lineages of Gyrinidae, Haliplidae, and the complex of dytiscoid families.
Bell	1967	Trachypachidae are monophyletic with Dytiscoidea excluding Haliplidae and Gyrinidae.
Evans	1977	
Hammond	1979	
Crowson	1981	
Roughley	1981	
Bell	1982	
Evans	1982	Gyrinidae may have arisen from early Trachypachidae or a pretrachypachid stock.
Evans	1985	
Kavanaugh	1986	Origin of Adephaga from a semiaquatic common ancestor. Trachypachidae belong to the Caraboidea.

Ruhnau	1986	<p>Sister group relationship between the Trachypachidae and the Hydradephaga.</p> <p>Sister group relationship between the Gyrinidae and the Noteridae+Haliplidae.</p> <p>Sister group relationship between the Amphizoidae and the Hygrobiidae + Dytiscidae.</p>
Beutel and Roughley	1988	<p>Gyrinidae is the sister group of the remaining Adephaga.</p> <p>Trachypachidae as the sister group of Noteridae, Amphizoidae, Hygrobiidae, and Dytiscidae.</p> <p>Noteridae, Amphizoidae, Hygrobiidae, and Dytiscidae appear to be a well-defined monophyletic unit.</p>
Burmeister	1990	<p>Sister group relationship between Noteridae and Haliplidae, which form a monophyletic group with Gyrinidae.</p>
Beutel	1995	<p>Gyrinidae and Haliplidae are basal to the lineage comprising Trachypachidae, the dytiscoids and the Geadephaga.</p>
Beutel and Haas	1996	<p>Sister group relationship between Dytiscoidea (=Noteridae, Amphizoidae, Hygrobiidae, Dytiscidae) and Haliplidae</p> <p>Monophyly of Geadephaga (Trachypachidae + Caraboidea).</p>
Beutel	1997	<p>Haliplidae arose from terrestrial forms independently.</p>



a)



b)

Figure 1. Proposed phylogenetic hypothesis of members of the Hydradephaga: a) polyphyly of Hydradephaga (Beutel 1995); b) monophyly of Hydradephaga (Ribera *et al.* 2002).

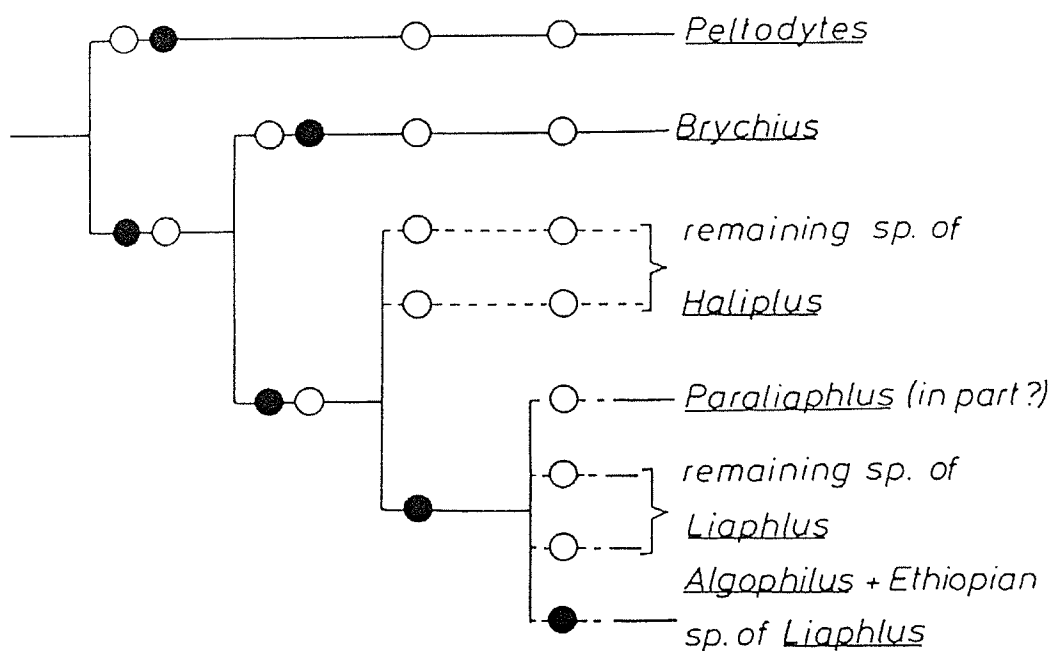


Figure 2. Cladogram of hypothesized evolution of members of Haliplidae; closed circles represent presence of apomorphic character states and open circles represent presence of plesiomorphic character states (Beutel and Ruhnau 1990).

CHAPTER III
TAXONOMY, CLASSIFICATION, RECONSTRUCTED PHYLOGENY AND
BIOGEOGRAPHY OF NEARCTIC SPECIES OF *BRYCHIUS* THOMSON
(COLEOPTERA: HALIPLIDAE).

Abstract

The Nearctic species of *Brychius* Thomson, 1859 (Coleoptera: Haliplidae) were revised by examining adult and larval specimens. *Brychius albertanus* Carr, 1928 is a junior subjective synonym of *Brychius hornii* Crotch, 1873. Descriptions of adults and larvae (excluding *B. pacificus*), distribution data, and a key to adults are provided for all Nearctic species. From a reconstructed phylogeny of all species of *Brychius*, *B. hornii* + *B. hungerfordi* is the sister-group to *Brychius elevatus* Panzer, 1794 + *Brychius glabratus* Villa, 1833; and these combined are the sister group to *Brychius pacificus* Carr, 1928. Species of *Brychius* are hypothesized to have arisen and diversified on Laurasia during the Jurassic Period. *Brychius hornii* and *B. hungerfordi* originated in the Tertiary Period before the formation of the Rocky Mountains, ca. 50 to 100 million years ago. It is thought that vicariance has played an important role in the present distribution, where species were once widespread in cool mountainous glacial streams, then became restricted to geographically isolated regions with the retreat of the glaciers and the extinction of intervening populations.

Introduction

The genus *Brychius* Thomson, 1859 is Holarctic in distribution, with three species in North America and two species in Europe. Research on this group of crawling water beetles has been minimal, consisting of short descriptions, brief references to localities, and a few preliminary biological observations.

There are four species of Nearctic *Brychius* described in the literature: *Brychius hornii* Crotch, 1873, *Brychius albertanus* Carr, 1928, *Brychius pacificus* Carr, 1928, and *Brychius hungerfordi* Spangler, 1954. In Carr's (1928) paper, he included a key to the three species known at that time, and provided a short description of them. However, these descriptions, and the one provided by Crotch in 1873, are of limited use, as the characters used for determination are variable and difficult to evaluate. This study, in part, was conducted to find informative characters to be used for species delineation.

Since Carr (1928) published his key to the Nearctic species of *Brychius*, no revisional work has been done regarding the genus worldwide. As there has been confusion regarding the identification and variation in these species, a revision of this group was necessary.

This research involved the examination of adults and larvae of Nearctic species of *Brychius* in an attempt to understand specific limits and distribution. Descriptions of adults and larvae, distributional data, and a key to adults are provided for all Nearctic species. Figures are provided for larvae of *B. hornii* (instars II and III) and *B. hungerfordi* (instar III). The leg chaetotaxy is compared between the two instars of *B. hornii*, between species of *Brychius* and between the genera of Haliplidae using Nilsson's (1988) work on *Haliphus lineolatus* Mannerheim, 1844, for comparison. A multiple

discriminant analysis was conducted on adult structural character measurements. A phylogeny was reconstructed for all species of *Brychius* and used to explain the present distribution of this group.

Materials and Methods

Specimens Examined

Descriptions of form and structure, taxonomic conclusions, geographical distributions, and other findings reported here are based on examination of adult and larval specimens of Nearctic species of *Brychius*. Specimens were initially separated according to geographic area (provincial region or county). A complete structural analysis of the specimens was then undertaken. The type material were examined for all Nearctic species. The number of specimens examined were as follows: *B. hornii* adults-1840, larvae 56; *B. hungerfordi* adults-113, larvae 12; *B. pacificus* adults-152.

Specimens examined were obtained from the following collections and individuals:

AMNH	American Museum of Natural History, New York, New York, U.S.A . 10024-5192; Lee Herman.
BYUM	Monte L. Bean Life Science Museum, Brigham Young University, Provo, Utah, U.S.A. 84602; Richard Baumann.
CAS	California Academy of Sciences, San Francisco, California, U.S.A. 94118; David Kavanaugh, Roberta Brett.
CNC	Canadian National Collection of Insects, Agriculture and Agri-Food Canada, Ottawa, Ontario, Canada K1A 0C6; Yves Bousquet, Anthony

Davies.

- CU Cornell University Insect Collections, Ithaca, New York, U.S.A. 14853;
Richard Hoebeke.
- DJLC David J. Larson, Department of Biology, Memorial University, St. John's,
Newfoundland, Canada A1B 3X9.
- EMEC Essig Museum of Entomology, University of California, Berkeley,
California, U.S.A. 94720; Cheryl Barr.
- FMNH Field Museum of Natural History, Chicago, Illinois, U.S.A. 60605-2496;
Philip Parrillo.
- INHS Illinois Natural History Survey, Champaign, Illinois, U.S.A. 61820-6970;
Colin Favret.
- JBWM J.B. Wallis Museum, Department of Entomology, University of Manitoba,
Winnipeg, Manitoba, Canada R3T 2N2; Robert E. Roughley.
- LACM Los Angeles County Museum of Natural History, Los Angeles, California,
U.S.A. 90007; Weiping Xie.
- MCZ Museum of Comparative Zoology, Harvard University, Cambridge,
Massachusetts, U.S.A. 02138; Philip Perkins.
- NHMV Naturhistorisches Museum Wien, Vienna, Austria A-1014; Manfred Jäch.
- NMNH National Museum of Natural History, Smithsonian Institution,
Washington, DC, U.S.A. 20013-7012; Warren Steiner, Jr.
- RBCM Royal British Columbia Museum, Victoria, British Columbia, Canada
V8W 9W2; Rob Cannings.
- SMDV Spencer Entomological Museum, Department of Zoology, University of

British Columbia, Vancouver, British Columbia, Canada V6T 1Z4; Rex Kenner.

UASM Strickland Museum, University of Alberta, Edmonton, Alberta, Canada T6G 2E9; Danny Shpeley.

UCRC Entomology Research Museum, University of California, Riverside, California, U.S.A. 92521-0314; Doug Yanega.

UMAA Museum of Zoology – Insect Division, University of Michigan, Ann Arbor, Michigan, U.S.A. 734-764-0471; Mark O'Brian.

UWIRC University of Wisconsin Insect Research Collection, Madison, Wisconsin, U.S.A. 53706-1598; Steven Krauth.

WSU The James Entomological Collection, Washington State University, Pullman, Washington, U.S.A. 99164-6382; Richard Zack.

Specimens that were field-collected during this study are deposited in the JBWM and CNC.

Preparation of Specimens

Adults

Adult specimens were best examined when properly dried and glued to triangular pieces of stiff white paper (points). It was noticed that specimens that had been stored in ethanol for several years tended to remain a darker colour after drying and pointing. For examination of male genitalia, dried specimens were first cleaned and relaxed by placing them in an ultrasonic cleaner (KOH-I-NOOR 25K42®), filled with hot water and detergent, for approximately ten minutes. The detergent also helped to clean the beetles

of any accumulated dirt and oils on the cuticle. Once relaxed, fine forceps were used to extract the genital capsule through the genital opening in the last abdominal segment. After removal, genitalia were either placed in a microvial with glycerin or glued to a small white card. Genitalia preparations were then placed on the same pin as the adult specimen. If the genitalia were glued to a card, the parameres were separated from the aedeagus before mounting for unobstructed views of each.

Larvae

Larval specimens were killed and stored in 70% ethanol. Representative whole larvae were glycerinated using the technique of Goulet (1977). Descriptions and illustrations for the larvae are based on second and third instars, which were discriminated based on overall size and the presence of spiracles on the mesothorax (third instar). Slide preparation of larval specimens followed Richards (1964) and was as follows:

1. Larval specimens were cleared in 10% KOH in a warming oven for approximately three hours. It was found that if the larvae were cut in half crosswise before placing in KOH, the inner tissue would clear faster and easier, and allow for the slide cover to be placed over the specimen with greater ease. There seemed to be a problem with larval specimens of *B. hornii* collected by D.L. Gustafson in 1988; the muscles would not clear in KOH after two days. Even though the specimens were stored in a vial of ethanol, it is possible they had been placed in formalin before being placed in ethanol, inhibiting the clearing process.

2. Specimens were then placed in lactophenol for approximately 16 hours in a warming oven.
3. Specimens were placed in KOH for two hours in a warming oven to remove the lactophenol.
4. Specimens were placed in a solution of one part glacial acetic acid and one part oil of wintergreen for 24 hours.
5. Specimens were then placed in a solution of one part cedarwood oil, one part oil of lilac, two parts of oil of wintergreen and one-half part glacial acetic acid for 24 hours.
6. Specimens were then dissected on a slide. The head capsule, mouthparts, legs, and urogomphus were separated for examination and illustration.
7. Specimens were mounted on slides with Canada balsam

Slide specimens are placed in the J.B. Wallis Museum.

Chaetotaxy

The larval legs of *B. hornii* (instars II and III) and *B. hungerfordi* (instar III) were examined for sensilla and other structures. I compared first instar larvae of previously described adephagan groups (Nilsson 1988; Bousquet and Goulet 1984) to infer whether a sensillum was ancestral or additional. The homologous ancestral seta χ on the coxa, trochanter, femur, tibia, and tarsus are referred to as CO_{χ} , TR_{χ} , FE_{χ} , TI_{χ} , and TA_{χ} . The additional setae are designated as $CO_{*\chi}$, $TR_{*\chi}$, $FE_{*\chi}$, $TI_{*\chi}$, and $TA_{*\chi}$.

Positions of single sensilla and rows of spinulae are indicated with the following symbols (modified from Wolfe and Roughley 1985): A, anterior; D, dorsal; Di, distal; P,

posterior; Pr, proximal; and V, ventral. The following sensilla and other structures were observed: 1) setae; 2) campaniform sensilla; 3) spinulae (nonsocketed cuticular structures often occurring in groups).

Drawings and Photographs

Photomicrographs were taken using a Nikon® 9500 digital camera placed over the eyepiece of a Leica® MZ8 dissecting microscope.

Line drawings were prepared by first pencil sketching the figure using either a Wild Leitz dissecting microscope or a Leitz® compound microscope, both fitted with a camera lucida. The pencil drawings were then inked, scanned, and imported into Adobe Photodeluxe™ for further digital processing.

Quantitative Analysis

Length and width measurements were obtained by measuring 24 external structural features on adults of species of *Brychius* (Table 2, characters 1-24). Specimens of *B. hornii* were measured from Creston, BC; Fort McMurray, AB; Cypress Hills, AB; Cowan MB. Specimens of *B. hungerfordi* were measured from Pellston, MI and Scone, ON. Specimens of *B. pacificus* were measured from Orick, CA.

Measurements were taken using a 20 x 20 square ocular reticule on a Wild M-5 stereomicroscope. The effect of parallax was taken into account by counting a measurement only when both ends of the structure were in sharp focus. All measurements are presented in millimeters.

The number of specimens measured for each sex, at each locality was 20;

however, only three females and two males could be measured from Fort McMurray, AB, and two females and three males from Cypress Hills, AB. Specimens were selected to represent the maximum size range at each locality. Two ratios that express pronotal dimensions and size relative to the body were added to the analysis (Table 2, characters 25-26).

Phylogeny

In order to determine the hypothetical relationships among species of *Brychius*, cladistic methods were used. This method of reconstructing relationships of organisms is discussed by Hennig (1966), Kavanaugh (1972) and Wiley (1981). In order to carry out the phylogenetic analysis, polarities of character states were determined using out-group comparison.

To determine the choice of out-group, a taxon should be "related" to the in-group (Watrous and Wheeler 1981). Beutel and Ruhna (1990), in a preliminary reconstructed phylogeny of the Haliplidae, suggested that *Haliphus* is the sister-group to *Brychius*, and *Peltodytes* is the basal lineage. However, because this work was preliminary, I decided to use an out-group composed of both genera. *Haliphus immaculicollis* Harris, 1828 was chosen as a representative for the genus *Haliphus*. Because this species is probably the most common haliplid found across North America, this will allow subsequent researchers to have adequate specimens for additional phylogenetic research. *Peltodytes edentulus* (LeConte, 1863) was chosen for the genus *Peltodytes*.

In this study, the majority of structural characters used to determine phylogenetic relationships were from adults. This was because: 1) larval specimens of *B. pacificus* and

B. glabratus were not available for study; 2) with only few larval specimens of *B. hornii*, *B. hungerfordi*, and *B. elevatus*, I was not confident regarding the variation in certain structures. The characters used are listed below (0, 1, and 2 are used as coding to distinguish between character states- 0 usually indicates an absence, 1 and 2 usually indicate presence).

1. Mandible, right: (0) one apical tooth; (1) two apical teeth.
2. Mandible, right: (0) no spines on basal projection; (1) few small spines on basal projection; (2) many distinct spines on basal projection.
3. Maxilla, apical segment of galea: (0) lateral margins smooth; (1) lateral margins with irregularities.
4. Labium, penultimate segment of labial palp: (0) lateral margins smooth; (1) lateral margins sinuate.
5. Labium, base: (0) square; (1) rectangular; (2) rounded.
6. Pronotum, in lateral view: (0) no impression; (1) basal transverse impression.
7. Pronotum, lateral margins: (0) no serration; (1) serration.
8. Pronotal process, anterior lateral margins: (0) no margins; (1) thick margins.
9. Prosternal process, anterior lateral margins: (0) parallel; (1) wedge-shaped.
10. Metasternum, lateral view of ventral margin: (0) not impressed; (1) impressed.
11. Metasternal process: (0) no impression; (1) large anterior median impression.
12. Metasternal process: (0) no foveae; (1) two median foveae.
13. Elytra: (0) no raised ridges; (1) raised longitudinal ridges.
14. Elytra, humeral region: (0) rounded; (1) angled.
15. Elytra, humeral margins: (0) no serration; (1) serration.

16. Elytra, apex: (0) rounded; (1) acute.
17. Aedeagus, median lobe: (0) rounded apex; (1) slender, pointed apex.
18. Aedeagus, hood lobe: (0) attached to median lobe; (1) detached to median lobe.
19. Abdomen, apical sternite: (0) blunt; (1) long, sharp point.
20. Pro-thoracic leg: (0) no spines along ventral margin; (1) spines along ventral margin.
21. Terminal abdominal sternite: (0) no incision; (1) incision.
22. Pronotum: (0) lateral margins not parallel; (1) lateral margins parallel.
23. Tarsal claws: (0) shorter than length of tarsomeres 2 and 3; (1) longer than length of tarsomeres 2 and 3.
24. Larval antennal segment 3: (0) longer than segment 2; (1) shorter than segment 2.
25. Larval urogomphus: (0) straight; (1) curved.

Character analysis was performed using MacClade® (Version 3.08). Parsimony analysis was performed using PAUP® (version 3.1) software. An exhaustive search method was used. All characters were unordered. Bootstrap values were obtained for the dataset using a Branch and Bound search method at 1000 and 10 000 replicates.

Distribution

Distribution maps and locality records are based on specimens examined. In the list of localities of specimens examined (Appendix 1, 2, and 3), adults and larvae are listed separately under the state or province. The following information is listed: country, state or province, county (or equivalent), locality, date, collector, other label information, number of specimens from that locality (male, female or example), and the acronym of

the collection from which the specimens were borrowed. In most cases, the information was recorded as it appeared on the label. For type specimens, I have enclosed abbreviated notes in square parentheses regarding the actual label. For instance, [hw] indicates the label was handwritten, [tw] indicates typewritten, [red] indicates the label paper was red, and [yellow] indicates the label paper was yellow.

Species Treatments

Structural characteristics of adults, second instar (*B. hornii*), and third instar larvae (*B. hornii* and *B. hungerfordi*) of species of *Brychius* are given in the descriptions. For each species treatment, the following are provided: citation of the valid species epithet; taxonomic references; information on the type specimen and other taxonomic notes; a diagnosis, consisting of distinctive characters; description of adult and larva; distribution.

Taxonomic characters and terms

Adults

Head. – Colour of the head varied from light yellow to brown, some specimens with an infuscate band at the base. The width between the eyes is a diagnostic character in species of *Haliphus* (Wallis 1933); however, no differences were found among species of *Brychius*. Colour of the eyes has been used in the past to differentiate species of *Brychius* (Crotch 1873; Carr 1928); however, specimens examined have many eye colours, such as silver, black, and brown, with one individual even having bright green eyes.

Mouthparts. – The mandibles (Figure 2) show differentiation with the apical tooth, and the shape and length of the retinaculum. As well, the amount of setae on the basal truncated lobe can be used to differentiate species. The maxilla (Figure 3) has a curved lacinia with long spines along the inner edge, and a long, two-segmented galea, the shape of which is distinct for each species of *Brychius*. The labium (Figure 4) has a large, varying-shaped, lobate mentum. The labial palps are three-segmented, the penultimate having ridged margins in *B. hornii*, and a distinct palpiger attached to the ligula.

Pronotum. – Colour of pronotum varied from light yellow to dark brown, with a basal, black band of variable width. This band is useful in recognition of specimens of *B. hungerfordi* because it extends to the middle of the plicae, forming a wide band. The pronotum is widest in adults of *B. hungerfordi*.

Elytron. – Colour of elytra varied from light yellow to dark brown. Elytron with ten rows of large, blackened punctures (Figures 5, 6). Pattern of maculation is distinct in specimens of *B. hungerfordi* (three lateral spots) and *B. pacificus* (three lateral spots and one large medial spot); however, individuals in each of these species may deviate from this pattern. Also, specimens of *B. hornii* vary greatly in elytral maculation and individuals may display patterns similar to the other two species.

Hind Wing. – Labeling of the venation of the hind wing follows Franciscolo (1979). Wing venation is distinct among the species of *Brychius* (Figure 7).

Ventral surface. – The shape and length of the prosternal process [referred to as the prosternal apophysis by Holmen (1987)], varied significantly among species (Figure 8). The abdominal sterna were quite uniform among species and no important identifying

characters (except on the apical sternite) could be found.

Legs. – The front and middle legs are unmodified. Rows of spines and swimming hairs, especially on the tibiae and tarsi, are of diagnostic importance.

Female Genitalia. – Two taxonomic characters of the female genitalia are used. The abdominal segment VIII located on the dorsal surface varies in the shape of the lateral margins (Figure 12). The gonocoxae are paired “genital valves” (Holmen 1987), which are flattened and triangular (Figure 13).

Male Genitalia. – The male genitalia of haliplids consist of the aedeagus and two lateral parameres. There are a number of lobes on the distal part of the aedeagus (Balfour-Browne 1915) (Figure 14), the shapes of these being distinct in different species of Haliplidae (Holmen 1987).

The aedeagus of species of *Brychius* is asymmetrical, laterally compressed, and the apex has a pronounced, dorsal swelling before the apical third. The aedeagus has three main lobes. The first is the median lobe, the main and most prominent structure of the aedeagus (Figure 14). The second lobe is an operculum (referred to as the tongue by Balfour-Browne (1915)) in the form of a long structure on the dorsal side (Figure 14). This lobe fits into a depression called the sperm groove (Holmen 1987) or ejaculatory duct (Zaitsev 1972). The third lobe is a large structure protruding from near the base and lying against the median lobe. This seems to be analogous to the hood (Balfour-Browne 1915) in other haliplids (Figure 14). The form of the hood lobe is an important taxonomic structure in species of *Brychius* and *Haliphus*.

The parameres are asymmetrical; the left paramere is larger and more strongly differentiated, the outer side convex and inner side concave (Figure 16). The left

paramere also has a stylus-like extension [referred to as the digitus by Brigham and Sanderson (1972)]. The right paramere is rounded, always convex dorsally and concave on the inner margin (Figure 17). Both parameres, especially the left, are covered with hairs in the form of a fringe on the ventral margin.

Sexual Dimorphism. – Adults of species of *Brychius* possess at least two sexually dimorphic characters, other than those of the male and female genitalia: 1) female specimens, on average, are larger than males of the same species; and 2) male specimens have short, dense setae on tarsal segments 1-3 on the prothoracic and mesothoracic legs, these setae are absent in females.

Larvae

Head. – The head capsule has a pronounced sinuate lateral margin. The sinuation varies among species. The width of the head capsule is also an important diagnostic feature.

Mouthparts. – The mouthparts appear to be similar in *B. hornii* and *B. hungerfordi*.

Thorax. – The pronotum, mesonotum, and metanotum each with a large, subrectangular tergum. The length of this tergum extends past the pleuron and is longer in specimens of *B. hungerfordi* than in *B. hornii*.

Abdomen. – Tergal and sternal sculpture is similar in both species. Urogomphus with more sclerites and curvature more pronounced in those of *B. hungerfordi*.

Legs. – Each leg bears one terminal claw. The legs have a number of spines, which are distinct between species and between instars II and III of *B. hornii*. The legs do not have natatorial hairs.

Classification

Genus *Brychius* Thomson, 1859

C.G. Thomson, 1859: 11
Matheson, 1912: 161
Roberts, 1913: 94
Rousseau, 1919: 271
Zimmermann, 1924: 65
Scholz, 1929: 6
Csiki, 1946: 555
Guignot, 1947: 37
Zaitsev, 1972: 37
Franciscolo, 1979: 71
Holmen, 1987: 84
Roughley, 2001: 141

Type species: *Dytiscus elevatus* Panzer, 1794 [= *Brychius elevatus* (Panzer, 1794)].

Diagnosis

Adults are easily recognized by the elongate, narrow outline of the body.

Pronotum quadrate, lateral margins sinuate; widest point slightly anterior of middle.

Well-marked basal impressions (plicae) present, reaching beyond middle of pronotum.

Each elytron marked with ten rows of punctures. Tarsi five-segmented, long and slender; claws long, almost as long as fourth tarsal segment.

Larvae are recognized by having the third antennal segment shorter than the second, and a slender, curved urogomphus.

Description

Adults

Body. – Total body length 3.0-4.4 mm; maximum body width 1.56-2.24 mm.

Shape fusiform, elongate. Colour light yellow to dark brown. Surface moderately shining, with larger punctures and distinct fine micro-punctuation. Elytron with ten longitudinal black rows of coarse punctures; distinct blotches of maculation on certain species.

Head. – Small, about two-thirds width of pronotum at base, somewhat retracted into prothorax, dorsally convex, surface punctate, without setae except for long setae on labrum. **Eyes** somewhat protruding (in dorsal view), moderately convex, outline infusate but not emarginated. **Antennae** with 11 glabrous antennomeres; antennomeres 1 (scape) and 2 broad and short, remainder filiform; antennomeres 3-11 of increasing length and slightly longer than wide, nearly uniform in width, inserted between the anterior portion of the eyes, well above base of mandibles; apical antennomere ending in a tapered point.

Mouthparts. – **Labroclypeus** transverse and narrow, shallowly emarginated, rounded at sides with long setae on anterior margin, covering most of mandibles. **Mandibles** small and robust, asymmetrical, with an apical tooth; retinaculum with a mesal comb or brush of setae. **Maxilla** short, broad, lacinia having spines along inner margin and an elongate, two-segmented galea; maxillary palp three-segmented with a basal palpiger. **Labium** subquadrate, with small anterolateral lobes; ligula present and small but extending between bases of labial palps; labial palpus short, moderately stout, three-segmented with a basal palpiger; apical segment of maxillary and labial palps triangular, shorter and narrower than penultimate segment. Mentum about half as wide apically as basally.

Pronotum. – Rectangular, posterolateral margins parallel, anterolateral margins

slightly indented; basal plicae very long, more than half length of pronotum, a transverse depression of various degrees at base between the two plicae; pronotum margined laterally. Anterior margin with a weak indentation laterally, slightly projecting anteriorly in the middle.

Elytron. – Fusiform, slightly broader anteriorly than base of pronotum, gradually broadening to middle and tapering toward apex, with an acute sutural angle. Colour light yellow to brown. Posterolateral margins finely serrate. Elytron with ten rows of black, well-marked punctures, though some may be strongly abridged or confluent forming maculation; rows five and six short and fused approximately mid-length; epipleuron wide apically and long, reaching at least to middle of last sternite.

Hind Wing. – Membranous, hyaline, well developed. Venation is of adephagan type, in which the M4 originates from Oblongum Cell; Oblongum Cell circular; M4 originates close to M3 (Holmen 1987). Wing folding of adephagan type, with the cubital hinge not very far removed from Oblongum Cell (Holmen 1987).

Ventral surface. – **Prosternal process**, in posterior half, bordered laterally by raised lines or carinae. **Metasternal process** between middle coxae very broad. **Metasternum** coarsely and sparsely punctate laterally, with deep foveae laterad of middle coxae. **Antecoxal piece** coarsely punctate laterally, finely and sparsely punctate medially. **Metacoxal plates** broad, without lateral margin, reaching only to posterior margin of abdominal sternite 4, lateral margin diverging from inner margin of the epipleuron; coarsely punctate laterally, becoming less punctate towards coxal suture. Last **abdominal sternite** with a noticeable slit, medially extending posteriorly from the apex, more than half length of segment and pointed apically.

Legs. – **Coxa** rounded. **Trochanter** smooth, without spines. **Femur** with small spines on ventral side with natatorial hairs. **Tibia** with spines on dorsal and ventral sides, two large spines at apex. **Tarsus** with five segments; pretarsus consisting of two long claws; almost as long as tarsal segment 4.

Larvae

Body. – Total length 5 mm (instar II), 10-12 mm (instar III). Shape elongate and subcylindrical. Surface not darkly pigmented but heavily sclerotized, dorsal and ventral surface with small tubercles or microtracheal gills. Colour pale yellowish white to yellow/reddish brown; frequently covered with dark organic material and/or strands of filamentous algae.

Head. – Prognathous; semi-circular, moderately compressed dorsoventrally, broader than long; surface granular and uneven, with spinules at the anterior margin. Six black stemmata on each side of head; all stemmata clustered directly behind antenna. **Antenna** short, four-segmented; antennomere 3 shorter than 2, antennomere 4 reduced, with a long seta; seta almost three times as long as segment; an additional, shorter and narrower, bare, ventral appendage (referred to as antennal appendix by Strand and Spangler 1994) contiguous with the fourth segment.

Mouthparts. – **Labrum** reduced and fused to head capsule. **Clypeus** small and pointed. **Labium** subquadrate, with minute ligula. Labial palp short, two-segmented. **Mandible** short, without mola, a distinct apical tooth enclosing the external opening of the feeding/suctorial channel; inner margin of mandible with spinules at base. **Maxilla** short and broad, cardo small and more or less fused to stipes.

Thorax. – Sclerotized plates on dorsal and ventral surfaces. Mesosternum with pair of anterolateral spiracles in instar III. Pronotum, mesonotum, and metanotum each with a large, subrectangular tergum. Terga densely covered with spine-like asperities. Pleural areas membranous. Prosternum with a presternite, an anterolateral episternum, and a posterolateral epimeron. Mesosternum and metasternum each with episternum and epimeron.

Abdomen. – Ten-segmented; segments 1-9 each with a single rectangular or subquadrate tergum and sternum. Tergal and sternal sculpture similar to sculpture on thoracic sclerites. Asperities along posterior margins of segments sparse except four dense clusters; one at posterolateral angle of each tergum and one on each side of midline. Segments 1-8 each with a lateral spiracle near midlength in pleural area. Rudimentary spiracle on segment 8. Segment 10 consisting of basoventral anus surrounded by small sclerites and a long, curved siphon-like urogomphus.

Legs. – Short and robust; five-segmented with tarsus bearing one long claw; natatory setae absent; prothoracic legs moderately chelate, much shorter than middle or hind legs, femur on pro-leg of some species modified ventroapically to form a grasping apparatus opposing the claw.

Key to the adults of Nearctic species of *Brychius*

1. Prosternal process constricted at the level of procoxae, gradually widening posteriorly to apex making the anterior lobe distinctly wedge-shaped (Figure 8c); last abdominal segment with blunt point; hood lobe of aedeagus truncated, a deep distinct channel separating it from the median lobe (Figure 15c).....

-*Brychius pacificus* Carr
- Prosternal process constricted at the level of procoxae, nearly parallel to apex
(Figures 8a, b); last abdominal segment with long sharp point; hood lobe of
aedeagus rounded, not distinctly separated from the median lobe.....2
2. Humeral margin of elytron with serrations; large specimens, total length 3.7-4.4
mm; aedeagus with apex of median lobe long and slender, narrowing at the tip;
hood lobe pointed (Figure 15b)*Brychius hungerfordi* Spangler
- Humeral margin of elytron without serrations; total length 3.0-3.8 mm; aedeagus
with curvature of the median lobe not pronounced, apex rounded and the hood
lobe small, laying almost against the median lobe (Figure 15a).....
-*Brychius hornii* Crotch

Species Treatments

BRYCHIUS HORNII CROTCH

Brychius hornii Crotch, 1873: 383.

Matheson, 1912: 161.

Zimmermann, 1924: 19. (misspelling)

Carr, 1928: 25.

Brychius albertanus Carr, 1928: 23 NEW SYNONYMY

(Figures 1a; 2a,d; 3a; 4a; 5a; 6a; 7a; 8a; 9a; 10a; 11a; 12a; 13a; 15a; 16a; 17a; 18a; 19a;
20a; 21-27).

TYPE MATERIAL: *Brychius hornii*: **Lectotype**: Male – “Cala.”, “Horn Coll / H 1217”,

“*Brychius hornii* Cr.” [hw] (MCZ). **Note**: There is another specimen that has been

labeled as the type of *B. hornii*: Female – “B. Col [tw]/ BC [hw]”, “F. symbol”, “Type /

7384” [red], “*Brychius Hornii* Cr” [hw] (MCZ). This specimen does not match the type

locality. It is unclear as to who put the type label on this specimen, but it was assigned in

1933/1934, from the LeConte Collection. In Crotch's original description, there are no type designations, only the type locality –California– is mentioned. The specimen labeled "Cala", which came to the MCZ in 1972 from the Horn Collection, fits Crotch's description and type locality, and has the likeness of Crotch's handwriting on the determination label, therefore I am designating the California specimen as the lectotype.

Brychius albertanus: **Holotype**: Male – "TYPE" [red], "So. Fork. / Alta 27.VIII.26 / F.S. Carr", "HoloTYPE / Brychius / albertanus / Carr / No. 2634" [red], "Brychius / albertanus / Carr / Type / ex coll. F.S. Carr" [white label w/ black trim]. **Paratypes**: Female – "M. symbol", "Beaver Cr. / Alta 22.v.26 / F.S. Carr" [hw], "PARATYPE / Brychius / albertanus / Carr / No. 2634" [yellow], "Paratype" [red, hw], "Brychius / albertanus / Carr / Paratype / ex coll. F.S. Carr" [white label w/ black trim], "Brychius horni [sic] / Crotch / det. GL. Daussin", "HT specimen / retained in CNC" [white label w/ black trim] (CNC). Male – "So. Fork Riv. / Alta. 22.VIII.26 / F.S. Carr" [hw], "Paratype" [red, hw], "Brychius / albertanus / Carr / Paratype / ex coll. F.S. Carr" [white label w/ black trim], "Brychius horni [sic] / Crotch / det. GL. Daussin" (UASM). Male – "Beaver Cr. / Alta 26.VIII.26 / F.S. Carr" [hw], "Paratype" [red, hw], "Brychius albertanus / Carr / Paratype / ex coll. F.S. Carr" [white label w/ black trim], "Brychius horni [sic] / Crotch / det. GL. Daussin" (UASM). Female – "F. symbol", "Beaver Cr. / Alta 22.v.26 / F.S. Carr" [hw], "Paratype" [red, hw], "Brychius albertanus / Carr / Paratype / ex coll. F.S. Carr" [white label w/ black trim], "Brychius horni [sic] / Crotch / det. GL. Daussin" (UASM).

Diagnosis

Males of this species can be distinguished from those of the other species by having no pronounced curvature of the median lobe, with the apex rounded and the hood lobe small, laying almost against the median lobe. Left paramere with a small rounded projection at apex. Females can be distinguished by tergite VIII semi-circular and covered in short, dense setae; gonocoxae with 2-3 rows of round, thick setae along distal and distolateral margins and apical-lateral margins rounded.

The larva can be distinguished from that of *B. hungerfordi* by having a narrow head with few lateral projections (Figure 18a), the tergites in ventral view not expanding past pleuron (Figure 20a) and the apex of the urogomphus slender.

Description

Adults

Body (Figure 1a). – Total body length 3.0-3.8 mm; maximum body width 1.56-1.94. Shape fusiform, elongate. Colour pale yellow to dark brown.

Head. – Surface with medium-sized, evenly-spaced punctures. Head and antennae pale yellow to brown; some specimens with an infusate ring at base of head.

Mouthparts. – **Labroclypeus** transverse and narrow, shallowly emarginated, rounded at the sides with long setae on anterior margin, covering most of mandibles.

Mandibles asymmetrical; right mandible (Figure 2a) with two apical teeth, dorsal tooth longer than ventral; retinaculum with a mesal comb or brush of setae extending to basal truncated projection. Truncated projection with many distinct spines. Left mandible (Figure 2d) with two apical teeth; retinaculum with brush of setae. **Maxilla** (Figure 3a)

lacinia with spines along inner margin and an elongate two-segmented galea; apical segment of galea with small irregularities along lateral margin. **Labium** (Figure 4a) rectangular, ligula with two lateral setae on each side, two small anterolateral projections; penultimate segment of labial palp with lateral sinuation.

Pronotum. – A deep transverse depression in lateral view at base between the two plicae; pronotum margined laterally. Colour light yellow to dark brown. Apical infuscation may be present. Surface covered in large punctures. Lateral edges margined with fine serrations.

Elytron (Figures 5a, 6a). – Elongate, slightly broader anteriorly than base of pronotum, gradually broadening to the middle and tapering toward apex. Posterolateral margins finely serrate; humeral margins without serration. Colour light yellow to dark brown. Each elytron with 10 rows of brown/black punctures, intervals with very fine micropunctuation. Maculation varies from no spots on elytra to having a small humeral spot, a medial lateral spot, and/or a small apicolateral spot. Apical margins of elytra acute.

Hind Wing (Figure 7a). – R3 without crossvein to C. Ct not forming a cell. Rr with horizontal vein; AP and AA veins absent.

Ventral surface. – **Prosternal process** margined on lateral edges; converging strongly from base to region of fore-coxae, then becoming nearly parallel to apex (Figure 10a); colour dark brown to testaceous, margins may be infusate; finely and sparsely punctured. **Metasternal process** depressed posteriorly; margined on lateral edges, margins may be infusate and continued in line with those of prosternal process; punctures same as on prosternal process, with micropunctures. **Metasternum** with

evenly spaced, uniform punctures. **Metacoxal plate** coarsely punctate laterally, becoming less punctate towards coxal suture; rounded posteriorly; not reaching fourth abdominal segment. **Abdominal sternites** testaceous to light yellow, first visible sternum piceous to infusate; coarsely and densely punctured. Last abdominal sternum finely punctate, apex with a long sharp point.

Legs. – Prothoracic leg (Figure 9a). **Coxa** rounded. **Trochanter** small, rectangular, subequal to length of tarsomere 1. **Femur** with dorsal row of spines, long dorsal natatory setae. **Tibia** slightly shorter than femur, dorsally with small spines and natatory setae, ventrally with large spines. **Tarsus** with five segments; tarsomere 1 with long natatory setae; tarsomere 2 and 3 equal in length; tarsomere 4 with long ventral spines; tarsomere 5 longest tarsal segment with large ventral spines. **Pretarsus** of two long claws equal in length.

Mesothoracic leg (Figure 10a). **Coxa** rounded. **Trochanter** small, rectangular. **Femur** with dorsal row of spines; natatory setae absent. **Tibia** slightly shorter than femur, with a dorsal and ventral row of stout spines, long dorsoapical natatory setae, reaching to tarsomere 5, two stout ventro-apical spines. **Tarsus** with five segments; tarsomere 1 subequal in length to tarsomere 3; tarsomere 2 shortest segment; tarsomere 4 with ventral spines; tarsomere 5 longest with stout row of ventral spines. **Pretarsus** of two long claws.

Metathoracic leg (Figure 11a). **Femur** with basal end bulbous, remainder long and slender, three stout baso-ventral spines, baso-dorsal spines extending past midway. **Tibia** slender, longest segment, with row of dorsal and ventral stout spines, long spines at apical end. **Tarsus** with five segments; tarsomere 1 equal to length of

tarsomere 5, with basal spines; tarsomere 2, 3, and 4 subequal with basal spines and few natatory setae; tarsomere 5 with row of ventral spines. Pretarsus of two long claws.

Female sexual characters. – **Tergite VIII** (Figure 12a) semi-circular; covered in short, dense setae. **Gonocoxae** (Figure 13a) with 2-3 rows of thick setae along distal and disto-lateral margins; apical-lateral margins rounded.

Male sexual characters. – **Aedeagus** (Figure 15a). Curvature of median lobe not pronounced, apex rounded/blunt; hood lobe small, lying almost against the median lobe. **Left paramere** (Figure 16a) with circular projection at apex. **Right paramere** (Figure 17a) with small projection at apex.

Larvae

Instar II

Body. – Total body length 5 mm; maximum body width (3rd abdominal segment) 0.4 mm, n=1. Elongate and slender. Head light brownish-yellow. Stemmata black. Thoracic and abdominal segments light brownish-yellow. Leg segments and urogomphus yellowish-white.

Head. – Length 0.25 mm; width 0.4 mm, n=1. Prognathous; moderately compressed dorsoventrally; granular. Six stemmata on each side of head, three large anterior and three small posterior; all stemmata clustered directly behind antenna. **Antenna** four-segmented; segment 1 slightly shorter than segment 2; segment 2 slightly longer than segment 3; apical segment slightly shorter than segment 3 and less than half the width, bearing a stout apical seta, seta longer than apical segment; antennal appendix similar in form to apical segment but without apical seta.

Mouthparts. – Similar to instar III

Thorax. – Dorsally with oval sclerotized terga. Mesosternum without pair of anterolateral spiracles.

Abdomen. – Segments 1-9 with rectangular tergum and sternum. Segments 1-8 each with a lateral spiracle near midlength in pleural area. Apex of urogomphus slender and curved.

Legs. – Prothoracic leg (Figure 22). **Coxa** rounded; six setae, five ancestral and one additional; one anterior campaniform sensilla; CO₇ larger than other CO setae. **Trochanter** with three ancestral setae; five anterior campaniform sensillae and two posterior campaniform sensillae; TR₄ needle-like. **Femur** modified ventroapically to form a grasping apparatus opposing the claw; 12 setae, six ancestral and six additional; one anterior campaniform sensilla; ventral spinulae in three rows on femoral projection. **Tibia** slightly longer than tarsus; five ancestral setae; one posterior campaniform sensilla; anterior spinulae scattered distally, ventral spinulae scattered dorsally. **Tarsus** shortest segment; two ancestral setae; anterior and posterior ventral spinulae. **Pretarsus** consisting of one claw; equal to length of tibia and tarsus combined; with two V setae.

Mesothoracic leg (Figure 23). **Coxa** having five setae, four ancestral and one additional; one anterior campaniform sensilla. **Trochanter** having five setae, four ancestral and one additional; five anterior campaniform sensillae and two posterior campaniform sensillae. **Femur** slightly shorter than tibia and tarsus combined; 10 setae, eight ancestral and two additional; one anterior campaniform sensilla; few anterior ventral spinulae, approximately five rows of posterior ventral spinulae. **Tibia** equal to length of tarsus; four ancestral setae; one posterior campaniform sensilla; ventral anterior

spinulae. **Tarsus** having four ancestral setae. **Pretarsus** consisting of one long claw, equal to length of femur; with two V setae.

Metathoracic leg (Figure 24). **Coxa** rectangular, slightly longer than femur; 12 setae, 11 ancestral and one additional; one anterior campaniform sensilla. **Trochanter** equal to length of tibia; five ancestral setae; TR₄ long and spine-like; five anterior campaniform sensillae and two posterior campaniform sensillae. **Femur** having 10 setae, six ancestral and four additional; one anterior campaniform sensilla. **Tibia** equal to length of tarsus; four ancestral setae; TI₂ longer than other TI setae; one posterior campaniform sensilla. **Tarsus** having four ancestral setae. Pretarsus consisting of single long claw, equal to length of tibia and tarsus combined; with pair of V setae.

Instar III.

Body – Elongate and slender. Total body length 10.0-11.0 mm; maximum body width (3rd abdominal segment) 0.8-0.95 mm, n=12. Head yellowish-brown, darker than rest of body. Stemmata black. Thoracic and abdominal segments vary from light yellowish-brown to orange to dark reddish-brown. Tergal sclerites and asperities slightly darker than thoracic and abdominal colouration. Thoracic and abdominal pleura whitish-yellow. Leg segments and urogomphus yellowish.

Head. – Average head length 0.35 mm; average head width 0.5 mm, n=12 (Figure 18a). Prognathous; moderately compressed dorsoventrally; shiny; granular. Six stemmata on each side of head, four dorsal and two lateral; all stemmata clustered directly behind antenna. **Antenna** four-segmented; segment 1 slightly shorter than segment 2; segment 2 slightly longer than segment 3; apical segment slightly shorter than

segment 3 and less than half the width, bearing a stout apical seta, seta longer than apical segment; antennal appendix similar in form to apical segment but without apical seta.

Mouthparts. - **Labroclypeus** with straight anterior margin. **Labium** subquadrate, with minute ligula. Labial palpus short, two-segmented. **Mandible** (Figure 19a) robust basally; with slender, perforate, incurved, spine-like process on apex, with large opening. **Maxilla** short and broad; cardo small and more or less fused to stipes; palp three-segmented.

Thorax. - Pronotal tergite oval; tergites in ventral view not expanding past pleuron (Figure 20a). Pronotum longer than mesonotum and metanotum. Sides of mesothorax each with a ventral spiracle anterolaterad of mesocoxa.

Abdomen. - Segments 1-9 with rectangular tergum and sternum. Segments 1-8 each with a lateral spiracle near midlength in pleural area. Apex of urogomphus slender and curved (Figure 21).

Legs. - Prothoracic leg (Figure 25). **Coxa** longest segment; 14 setae, nine ancestral and five additional; one anterior campaniform sensilla; anterior spinulae. **Trochanter** half the length of femur; eight setae, five ancestral and three additional; five anterior campaniform sensillae and two posterior campaniform sensillae; ventral anterior spinulae. **Femur** modified ventroapically opposing the claw; 17 setae, five ancestral and 12 additional; FE₂ and FE₈ large; one anterior campaniform sensilla; three distinct areas of anterior spinulae: DPr, VPr, and VDi. **Tibia** slightly longer than tarsus; seven ancestral setae; one posterior campaniform sensilla. **Tarsus** shortest leg segment; four ancestral setae. **Pretarsus** consisting of one claw; length of tibia and tarsus combined; with two V setae.

Mesothoracic leg (Figure 26). **Coxa** equal to length of femur; nine setae, six ancestral and three additional; one anterior campaniform sensilla. **Trochanter** equal to length of tibia; six setae, four ancestral and two additional; TR₄ needle-like; five anterior campaniform sensillae and two posterior campaniform sensillae; anterior spinulae near TR₃. **Femur** equal to length of tibia and tarsus combined; 18 setae, eight ancestral and 10 additional; one anterior campaniform sensilla; ventral posterior spinulae. **Tibia** slightly longer than tarsus; six setae, five ancestral and one additional; one posterior campaniform sensilla. **Tarsus** shortest segment; four ancestral setae. **Pretarsus** consisting of one claw with two V setae.

Metathoracic leg (Figure 27). **Coxa** equal to length of femur, widest segment; 12 setae, 10 ancestral and two additional; one anterior campaniform sensilla. **Trochanter** equal to length of tibia; five ancestral setae; TR₄ long and needle-like; five anterior campaniform sensillae and two posterior campaniform sensillae; posteroventral spinulae. Femur long and slender; 14 setae, seven ancestral and seven additional; one anterior campaniform sensilla; ventral spinulae on both anterior and posterior sides. **Tibia** slightly longer than tarsus; five ancestral setae; one posterior campaniform sensilla. **Tarsus** shortest segment; four ancestral setae. **Pretarsus** consisting of single claw with pair of V setae.

Distribution

(Figures 31, 35, 36).

The general range of this species extends from Vancouver Island, British Columbia to Manitoba, and south to California. No specimens have so far been collected in

Saskatchewan. It is possible that the range extends into Quebec. The Quebec locality (Duparquet, 1.vii.1944, G. Stace Smith) is questionable as only one specimen has been found and it is possible the specimen was mislabeled. However, other insects show similar distribution patterns, such as the monotomid beetle, *Rhizophagus pseudobrunneus* Bousquet (Paquin and Dupérré 2001). The range may also extend into Arizona; however, the one specimen labeled “Arizona” is questionable as the label is incomplete and the specimen was said to be collected from a malaise trap (no other specimen of *Brychius* has ever been collected from this type of trap, designed to catch flying insects).

Remarks

Brychius hornii is by far the commonest and most widespread species of *Brychius*. This species displays variation in the colour and maculation of the elytra and has a large size range.

BRYCHIUS HUNGERFORDI SPANGLER

Spangler, 1954: 114

Roughley, 1991: 295

Strand and Spangler, 1994: 209 (larval description)

(Figures 1b; 2b, e; 3b; 4b; 5b; 6b; 7b; 8b; 9b; 10b; 11b; 12b; 13b; 15b; 16b; 17b; 18b; 19b; 20b; 28-30).

TYPE MATERIAL: *Brychius hungerfordi*: **Holotype**: Male – “29. Maple River /

McKinley Twp. / Emmet Co. Mich. / VIII-8-1952 / Paul J. Spangler” [genitalia in glass

vial], “HOLOTYPE / *Brychius* / *hungerfordi* / P.J. Spangler” [red], “Type No. / 62208 /

USNM" [red], "Brychius / hungerfordi / Spangler" [white label w/ black trim] (USNM).

Paratypes: 1 Male, 3 Female – "29. Maple River / McKinley Twp. / Emmet Co. Mich. / VIII-8-1952 / Paul J. Spangler", "PARATYPE / Brychius / hungerfordi / P.J. Spangler" [blue], "PARATYPE / Brychius / hungerfordi / No. 6242 Spangler" [yellow] (CNC). 1 Male, 1 Female – "29. Maple River / McKinley Twp. / Emmet Co. Mich. / VIII-8-1952 / Paul J. Spangler", "PARATYPE / Cornell U. / No. 3152.1" [light blue], "Brychius / hungerfordi / Spangler / det. GL. Daussin" (Cornell). 3 Males, 3 Females – "29. Maple River / McKinley Twp. / Emmet Co. Mich. / VIII-8-1952 / Paul J. Spangler" "PARATYPE / Brychius / hungerfordi / P.J. Spangler" [blue], "P.J. Spangler / Coll. 1958 / 221697" (USNM). 2 Males, 1 Female – "29. Maple River / McKinley Twp. / Emmet Co. Mich. / VIII-8-1952 / Paul J. Spangler" "PARATYPE / Brychius / hungerfordi / P.J. Spangler" [blue] (CAS).

Diagnosis

The adults of *B. hungerfordi* can be distinguished from the other species by: humeral margins of elytra denticulate, presence of a thick black band on basal margin of pronotum, and larger average size.

The larvae can be distinguished from those of *B. hornii* by: wide head with many lateral projections (Figure 18b), the tergites in ventral view expanding past pleuron (Figure 20b) and the apex of the urogomphus wide and very curved.

Description

Adults

Body (Figure 1b). – Total body length ranges from 3.7-4.4 mm; maximum body width ranges from 1.90-2.25 mm. Robust; elytra pointed at humeral region. Colour testaceous.

Head. - Surface with coarse punctures, smaller than those of pronotum. Head and antennae testaceous, black ring at base of head.

Mouthparts. - **Labroclypeus** transverse and narrow, shallowly emarginated, rounded at the sides with long setae on anterior margin, covering most of mandibles.

Mandibles asymmetrical; right mandible (Figure 2b) with two apical teeth, ventral tooth hardly noticeable from under dorsal tooth; retinaculum with a mesal comb or brush of setae extending to basal truncated projection. Truncated projection with a small number of ridges. Left mandible (Figure 2e) with one apical tooth; retinaculum with brush of setae. **Maxilla** (Figure 3b) lacinia with spines along inner margin and an elongate two-segmented galea; apical segment of galea rectangular, without small irregularities along lateral margin. **Labium** (Figure 4b) wide, ligula with two lateral setae, two small anterolateral projections; penultimate segment of labial palp without lateral sinuation.

Pronotum. - A moderate transverse depression in lateral view at the base between the two plicae; pronotum margined laterally. Colour testaceous except: piceous apical spot, lateral and posterior margins, two basal spots, and plicae. Punctures larger and less dense than those of head, interspaces micropunctate; disc less densely punctate. Lateral edges margined with fine serrations.

Elytron (Figures 5b, 6b). – Elongate, slightly broader anteriorly than base of pronotum, gradually broadening to the middle and tapering toward the apex.

Posterolateral margins and humeral margins finely serrate. Colour testaceous with 10

rows of setigerous punctures not extending completely to apex, intervals micropunctate; elytral margins, sutural stripe and rows of punctures piceous. A piceous humeral spot is present covering the fifth, six, and seventh striae and intervals. At the outer edge is another spot covering the fifth, six, seventh, eighth, and sometimes ninth striae and intervals. At the three quarters is another spot covering the fourth, seventh, eighth, and ninth striae and intervals. Apical margins of elytra acute.

Hind Wing (Figure 7b). – R3 with crossvein to C forming closed cell. Ct forming closed cell. Rr with horizontal vein; AP and AA veins absent.

Ventral surface. – **Prosternal process** margined on lateral edges; converging strongly from base to region of fore-coxae, becoming nearly parallel to apex (Figure 8b); margins and base infusate, medial portion testaceous; finely and sparsely punctured basally with micropunctures in the interspaces, more coarsely punctate on apical third.

Metasternal process strongly margined on lateral edges, margins continued in line with those of prosternal process, sinuate and divergent apically; more finely punctate than prosternum, with micropunctures; margins and base infusate, depressed posteriorly.

Metasternum with evenly spaced, uniform punctures. **Metacoxal plate** coarsely punctate laterally, becoming less punctate towards coxal suture; rounded posteriorly; not reaching fourth abdominal segment. **Abdominal sternites** with fringe of hairs along lateral edges; first visible sternum piceous, coarsely and densely punctured; second visible sternum infusate; third may be infusate or brown, the last abdominal sternum testaceous, finely and more densely punctate, with a noticeable slit medially from more than half the length of the segment; apex with long sharp point.

Legs. – Prothoracic leg (Figure 9b). **Coxa** oval. **Trochanter** small, rectangular,

subequal to length of tarsomere 1. **Femur** with dorsal and ventroapical row of spines, few long dorsal-apical natatory setae. **Tibia** slightly shorter than femur, dorsally and ventrally with small spines, apical end with short dorsal natatory setae and stout ventral spines. **Tarsus** with five segments; tarsomeres without natatory setae; tarsomere 1 subequal to length of tarsomere 2 and 3 combined; tarsomere 2 slightly longer than tarsomere 3; tarsomere 4 with long ventral spines; tarsomere 5 longest tarsal segment with large ventral spines. **Pretarsus** of two long claws.

Mesothoracic leg (Figure 10b). **Coxa** rounded. **Trochanter** small, rectangular. **Femur** with dorsal row of small spines; natatory setae present in cluster at apical end. **Tibia** slightly shorter than femur, with a dorsal and ventral row of slender spines, long dorso-apical natatory setae, two stout ventro-apical spines. **Tarsus** with five segments; tarsomere 1 subequal in length to tarsomere 2 and 3 combined, with long ventral natatory setae; tarsomere 2 subequal to tarsomere 4; tarsomere 3 shortest segment; tarsomere 4 with ventral spines; tarsomere 5 longest segment with stout row of ventral spines. **Pretarsus** of two long claws.

Metathoracic leg (Figure 11b). **Femur** with basal end bulbous, remainder long and slender, dorsal and ventral apical spines. **Tibia** slender, longest segment, with row of dorsal and ventral slender spines, long stout spines at apical end. **Tarsus** with five segments; tarsomere 1 with long natatory setae and small spines; tarsomere 2 and 3 with long natatory setae; tarsomere 5 with row of ventral spines. **Pretarsus** of two long claws.

Female sexual characters. – **Tergite VIII** (Figure 12b) triangular, pointed at apex; lateral margins straight. **Gonocoxae** (Figure 13b) with 1-2 rows of sparse setae along distal and disto-lateral margins.

Male sexual characters. – **Aedeagus** (Figure 15b) with apex of median lobe long, slender with a downward angle; hood lobe pointed. **Left paramere** (Figure 16b) with hook-like projection at apex. **Right paramere** (Figure 17b) with almost a flat surface at apex.

Larvae

Instar III

Body. – Total body length 11.5-13.0 mm; maximum body width (3rd abdominal segment) 1-1.2 mm, n=12. Elongate, robust. Head brown. Stemmata black. Thoracic and abdominal segments light yellowish-brown. Tergal and sternal sclerites and asperities dark reddish-brown. Thoracic and abdominal pleura whitish yellow. Leg segments yellowish-brown. Urogomphus yellow.

Head. – Average head length 0.35 mm, average head width 0.75 mm, n=12 (Figure 18b). Lateral margins sinuate.

Mouthparts. – Similar to *B. hornii*; mandible (Figure 19b).

Thorax. – Pronotal tergite rectangular; tergites in ventral view expanding past pleuron (Figure 20b). Pronotum equal in length to metanotum, longer than mesonotum. Sides of mesothorax each with a ventral spiracle anterolaterad of mesocoxa.

Abdomen. – Segments 1-9 with rectangular tergum and sternum covered in dark asperities. Asperities along posterior margins of segments with four dense clusters; one at posterolateral angle of each tergum and one on each side of midline. Urogomphus similar to that of *B. hornii* (Figure 21) but more densely covered with asperities and with many sensillae at the apex; apex of urogomphus wide and strongly curved.

Legs. – Prothoracic leg (Figure 28). **Coxa** longest segment; 16 setae, 13 ancestral and three additional; one anterior campaniform sensilla. **Trochanter** having seven setae, four ancestral and three additional; five anterior campaniform sensillae and two posterior campaniform sensillae; ventral anterior spinulae. **Femur** without ventroapical modification; slightly longer than tibia and tarsus combined; 20 setae, five ancestral and 15 additional; one anterior campaniform sensilla; one row of stout ventral anterior spinulae and one row of smaller spinulae. **Tibia** equal to length of tarsus; six ancestral setae; one posterior campaniform sensilla. **Tarsus** having three ancestral setae; ventral posterior spinulae. **Pretarsus** consisting of one claw; shorter than length of tibia and tarsus combined; with two V setae.

Mesothoracic leg (Figure 29). **Coxa** longest segment; 12 setae, nine ancestral and three additional; one anterior campaniform sensilla. **Trochanter** having six ancestral setae; five anterior campaniform sensillae and two posterior campaniform sensillae; ventral rows of anterior and posterior spinulae. **Femur** long, slender, length of tibia and tarsus combined; 22 setae, 10 ancestral and 12 additional; one anterior campaniform sensilla; ventral posterior spinulae. **Tibia** equal to length of tarsus; eight setae, seven ancestral and one additional; one posterior campaniform sensilla; ventral posterior spinulae. Tarsus having five ancestral setae. **Pretarsus** consisting of one claw; shorter than length of tibia and tarsus combined; with two V setae.

Metathoracic leg (Figure 30). **Coxa** having 10 setae, nine ancestral and one secondary; one anterior campaniform sensilla. **Trochanter** having six ancestral setae; five anterior campaniform sensilla and two posterior campaniform sensilla; one area of anterior spinulae proximal, one row of spinulae beside TR₂, one row of posterior

ventral spinulae. **Femur** long, slender; 24 setae, nine ancestral and 15 additional; one anterior campaniform sensilla; four rows of ventral posterior spinulae. **Tibia** equal to length of tarsus; six ancestral setae; one posterior campaniform sensilla. **Tarsus** having four ancestral setae; posterior covered in spinulae. **Pretarsus** consisting of one claw with two V setae.

Distribution

(Figures 32, 33).

This species has only been found in Michigan and Ontario.

BRYCHIUS PACIFICUS CARR

Carr, F.S., 1928: 23

(Figures 1c; 2c, f; 3c; 4c; 5c; 6c; 7c; 8c; 9c; 10c; 11c; 12c; 13c; 15c; 16c; 17c).

TYPE MATERIAL: *Brychius hornii*: **Holotype**: Male – “Hmbldt Co / Cal”, Coll’. JD / Sherman / Jr. 1926”, “Type No. / 41755 / U.S.N.M.” [red], “*Brychius / pacificus / Carr* / Type [written sideways] / ex coll. F.S. Carr” [white label w/ black trim] (USNM).

Diagnosis

The adults of this species can be distinguished from the other species by: prosternal process constricted at level of procoxae, gradually widening to apex making the anterior lobe distinctly wedge-shaped; last abdominal segment with blunt point. Males can be distinguished from those of the other species by having the median lobe elongate and slender, with the apex slightly pointed and the hood lobe truncated, with a

deep, distinct channel separating it from the median lobe. Left paramere with a larger, rough surface at apex.

The larva is unknown.

Description

Adults

Body (Figure 1c). – Total body length 3.3-3.7 mm; maximum body width 1.71-1.93 mm. Elongate, slender. Colour testaceous to dark brown. Characteristic elytral maculation.

Head. - Surface with evenly spaced, larger punctures. Head and antennae yellow to testaceous. Light infuscation on base of head on some specimens.

Mouthparts. - **Labroclypeus** similar to that of *B. hornii* and *B. hungerfordi*.

Mandibles asymmetrical; right mandible (Figure 2c) with one notched apical tooth; retinaculum with mesal comb or brush of setae not extending past retinaculum concavity. Truncated projection smooth. Left mandible (Figure 2f) with one apical tooth; retinaculum with brush of setae. **Maxilla** (Figure 3c) with lacinia having spines along inner margin and elongate two-segmented galea; apical segment of galea tapered towards apex, smooth. **Labium** (Figure 4c) with very wide, rounded base, ligula with lateral setae, two anterolateral small projections; penultimate segment of labial palp without lateral sinuation.

Pronotum. - No transverse depression in lateral view at base between two plicae; pronotum margined laterally. Colour testaceous to brown; anterior margin usually infuscate; two piceous to brown spots on posterior margins; piceous band on posterior

margin. Surface covered with punctures, which are larger and coarser in piceous areas. Lateral edges margined with fine serrations.

Elytron (Figures 5c, 6c). – Elongate, tapering from sixth abdominal segment to apex. Posterolateral margins finely serrate. Colour testaceous to brown; five inner striae of punctures on each elytron, pigmented; pigmentation abbreviated apically but hardly basally, spreads out from punctures. Piceous humeral spot present covering sixth and seventh striae and intervals. At outer edges, another spot stretching over sixth, seventh, eighth and ninth striae and intervals. At three quarter length, another spot covering seventh and eighth striae and intervals. In some specimens, there is a spot in the middle connecting the sutural stripe with the first and second striae. Apical margin of elytra rounded, apices denticulate.

Hind Wing (Figure 7c). – R3 without crossvein to C. Ct forming semi-circular open cell. Rr without horizontal vein; AP and AA present.

Ventral surface. – **Prosternal process** with poorly developed lateral margins becoming very faint or disappearing anteriorly; constricted at level of procoxae, gradually widening anteriorly, making anterior lobe appear distinctly wedge-shaped (Figure 8c); reddish-yellow; surface coarsely punctate with micropunctures in interspaces.

Metasternal process not depressed posteriorly; margined on lateral edges, thicker margining in anterior portion, margins continued in line with those of prosternal process; punctures same as on prosternal process with micropunctures in interspaces.

Metasternum with large, sparse punctures. First two visible **abdominal sternites** heavily pigmented with piceous, coarse punctures; last two segments more finely punctate. The last segment almost obtusely angulate with noticeable slit medially from

apex, more than half length of segment; apex with short point.

Legs. – Prothoracic leg (Figure 9c). **Coxa** square-shaped. **Trochanter** small, rectangular, length of tarsomere 1. **Femur** with dorsal row of spines, long dorsal natatory setae. **Tibia** slightly shorter than femur, dorsally and ventrally with stout spines, apical end with short dorsal natatory setae and two stout ventral spines. **Tarsus** with five segments; all tarsomeres with long natatory setae; tarsomere 1 equal to length of tarsomere 4; tarsomere 2 slightly longer than tarsomere 3; tarsomere 4 with long ventral spines; tarsomere 5 longest tarsal segment with large ventral spines. **Pretarsus** of two long claws.

Mesothoracic leg (Figure 10c). **Coxa** rounded. **Trochanter** small, rectangular. **Femur** with dorsal row of spines; few natatory setae dorso-basally, cluster of natatory setae dorso-apically. **Tibia** slightly shorter than femur, with dorsal and ventral rows of stout spines, long dorso-apical natatory setae, two ventroapical stout spines. **Tarsus** with five segments; tarsomere 1 with natatory setae; tarsomere 2 shortest segment; tarsomere 3 and 4 equal in length; tarsomere 5 longest segment with stout row of ventral spines. **Pretarsus** of two long claws.

Metathoracic leg (Figure 11c). **Femur** with basal end bulbous, remainder long and slender, dorsal and ventral spines. **Tibia** slender, longest segment, with row of dorsal and ventral spines, longer spines at apical end. **Tarsus** with five segments; long natatory setae absent; tarsomere 1 subequal to length of tarsomeres 2 and 3 combined, with basal spines; tarsomere 2, 3, and 4 subequal with basal spines; tarsomere 5 with row of ventral spines. **Pretarsus** consisting of two long claws.

Female sexual characters. – **Tergite VIII** (Figure 12c) rounded, wide basally.

Gonocoxae (Figure 13c) with large space separating two apical lobes; apices of lobes with long, stout spines.

Male sexual characters. – **Aedeagus** (Figure 15c) with median lobe having a distinct curvature, apex elongate, slender, with a slightly pointed tip; hood lobe distinctly square, a deep distinct channel separating it from the median lobe. **Left paramere** (Figure 16c) with larger platform surface at apex. **Right paramere** (Figure 17c) with truncated apex.

Distribution

(Figures 34-36).

This species is found on the west coast of Oregon and California.

Quantitative Analysis of Structure

A morphometric analysis was undertaken with the intention of providing quantitative length and width measurements of body structures to discriminate adults of Nearctic species of *Brychius*. Initial analysis using basic graphing was first performed to determine if any of the characters were uninformative. Principal Component Analysis (PCA) using a covariance matrix was performed to identify the most informative characters and eliminate autocorrelated characters. Multiple Discriminant Analysis (MDA) was then performed to test species discrimination and to observe variation within the species. Discriminant analysis was carried out using raw and ratio data.

Males and females were analyzed separately, as females are larger, on average,

than males in all species of *Brychius*. Populations of *B. hornii* from Creston, BC; Fort McMurray, AB; Cypress Hills, AB; and Cowan, MB were analyzed separately. These populations are geographically isolated and it was thought they could show significant structural differences.

Males

In the analysis, specimens of *B. hungerfordi* were the only ones to separate completely from specimens of the other species. This occurred on the first axis with the characters pronotal width (Pr1) and pronotal length (Pr2) (Figure 37a). Even though specimens of *B. pacificus* and *B. hornii* completely overlapped in size, 95% confidence ellipses placed around the centroids produced noticeable population groups within *B. hornii*. The population of *B. hornii* from Cowan, MB was the most similar to those of *B. hungerfordi* and the least similar to those of *B. pacificus*. The population of *B. hornii* from Cypress Hills, AB was the least similar to those of *B. hungerfordi*. The population of *B. hornii* from Fort McMurray, AB completely enclosed the centroid radius of *B. pacificus* and the population of *B. hornii* from Creston, BC.

The character most closely associated with the second axis was tarsomere 1 length (Ta1); however, this only slightly separated specimens of *B. pacificus* from specimens of the other species.

Females

Separation of females of *Brychius* spp. was less definitive on the first axis than for male specimens; however, the trends were the same (Figure 37b). Similar to the analysis of males, specimens of *B. hungerfordi* were seen to separate distinctly from specimens of the other species, while specimens of *B. pacificus* and *B. hornii* completely overlapped in

size. Within *B. hornii*, the population from Cowan, MB was the most similar to those of *B. hungerfordi* and the least similar to those of *B. pacificus*. The population of *B. hornii* from Cypress Hills, AB was more similar to the remaining *B. hornii* populations in the female analysis than in the male analysis. The population of *B. hornii* from Fort McMurray, AB was closer to *B. pacificus* than it was to the population of *B. hornii* from Creston, BC.

In the analysis of females, the second axis was more effective than that of the analysis of males for distinguishing populations of *B. pacificus* and the population of *B. hornii* from Creston, BC using the length of the metasternum (M2). However, there was still complete overlap among specimens of the two species.

Overall Trends

The populations of *B. hornii* from Fort McMurray, AB and Cypress Hills, AB had the greatest variation out of the six groups analyzed. In both sexes, specimens of *B. hornii* overlapped greatly with specimens of *B. pacificus*. Specimens of *B. hungerfordi* were the only ones to separate completely from specimens of the other species. This is not surprising as *B. hungerfordi* is quite isolated from the other species. The character that was best to discriminate this species from the others was the width of the pronotum. However, because the width differed from specimens of *B. hornii* by only 0.02 mm (Figure 38), it is impractical to use this character for identification purposes. The overall size of specimens of *B. hungerfordi* was also variable, as with the other species. This is congruent to the findings of Spangler (1954, p. 116) who stated "the size of *B. hungerfordi* from Maple River, Emmet Co. Michigan varies considerably within each sex. The smallest specimen in the series is a male, 3.70 mm in length and 1.90 mm in

width, while the largest is a female, 4.35 mm in length and 2.25 mm in width". The addition of selected ratios can sometimes reduce the error of overlapping discriminate groups through compensating for variation of body size among a species; however, this did not affect the results of my analysis when added.

Phylogeny

A structural matrix including 20 adult characters was produced (Table 2). In the PAUP analysis, the exhaustive search yielded one tree (Figure 39) of length 33, with a Consistency Index of 0.82, and a Retention Index of 0.71. Generally, nodes had low bootstrap support; therefore, interpretation of the tree should be regarded with caution.

In the cladogram, *B. pacificus* is basal to all other species of *Brychius*. *Brychius hornii* and *B. hungerfordi* are sister species and *B. elevatus* and *B. glabratus* are sister species. The monophyly of *B. hornii* and *B. hungerfordi* is indicated by four characters: 1) prosternal process with anterior lateral margins parallel (C 9); 2) lateral view of ventral margin of metasternum impressed (C10); 3) humeral region of elytra angled (C14); and 4) apical sternite of abdomen with a long, sharp point (C 19). The monophyly of *B. elevatus* and *B. glabratus* is indicated by one character: metasternal process with a large anterior median impression (C 11). The monophyly of species of *Brychius* excluding *B. pacificus* is indicated by four characters: 1) mandible with two apical teeth (C1); 2) pronotum in lateral view with a basal transverse impression (C6); 3) anterior lateral margins of pronotal process with thick margins (C8); and 4) apex of elytra acute.

Discussion

Species Classification

Within the new classification, I have placed *B. albertanus* as a junior, subjective synonym of *B. hornii*. *Brychius albertanus* was described by Carr (1928) who had seen only three specimens. Because *B. hornii* has a wide distribution range across Canada and is quite variable with regards to external colouration and size, it is understandable how a few smaller, lighter-coloured specimens from Alberta could have been conceived as being a separate species, especially if the male genitalia were not examined.

Similar confusion has been seen in *B. elevatus* from Europe. Slight differences have been noticed among local populations of *B. elevatus* (Holmen 1987), and some authors have classified these divergent populations into subspecies. For instance, Zaitsev (1972) considered *B. elevatus* as consisting of a number of geographical forms (subspecies) which may be connected by transitional forms. A similar study as this one, especially documenting the male genitalia, is needed to disentangle the species and subspecies of *Brychius* in Europe.

In this study, I have found that characters of the male genitalia are key features to identify species of *Brychius*. In Coleoptera, as well as in other insects, the male genitalia have commonly provided the best characters for separating closely related species, and can be distinctive in groups at most classification levels (Sharp and Muir 1912). Examination of the male genitalia is imperative in making specific identifications in most species of the Haliplidae (Leech and Chandler 1956; Gunderson and Otremba 1988; Balfour-Browne 1915; Matta 1976). Edwards (1911) was the first to use the form of the median lobe and parameres for identification of species of Haliplidae; however, it was

Balfour-Browne in 1915 who realized the advantage of using the aedeagus, which he stated (p 97), "is the only absolutely reliable specific one".

I have also included structures of the female genitalia in this study. There has been very little work done on these structures within the members of Haliplidae (Holmen 1987), as is similar in other families of Coleoptera (Crowson 1984). This may be partly due to the increase in time and effort of preparing the structures for examination. Holmen (1987) suggested that the spermatheca, ductus receptaculi, and other weakly sclerotized parts of the female genitalia are liable to provide good diagnostic characters and are best examined on permanent slides. In contrast, Vondel (1992, 1993) stated that the female genitalia of Haliplidae are usually very uniform, but also added that further research is necessary to determine if there are characters sufficiently reliable to separate the species. Although I did not study internal female genitalic structures, the form of external structures were found to be distinct among the species of *Brychius*.

The mandibles of adult females of *Brychius* spp. were also examined. Galewski (1972) examined the mandibles of females of central European species of Haliplidae and this was suggested as a reliable taxonomic character. The mandibles of females of *Halipplus* spp. are used for extending holes in certain plants and algae so they can deposit their eggs into the tissue (Beier 1929; Burmeister 1980). I also found the form of the mandibles of female specimens of species of *Brychius* to be distinct.

General elytral maculation patterns were described for species of *Brychius* in this study; however, the patterns varied among individuals of one species. Elytral maculation is a deceptive character, much like overall colouration. Brigham and Sanderson (1973) stated that little significance should be put on the shape of the elytral blotches, where

only 16 out of 40 specimens of one species of *Haliphus* had similar patterns. Young (1961) suggested that the bright patterns on some haliplids may be warning colouration, and that perhaps mimicry is involved. Adults of *Peltodytes* spp. resemble each other very closely in colour pattern, yet are shown to be distinct on the basis of genitalia or other internal structures (Young 1961).

The larvae of beetles provide a very different set of taxonomic states; however, the chaetotaxy of larval haliplids has not been studied extensively. The legs of larval specimens of *Brychius* have a number of setae, which may prove to be useful for the study of chaetotaxy. Preliminary leg chaetotaxic work has been published for *B. hungerfordi* (Strand and Spangler 1994), *B. elevatus* (Jaboulet 1860), *Haliphus lineatocollis* Marsham 1802 (Seeger 1971a), and *Haliphus lineolatus* Mannerheim 1844 (Nilsson 1988). In this study, I illustrated the larval leg chaetotaxy for the second and third instars of *B. hornii* and the third instar of *B. hungerfordi*. I was interested in determining if there were differences in chaetotaxy between the different instars of a species, between two different species, and between different genera of Haliplidae.

The leg chaetotaxy of *B. hornii* differed between instars II and III. Overall there were more setae on the legs of instar III (prothoracic leg 52, mesothoracic leg 45, metathoracic leg 41) than of instar II (prothoracic leg 30, mesothoracic leg 30, metathoracic leg 37). The number and position of the campaniform sensillae was the same between instars. The amount and position of the spinulae differed.

The leg chaetotaxy of *B. hornii* (instar III) differed from that of *B. hungerfordi* (instar III). Overall there were more setae on the legs of *B. hungerfordi* (prothoracic leg 54, mesothoracic leg 55, metathoracic leg 52). The number and position of the

campaniform sensillae remained the same between species.

The leg chaetotaxy of *H. lineolatus* differed from that of *B. hornii* and *B. hungerfordi*. There were 47 setae on the metathoracic leg of *H. lineolatus* (instar I). One major difference was the lack of a campaniform sensilla on the anterior coxa of *H. lineolatus*. *Haliphus lineolatus* also lacked spinulae. The comparison of the leg chaetotaxy between species of *Brychius* and *H. lineolatus* should be regarded as preliminary as Nilsson (1987) only described the hind leg of the first instar of *H. lineolatus* and was not certain of the correct number of setae.

There were more spinules on the prothoracic leg of *B. hornii* (third instar) than on the mesothoracic and metathoracic legs. Perhaps they use their prothoracic legs to grasp on to algae or plants while feeding. There were more spinules on the metathoracic leg of *B. hornii* (third instar) than on the metathoracic leg of *H. lineolatus* (first instar). The function of these spinules may be to provide increased adhesion to the substrate and vegetation, decreasing the risk of being dislodged by water currents.

Biogeography

The biogeography of the Haliplidae has not been comprehensively studied, even though the distribution patterns are intriguing. Species of Haliplidae occur in all major faunal areas of the world; however, the majority of species are distributed in the northern hemisphere from the temperate and subtropical zones (for world distribution maps see Franciscolo 1979). Species of *Haliphus* are almost worldwide in distribution, with the majority found in the Palaearctic region. Species of *Peltodytes* occur in most parts of the world, particularly in the warmer areas, and a high number can be found in North

America. A few species live in the northern parts of the Neotropical region, Palaearctic, Afrotropical and Oriental regions.

Species of *Brychius* are Holarctic in distribution. In the Nearctic Region, populations of *B. hornii* are found across Canada (except for eastern Quebec and the Maritimes) and western United States, south to California. Many insects exhibit this distribution pattern with the majority of populations in the west and isolated populations in Manitoba and Quebec (*e.g.* Paquin and Dupéré 2001). In the Palaearctic Region, populations of *Brychius* are found in most of Europe except southern and western parts, but are present in France and the United Kingdom, and are found in the northern and central parts of Russia, east to central Siberia (Holmen 1987).

It is thought that the center of origin for the Haliplidae is North America (Canadian Shield) (Zaitsev 1972). This is because members of *Peltodytes*, *Brychius* and some species of *Haliphus*, occurring in North America, are thought to be more primitive than species of the subgenus *Liaphlus*, occurring in Europe (Zaitsev 1972). However, Zaitsev does not give any support as to how he concluded that the species of *Liaphlus* are more recently evolved.

Fossils of Haliplidae are not known. Species of *Triaplus* Ponomarenko (Triaplidae), described from the Upper Triassic Period, have the same enlarged metacoxal plates as the Haliplidae; however, it is unlikely that extant haliplids are the descendants of a Triassic haliplomorph group (Evans 1985). For instance, synapomorphic features of the entire Adephagan suborder, excluding Gyrinidae, include a well-developed prosternal process and narrow mesosternum with a typical hexagonal groove (Evans 1985). These are found in Haliplidae but not in Triaplidae (Beutel 1995).

Large metacoxal plates are most likely a derived ground plan feature of Adephaga, excluding Gyrinidae, with haliplids and triaplids more likely representing convergence (Kavanaugh 1986), triaplids probably having no extant descendants or near relatives.

In order to explain the present day distribution of species of *Brychius*, I have used the results from the phylogenetic analysis to determine relationships among the species, then compared this with accepted geologic and geographic history. There are five important aspects of the members of *Brychius* regarding the hypothesis of their origin and biogeography: 1) *B. hornii* and *B. hungerfordi* are more closely related to the European species than to *B. pacificus*; 2) species of *Brychius* occur only in North America and Europe; 3) populations of *B. hornii* exist on both sides of the Rocky Mountains; 4) species of *Brychius* display disjunct geographic distributions; 5) all species are found in cool to cold montane or sub-montane streams where adults and larvae live along the gravel margins or undercut banks.

According to the reconstructed phylogeny, *B. hornii* and *B. hungerfordi* are more closely related to the European species than to *B. pacificus*. This suggests that species of *Brychius* may have arose and diversified on Laurasia during the Jurassic Period (Noonan 1986). In the late Cretaceous and the Early Tertiary, Laurasia divided into two distinct land masses (Noonan 1986): Asiamerica and Euramerica. The species of *Brychius* display a Euramerican distribution, which included much of present North America, Greenland, various Atlantic islands, portions of the British Isles, and part of western Europe (Cox 1974).

The presence of *B. hornii* on both sides of the Rocky Mountains indicates that this species, and *B. hungerfordi*, originated before the advent of the mountains. The

formation of the Rocky Mountains, referred to as the Laramide orogeny, is thought to have occurred ca. 45-80 mya (Maxon and Tikoff 1996).

During the Wisconsin glaciation, ca. 12 thousand years ago, species of *Brychius* would have survived in glacial refugia (Lindroth 1970). The restricted coastal distribution of *B. pacificus* suggests it may have survived within the southern coastal refugia, south of the ice sheet (Kavanaugh 1988). *Brychius hornii* probably utilized the large, ice-free south-western region of the United States, and perhaps other pocket refugia such as the Cypress Hills, Alberta (Matthews 1979). It is likely that *B. hungerfordi* survived in the Mississippian refugium south of the Great Lakes (Mandrak and Crossman 1992). With the retreat of the glacial ice northward, *B. hornii* may have spread throughout the numerous cool glacial streams; while *B. hungerfordi* remained isolated in the eastern region, perhaps trapped by the formation of the Great Lakes.

The populations of *Brychius* are widely disjunct. Two reasons why species of *Brychius* may show localized, disjunct populations are: 1) limited capacity for dispersal, or 2) immediate ecological factors that prevent local populations from expanding. Vicariance has probably played an important role in this present distribution, where populations may have once been widespread in cool mountainous glacial streams, then became restricted to geographically isolated regions with the retreat of the glaciers and the extinction of intervening populations. For instance, extant coastal insect species like *B. pacificus* that survived in coastal refugia have generally been unable to extend their ranges to other parts of the Coastal region following glacial retreat (Kavanaugh 1988).

Conclusion

By examining external structural characters of adult and larval specimens of *Brychius*, I have reached the conclusion that there are three valid species of *Brychius* in North America: *B. hornii* Crotch, *B. hungerfordi* Spangler, and *B. pacificus* Carr. *Brychius albertanus* is placed as a junior subjective synonym of *B. hornii*. *Brychius hornii* is distributed across western Canada to Manitoba, possibly extending into Quebec, and south to California. *Brychius hungerfordi* is found in isolated populations in Michigan and southern Ontario. *Brychius pacificus* is found on the west coasts of Oregon and California.

Using a phylogenetic analysis on the external characters of adults of *Brychius* spp., *B. hornii* and *B. hungerfordi* form a sister-group and *B. elevatus* and *B. glabratus* form a sister-group. *Brychius pacificus* represents the basal lineage. By comparing these results with accepted geologic and geographic history, species of *Brychius* have arisen and diversified on Laurasia, displaying a Euramerican distribution. The origin of *B. hornii* and *B. hungerfordi* must have been before the advent of the Rocky Mountains, 45-80 mya. During the Wisconsinan glaciation, species of *Brychius* survived in glacial refugia: *B. pacificus* within the southern coastal refugia; *B. hornii* within the southwestern region of the United States, and perhaps other scattered refugium; and *B. hungerfordi* within the Mississippian refugium.

Acknowledgements

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Table 1. Position of sensillae on legs of larvae of *B. hornii* Crotch (instar II and III and *B. hungerfordi* Spangler (instar III) (Coleoptera: Haliplidae). Numbering corresponds to homologous adepagan setae (Bousquet and Goulet 1984; Nilsson 1987); numbering with an asterisk refers to additional setae; positions as in Wolfe and Roughley (1985): A, anterior; D, dorsal; Di, distal; P, posterior, Pr, proximal; V, ventral.

Sensilla	Position	Sensilla	Position	Sensilla	Position
CO ₁	DPr	TR _{*1}	A	FE _{*14}	AD
CO ₂	ADPr	TR _{*2}	AV	FE _{*15}	PPr
CO ₃	ADPr	TR _{*3}	AV	FE _{*16}	PV
CO ₄	APr	TR _{*4}	AVPR	FE _{*17}	PV
CO ₅	APr	TR _a	A	FE _{*18}	PD
CO ₆	A	TR _b	A	FE _{*19}	P
CO ₇	AV	TR _c	A	FE _{*20}	P
CO ₈	ADi	TR _d	A	FE _{*21}	P
CO ₉	ADi	TR _e	A	FE _{*22}	PD
CO ₁₀	AVDi	TR _f	P	FE _a	A
CO ₁₁	PVDi	TR _g	P		
CO ₁₂	DDi			TI ₁	D
CO ₁₃	P	FE ₁	DPr	TI ₂	ADDi
CO ₁₄	PPr	FE ₂	DDi	TI ₃	ADi
CO ₁₅	PPr	FE ₃	ADi	TI ₄	AVDi
CO ₁₆	DPr	FE ₄	PVDi	TI ₅	PVDi
CO ₁₇	PVPr	FE ₅	PDi	TI ₆	PDi
CO _{*1}	PDi	FE ₆	PDDi	TI ₇	PDDi
CO _{*2}	PDDi	FE ₇	AVDi	TI _{*1}	P
CO _{*3}	PDDi	FE ₈	AV	TI _a	P
CO _{*4}	PD	FE ₉	AV		
CO _{*5}	P	FE ₁₀	AVPr	TA ₁	DDi
CO _{*6}	PPr	FE _{*1}	DPr	TA ₂	ADDi
CO _{*7}	PDPPr	FE _{*2}	DPr	TA ₃	ADi
CO _{*8}	PVDi	FE _{*3}	DPr	TA ₄	AVDi
CO _{*9}	PV	FE _{*4}	D	TA ₅	PVDi
CO _a	A	FE _{*5}	D	TA ₆	PDi
		FE _{*6}	DDi	TA ₇	PDDi
TR ₁	D	FE _{*7}	AD		
TR ₂	ADi	FE _{*8}	A	Pretarsus ₁	AVPr
TR ₃	ADi	FE _{*9}	A	Pretarsus ₂	PVPr
TR ₄	VDi	FE _{*10}	ADDi		
TR ₅	PVDi	FE _{*11}	A		
TR ₆	PDi	FE _{*12}	ADi		
TR ₇	VDi	FE _{*13}	ADPr		

Table 2. Character matrix used for phylogenetic analysis of species of *Brychius* Thomson (Coleoptera: Haliplidae).

Characters (C): 1, mandible, right: (0) one apical tooth; (1) two apical teeth; 2, mandible, right: (0) no spines on basal projection; (1) few small spines on basal projection; (2) many distinct spines on basal projection; 3, maxilla, apical segment of galea: (0) lateral margins smooth; (2) lateral margins with irregularities; 4, labium, penultimate segment of labial palp: (0) lateral margins smooth; (1) lateral margins with irregularities; 5, labium, base: (0) square; (1) rectangular; (2) rounded; 6, pronotum, in lateral view: (0) no impression; (1) basal transverse impression; 7, pronotum, lateral margins: (0) no serration; (1) serration; 8, pronotal process, anterior lateral margins: (0) no margins; (1) thick margins; 9, prosternal process, anterior lateral margins: (0) parallel; (1) wedge-shaped; 10, metasternum, lateral view of ventral margin: (0) not impressed; (1) impressed; 11, metasternal process: (0) no impression; (1) large anterior median impression; 12, metasternal process: (0) no foveae; (1) two median foveae; 13, elytra: (0) no raised ridges; (1) raised longitudinal ridges; 14, elytra, humeral region: (0) rounded; (1) angled; 15, elytra, humeral margins: (0) no serration; (1) serration; 16, elytra, apex: (0) rounded; (1) acute; 17, aedeagus, median lobe: (0) rounded apex; (1) slender, pointed apex; 18, aedeagus, hood lobe: (0) attached to median lobe; (1) detached to median lobe; 19, abdomen, apical sternite: (0) blunt; (1) long, sharp point; 20, prothoracic leg: (0) no spines along ventral margin; (1) spines along ventral margin; 21, terminal abdominal sternite: (0) no incision; (1) incision; 22, pronotum: (0) lateral margins not parallel; (1) lateral margins parallel; 23, tarsal claws: (0) shorter than length of tarsomeres 2 and 3; (1) longer than length of tarsomeres 2 and 3; 24, larval antennomere 3: (0) longer than antennomere 2; (1) shorter than antennomere 2; 25, larval urogomphus: (0) straight; (1) curved; / = structure not recognized on species; ? = no specimens available for examination of structure.

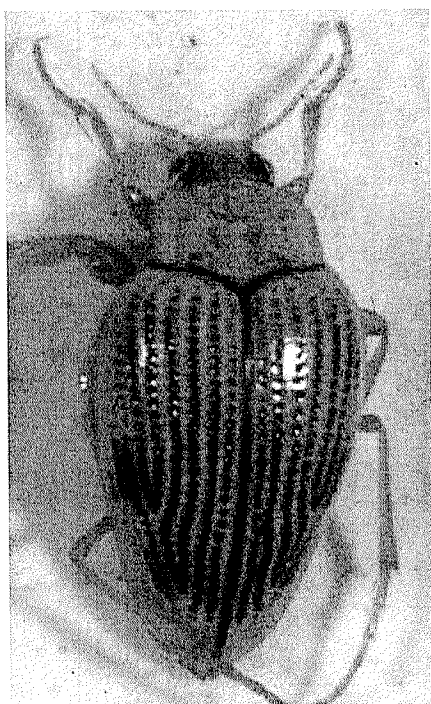
C	<i>B.</i> <i>hornii</i>	<i>B.</i> <i>hungerfordi</i>	<i>B.</i> <i>pacificus</i>	<i>B.</i> <i>elevatus</i>	<i>B.</i> <i>glabratus</i>	<i>H.</i> <i>immaculicollis</i>	<i>P.</i> <i>edentulus</i>
1	1	1	0	1	1	0	0
2	2	1	0	1	1	/	/
3	1	0	0	0	0	0	0
4	1	0	0	0	0	0	0
5	0	1	2	1	1	1	1
6	1	1	0	1	1	0	0
7	0	1	1	1	1	0	0
8	1	1	0	1	1	0	1
9	0	0	1	1	1	0	1
10	1	1	0	0	0	0	1
11	0	0	0	1	1	0	0
12	0	0	0	1	0	0	0
13	0	0	0	1	0	0	0
14	1	1	0	0	0	0	0
15	0	1	0	0	0	0	0
16	1	1	0	1	1	0	1
17	0	1	0	0	?	0	/
18	0	0	1	0	?	0	/

Table 2. continued.

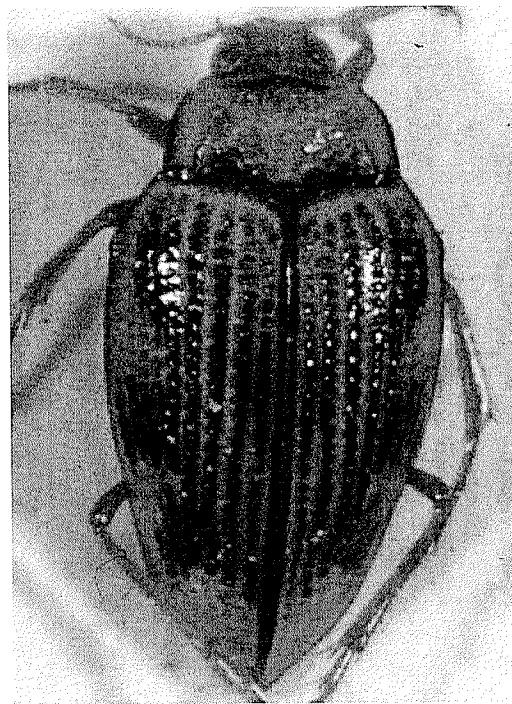
C	B. <i>hornii</i>	B. <i>hungerfordi</i>	B. <i>pacificus</i>	B. <i>elevatus</i>	B. <i>glabratus</i>	H. <i>immaculicollis</i>	P. <i>edentulus</i>
19	1	1	0	0	0	0	0
20	0	1	0	1	1	1	1
21	1	1	1	1	1	0	0
22	1	1	1	1	1	0	0
23	1	1	1	1	1	0	0
24	1	1	1	1	1	0	0
25	1	1	1	1	1	0	0

Table 3. Morphometric characters measured on adult specimens of Nearctic species of *Brychius* Thomson (Coleoptera: Haliplidae).

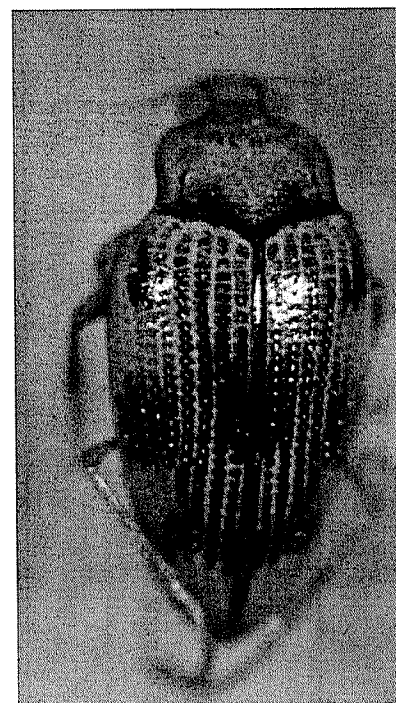
No.	Acronym	Character
1	H1	Maximum width across eyes
2	H2	Minimum width between eyes
3	Pr1	Maximum width of pronotum
4	Pr2	Length of pronotum on midline
5	E1	Length of elytra on midline
6	E2	Maximum width of elytra
7	Pst1	Minimum width of prosternal process
8	Pst2	Maximum width of prosternal process
9	Pst3	Length of prosternal process
10	M1	Maximum width of metasternal process
11	M2	Length of metasternal process
12	Ts	Length of transverse suture
13	Ac1	Length of anti-coxal plate
14	Ac2	Length of anti-coxal diagonal suture
15	Hc	Length of hind coxal plate
16	V	Length of fifth abdominal sternite
17	VI	Length of sixth abdominal sternite
18	VII	Length of seventh abdominal sternite
19	Ti	Length of tibia
20	Ta1	Length of first tarsomere
21	Ta2	Length of second tarsomere
22	Ta3	Length of third tarsomere
23	Ta4	Length of fourth tarsomere
24	Ta5	Length of fifth tarsomere
25	PP	Pronotal proportion, defined as the ratio Pr1/Pr2
26	RP	Relative pronotal length, defined as the ratio Pr2/E1



a)



b)



c)

1.0 mm

Figure 1. Dorsal images of adult Nearctic *Brychius* spp. (Coleoptera: Halipilidae): a) *B. hornii* Crotch; b) *B. hungerfordi* Spangler; c) *B. pacificus* Carr.

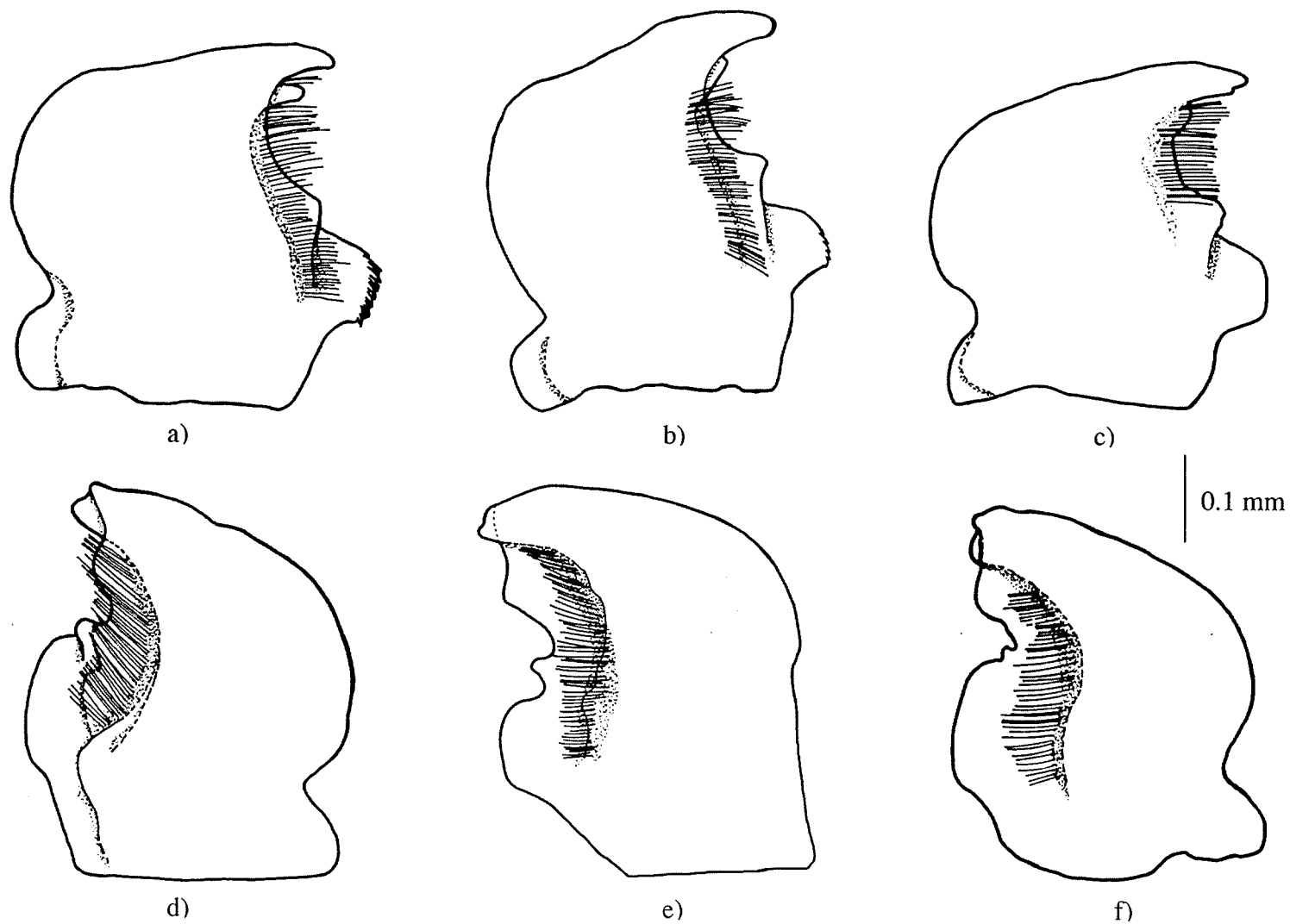


Figure 2. Mandibles of adult female Nearctic *Brychius* spp. (Coleoptera: Haliplidae), ventral view: *B. hornii* Crotch: a) right, d) left; *B. hungerfordi* Spangler: b) right, e) left; *B. pacificus* Carr: c) right, f) left.

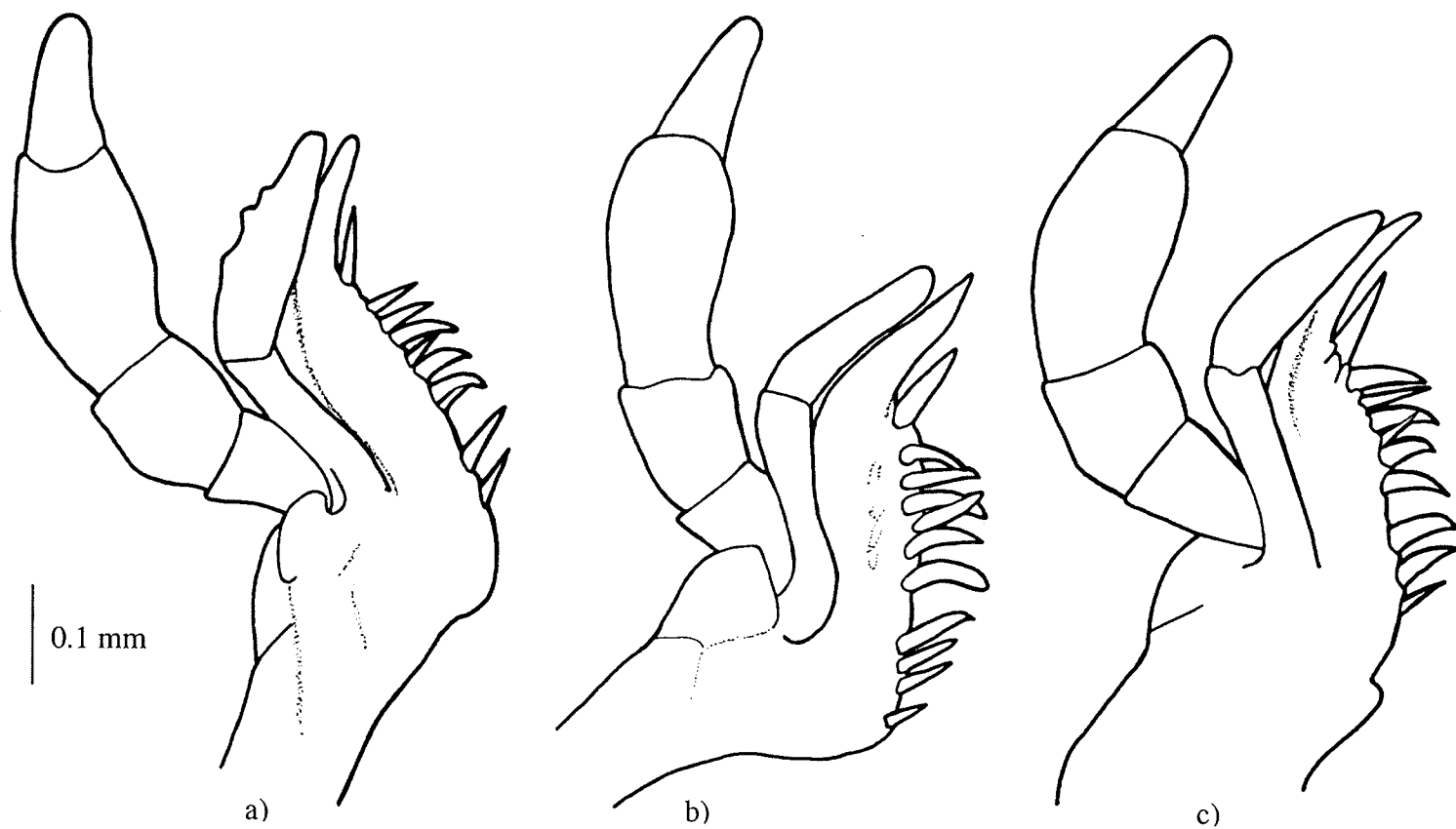


Figure 3. Maxilla of adult Nearctic *Brychius* spp. (Coleoptera: Haliplidae); left side, ventral view: a) *B. hornii* Crotch; b) *B. hungerfordi* Spangler; c) *B. pacificus* Carr.

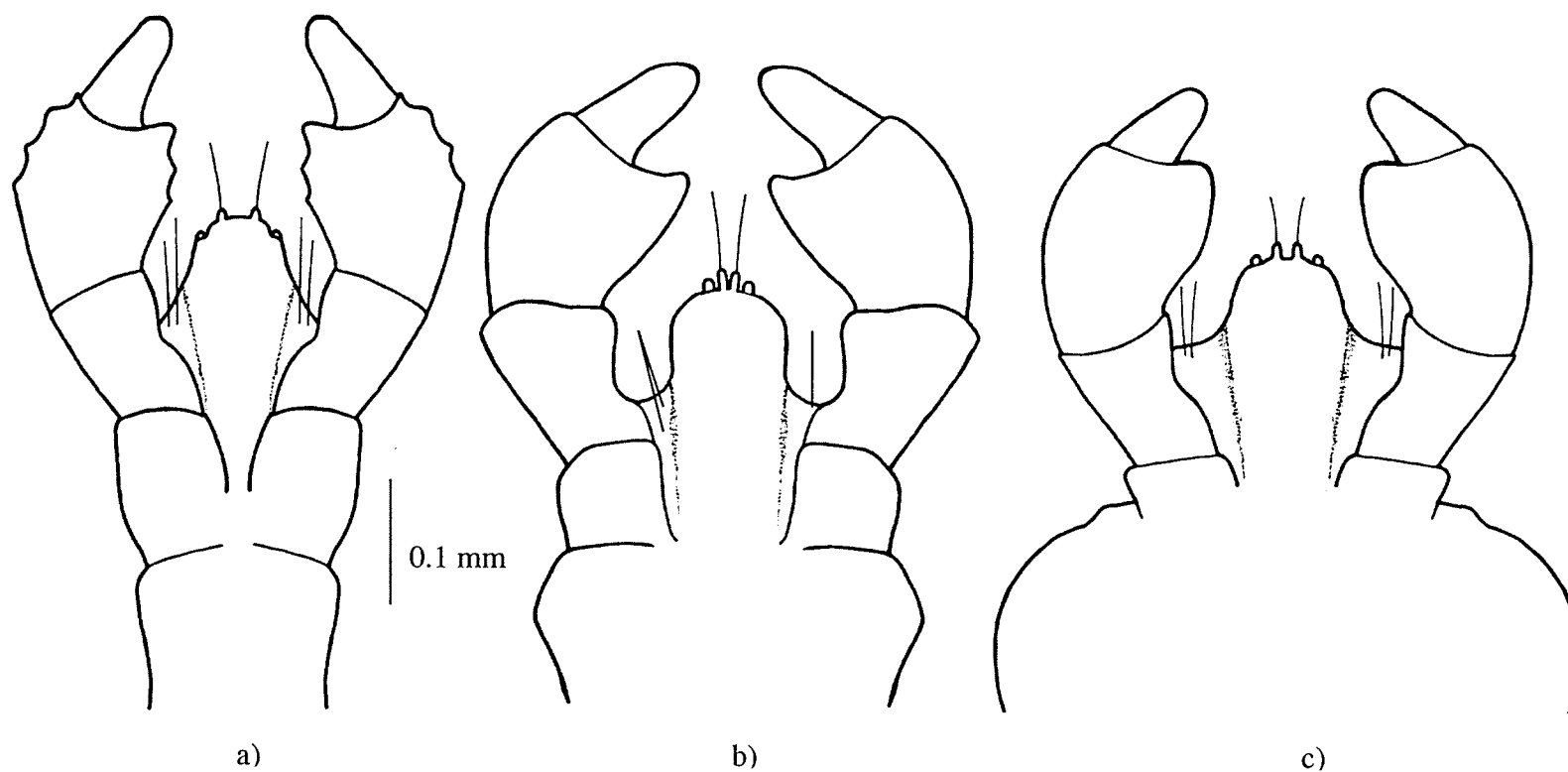


Figure 4. Labium of adult Nearctic *Brychius* spp. (Coleoptera: Haliplidae), dorsal view: a) *B. hornii* Crotch; b) *B. hungerfordi* Spangler; c) *B. pacificus* Carr.

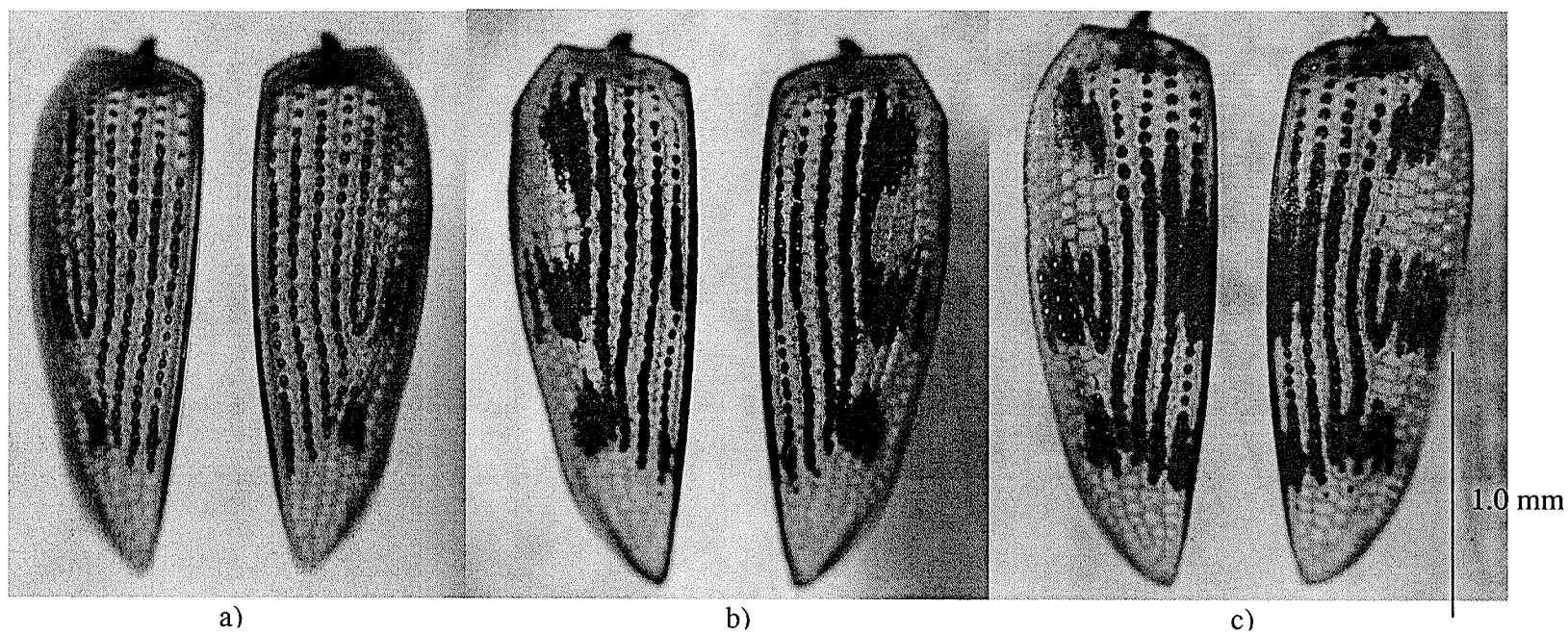


Figure 5. Dorsal view of elytra of adult Nearctic *Brychius* spp. (Coleoptera: Haliplidae): a) *B. hornii* Crotch; b) *B. hungerfordi* Spangler; c) *B. pacificus* Carr.

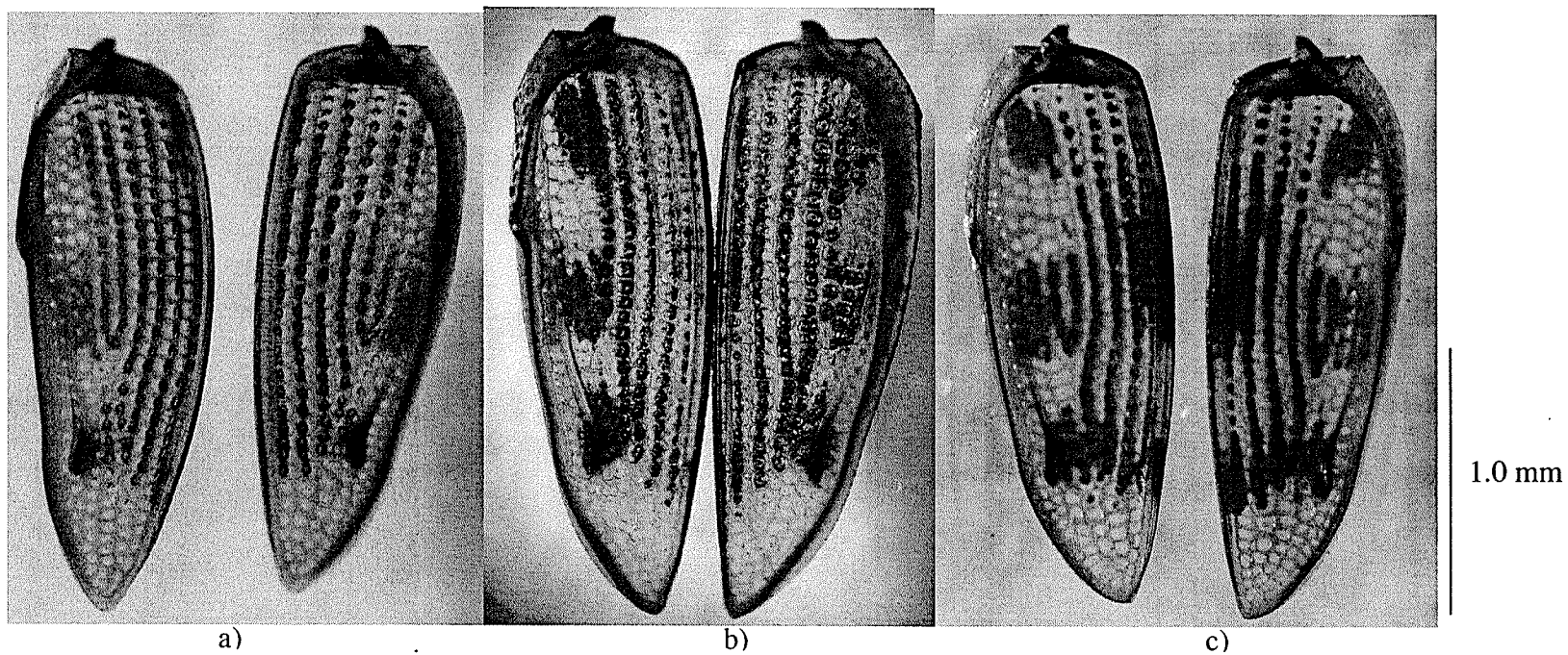


Figure 6. Ventral view of elytra of adult Nearctic *Brychius* spp. (Coleoptera: Haliplidae): a) *B. hornii* Crotch; b) *B. hungerfordi* Spangler; c) *B. pacificus* Carr.

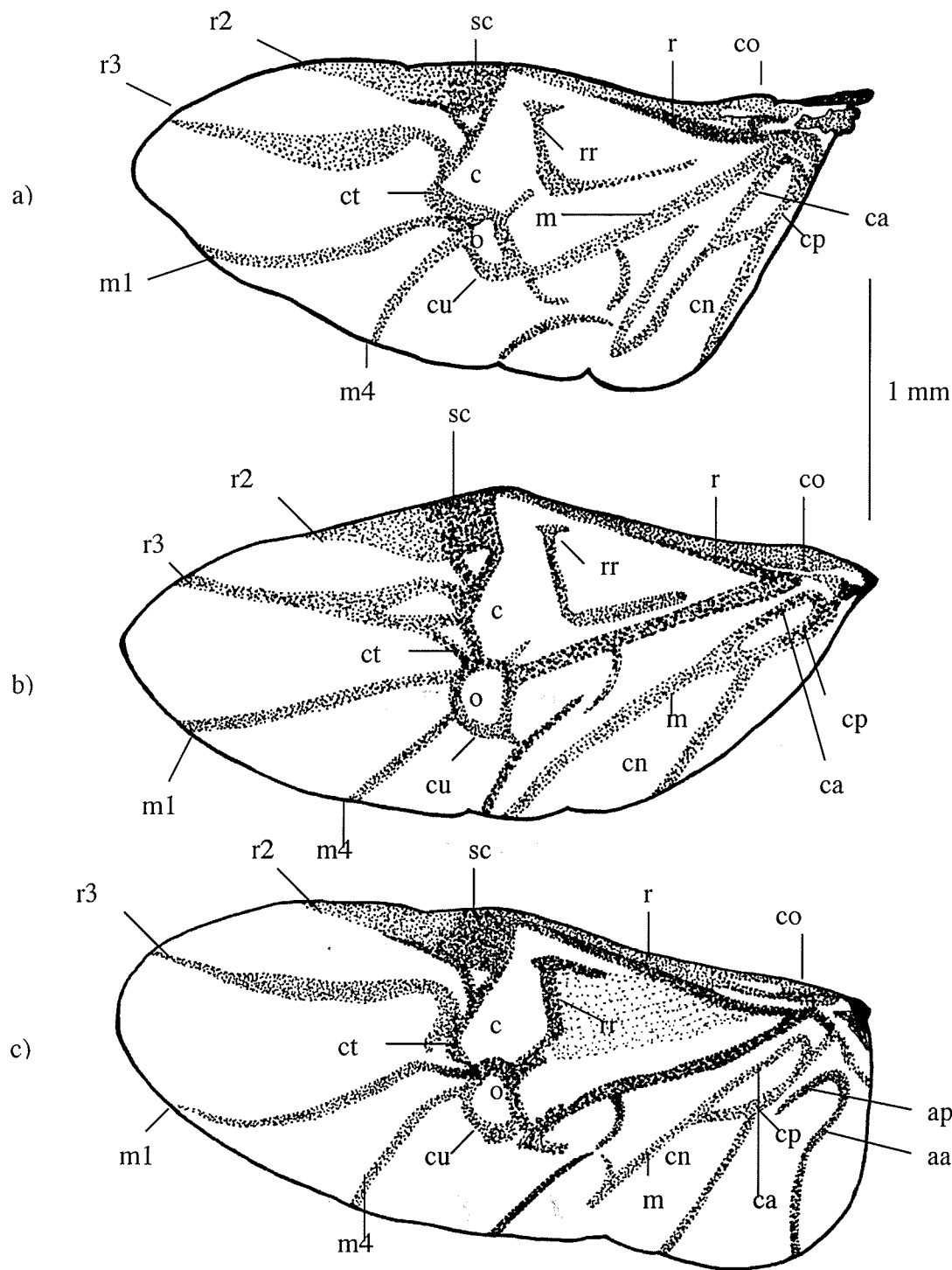


Figure 7. Hind wing of adult Nearctic *Brychius* spp. (Coleoptera: Halipilidae): a) *B. hornii* Crotch; b) *B. hungerfordi* Spangler; c) *B. pacificus* Carr. aa-anterior anal vein, ap-posterior anal vein; c-costal cell; ca-anterior cubitus; cn-cuneus cell; co-costa; cp-posterior cubitus; ct-transverse costal; cu-cubitus; m-media; m1, m4-residual extensions of media; o-oblong cell; r-radius; r2, r3-residual extensions of radius; rr-recurrent radius; sc-subcosta (labeling follows Francisco 1979).

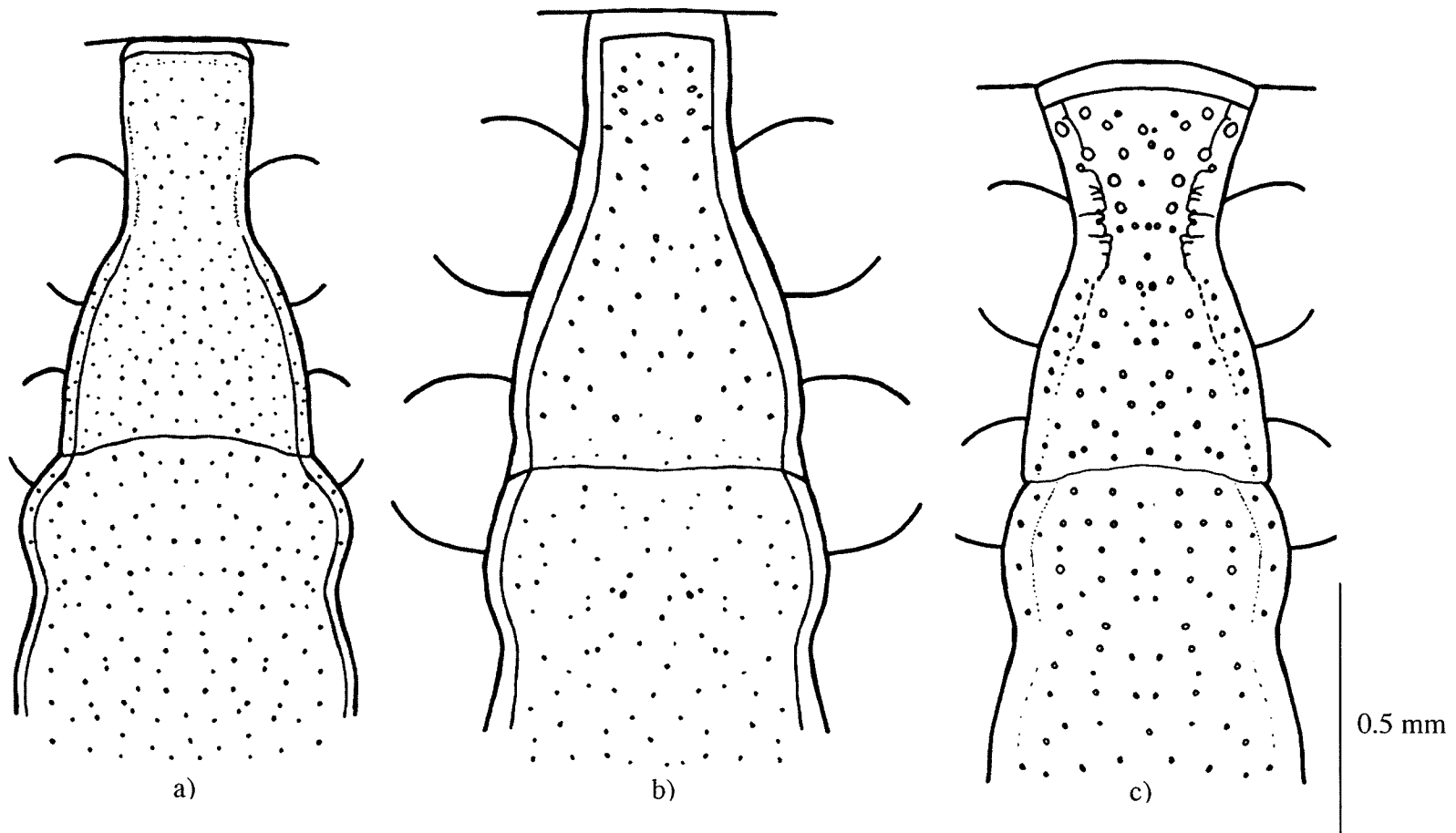


Figure 8. Prosternal and metasternal processes of adult Nearctic *Brychius* spp. (Coleoptera: Haliplidae): a) *B. hornii* Crotch; b) *B. hungerfordi* Spangler; c) *B. pacificus* Carr.

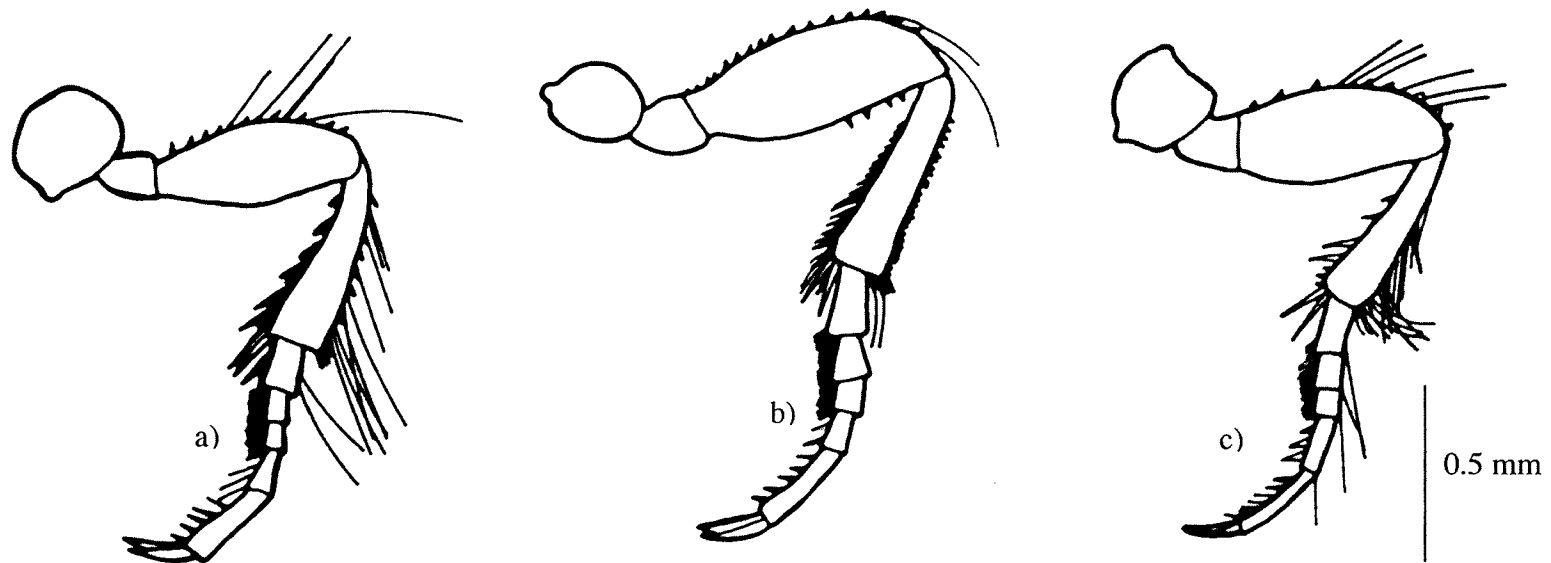


Figure 9. Prothoracic leg of adult male Nearctic *Brychius* spp. (Coleoptera: Haliplidae), right, dorsal: a) *B. hornii* Crotch; b) *B. hungerfordi* Spangler; c) *B. pacificus* Carr.

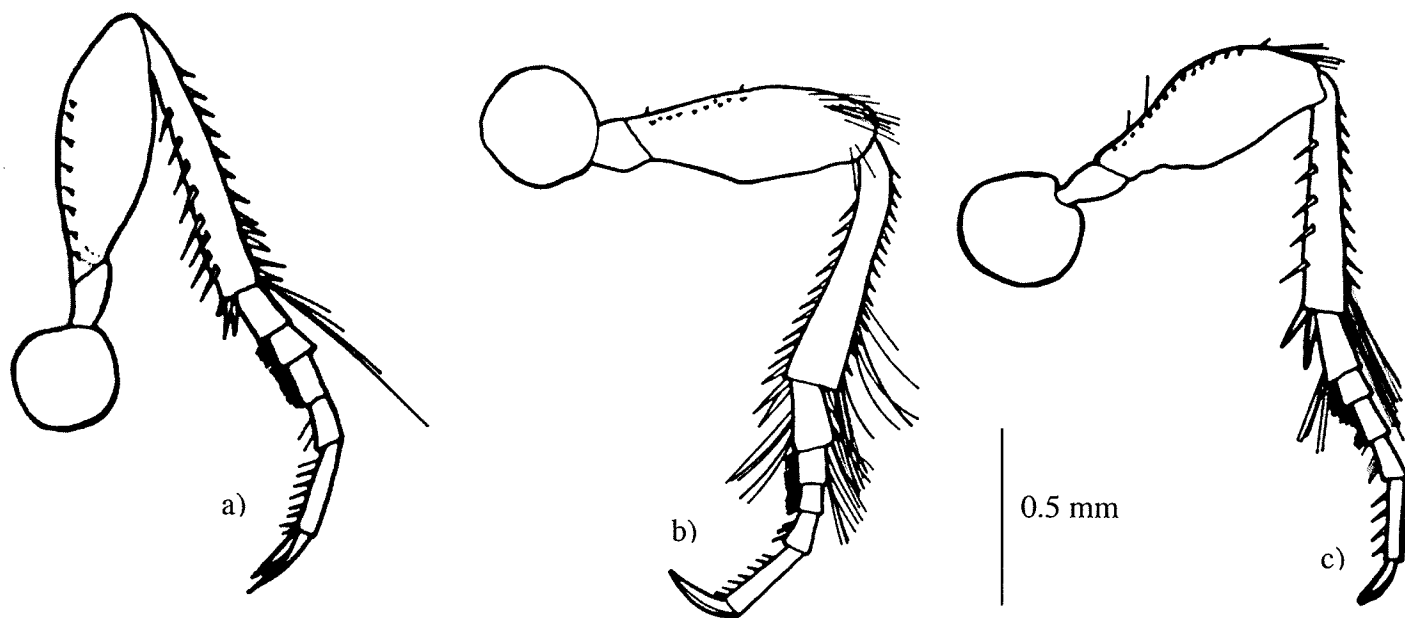


Figure 10. Mesothoracic leg of adult male Nearctic *Brychius* spp. (Coleoptera: Haliplidae), right, dorsal: a) *B. hornii* Crotch, b) *B. hungerfordi* Spangler; c) *B. pacificus* Carr.

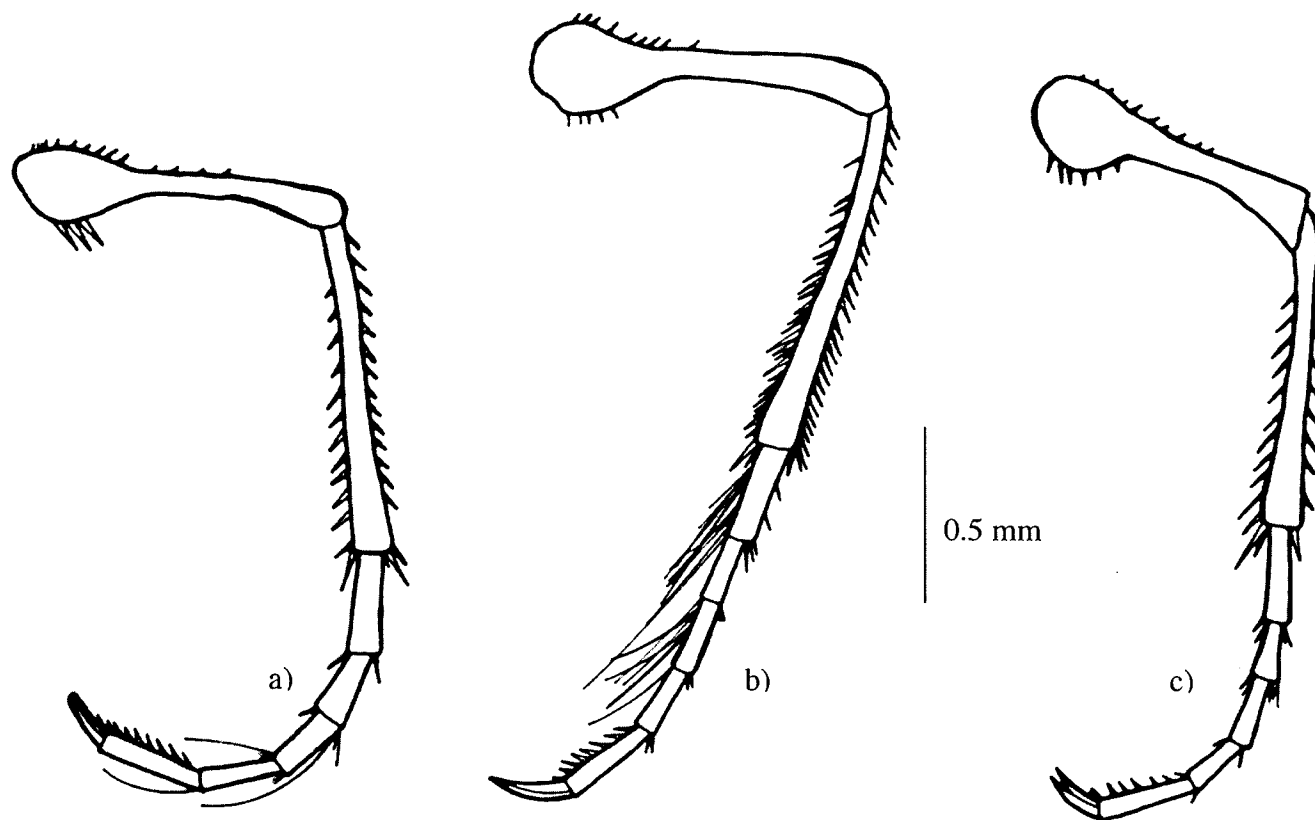


Figure 11. Metathoracic leg of adult male Nearctic *Brychius* spp. (Coleoptera: Halipilidae), right, dorsal: a) *B. hornii* Crotch, b) *B. hungerfordi* Spangler; c) *B. pacificus* Carr.

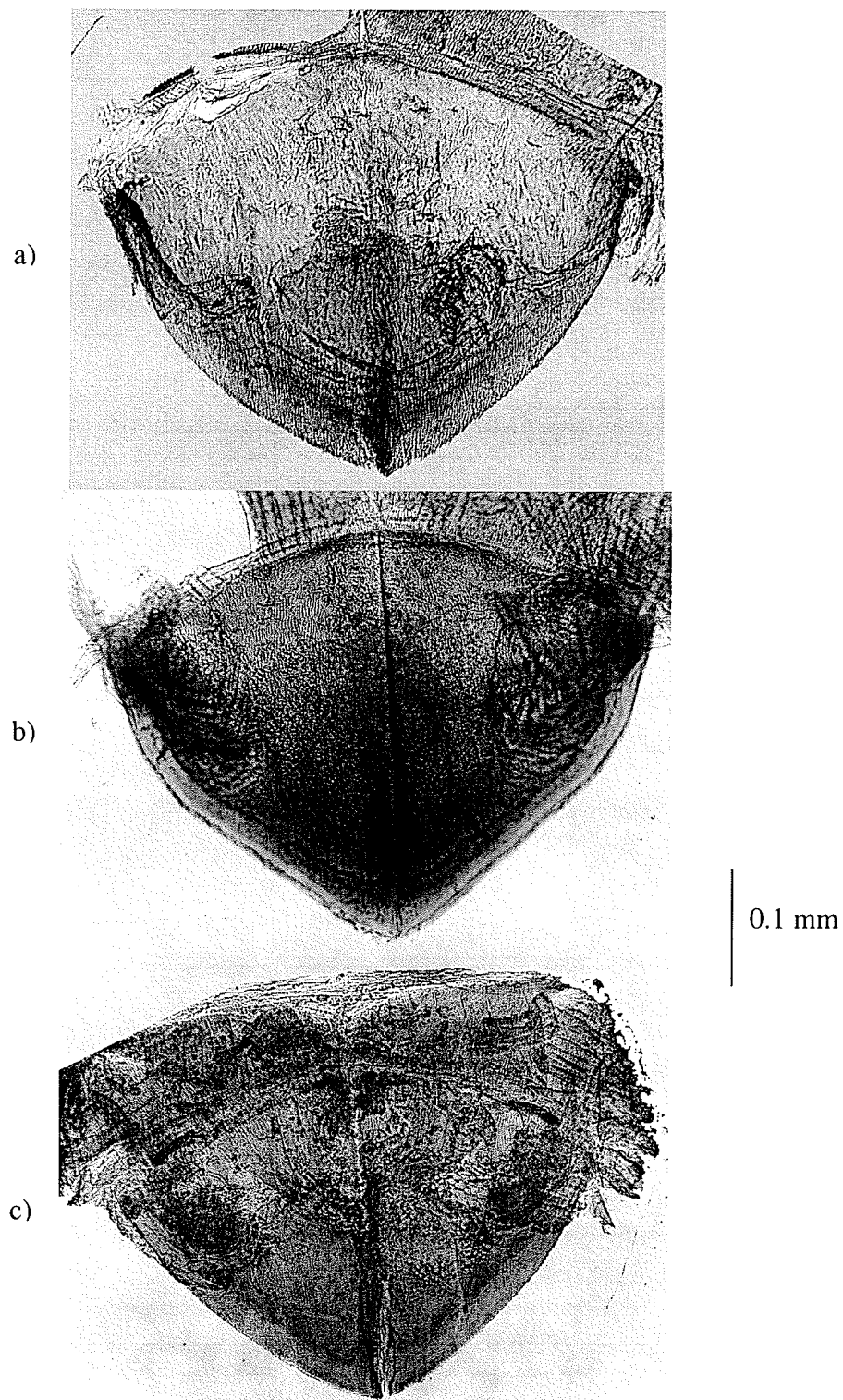


Figure 12. Tergite VIII of female Nearctic *Brychius* spp. (Coleoptera: Haliplidae): a) *B. hornii* Crotch; b) *B. hungerfordi* Spangler; c) *B. pacificus* Carr.

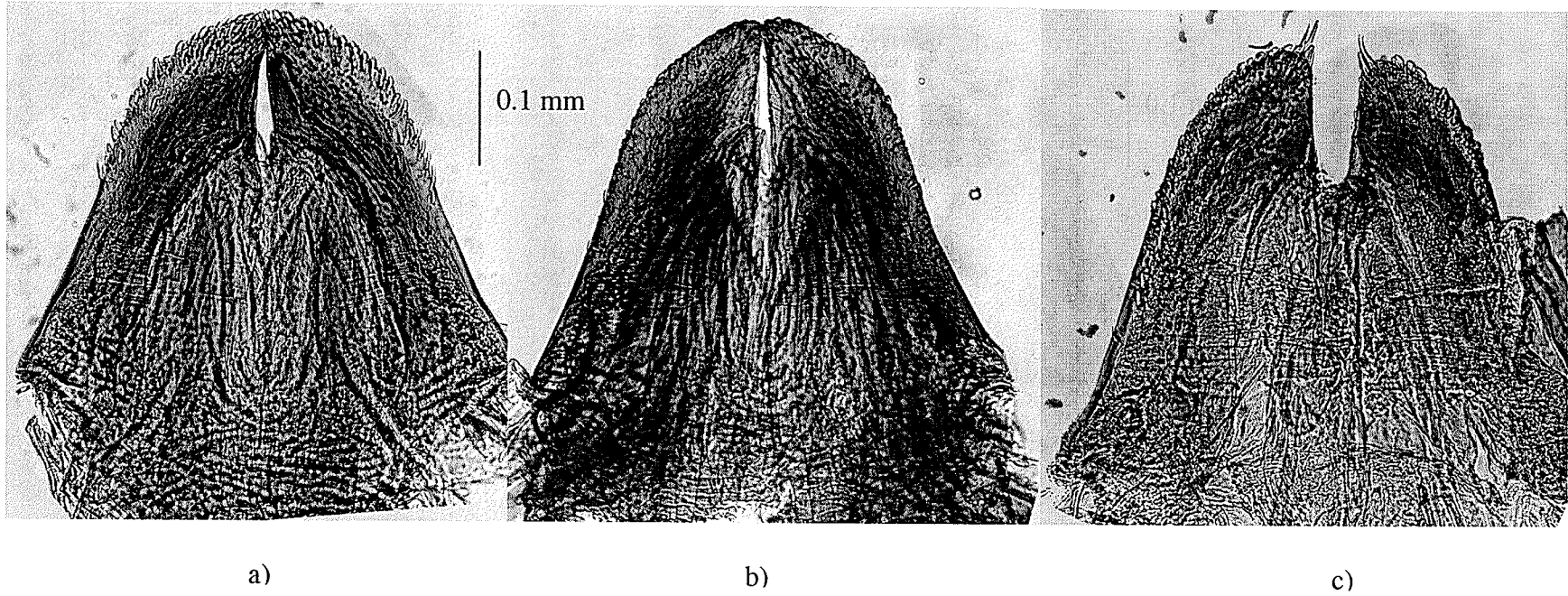


Figure 13. Gonocoxa of Nearctic *Brychius* spp. (Coleoptera: Haliplidae); a) *B. hornii* Crotch; b) *B. hungerfordi* Spangler; c) *B. pacificus* Carr.

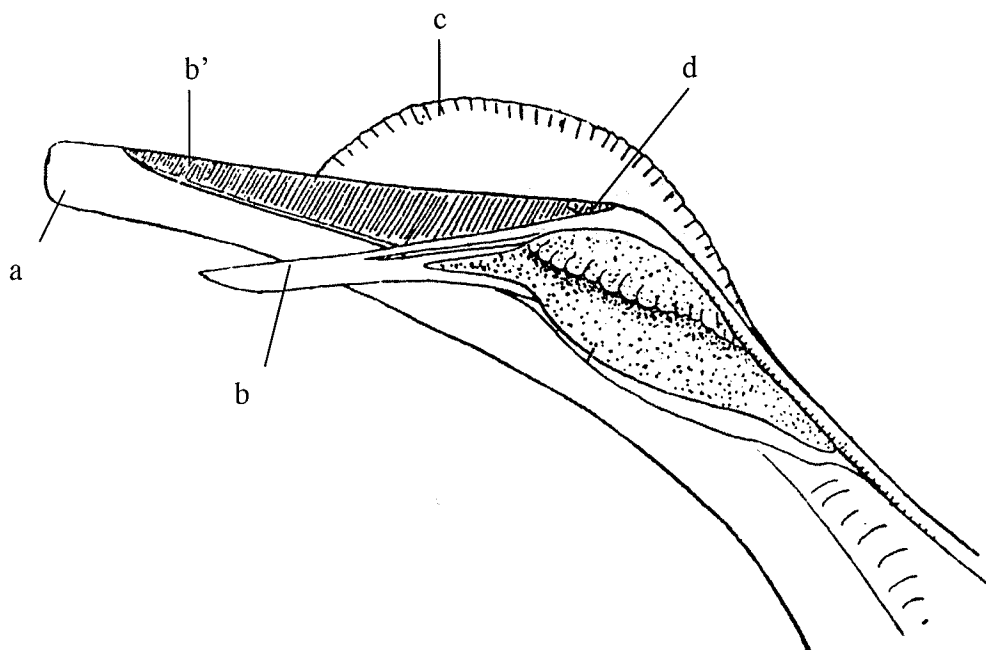


Figure 14. Aeadeagus of *Halipus* sp. (Coleoptera: Halipidae), with the operculum (b) moved out of position, to show the depression (b') in which it lies and the opening to the ductus ejaculatorius (d); a) median lobe; b) operculum (tongue); b') depression; c) hood lobe; d) ductus ejaculatorius (modified from Balfour-Browne 1915).

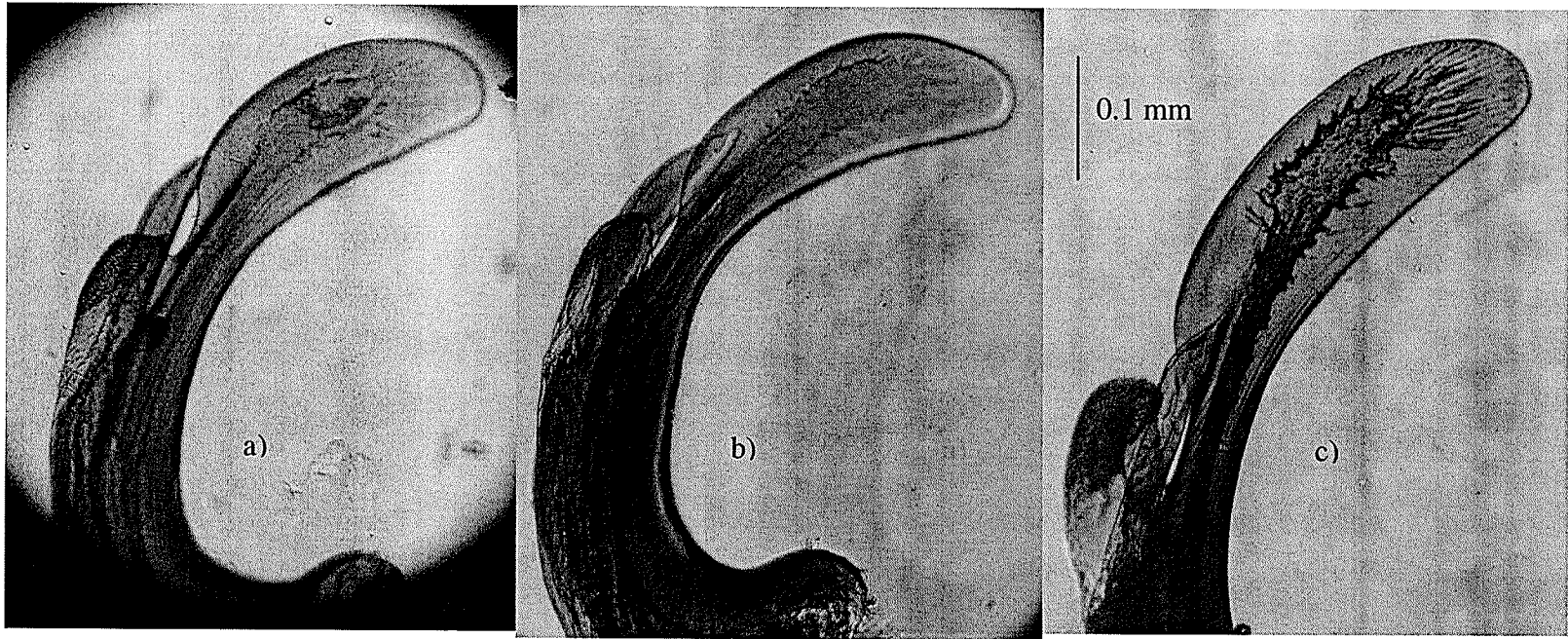


Figure 15. Aedeagus of Nearctic *Brychius* spp. (Coleoptera: Haliplidae): a) *B. hornii* Crotch; b) *B. hungerfordi* Spangler; c) *B. pacificus* Carr.

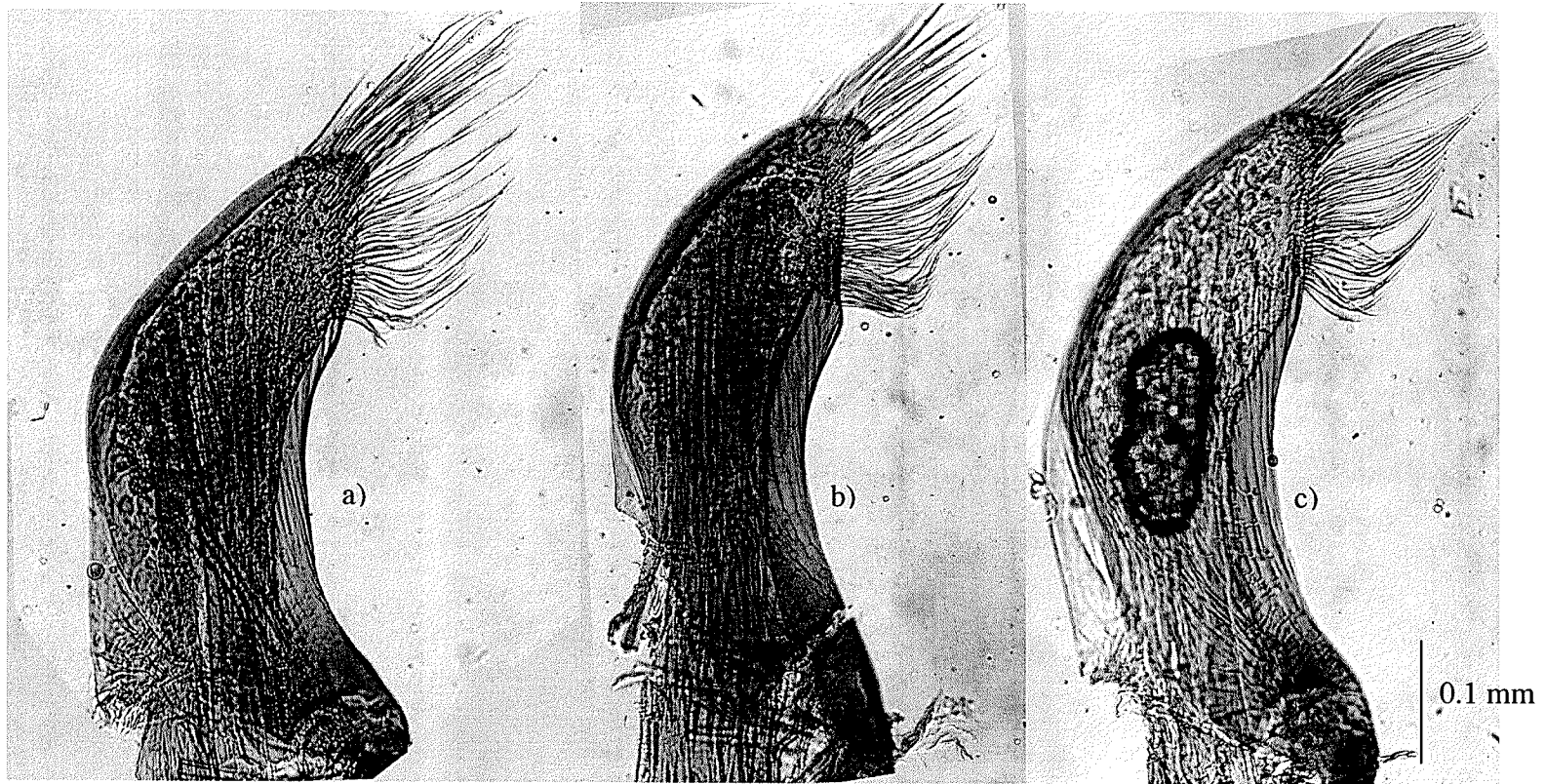


Figure 16. Left paramere of Nearctic *Brychius* spp. (Coleoptera: Haliplidae): a) *B. hornii* Crotch; b) *B. hungerfordi* Spangler; c) *B. pacificus* Carr.

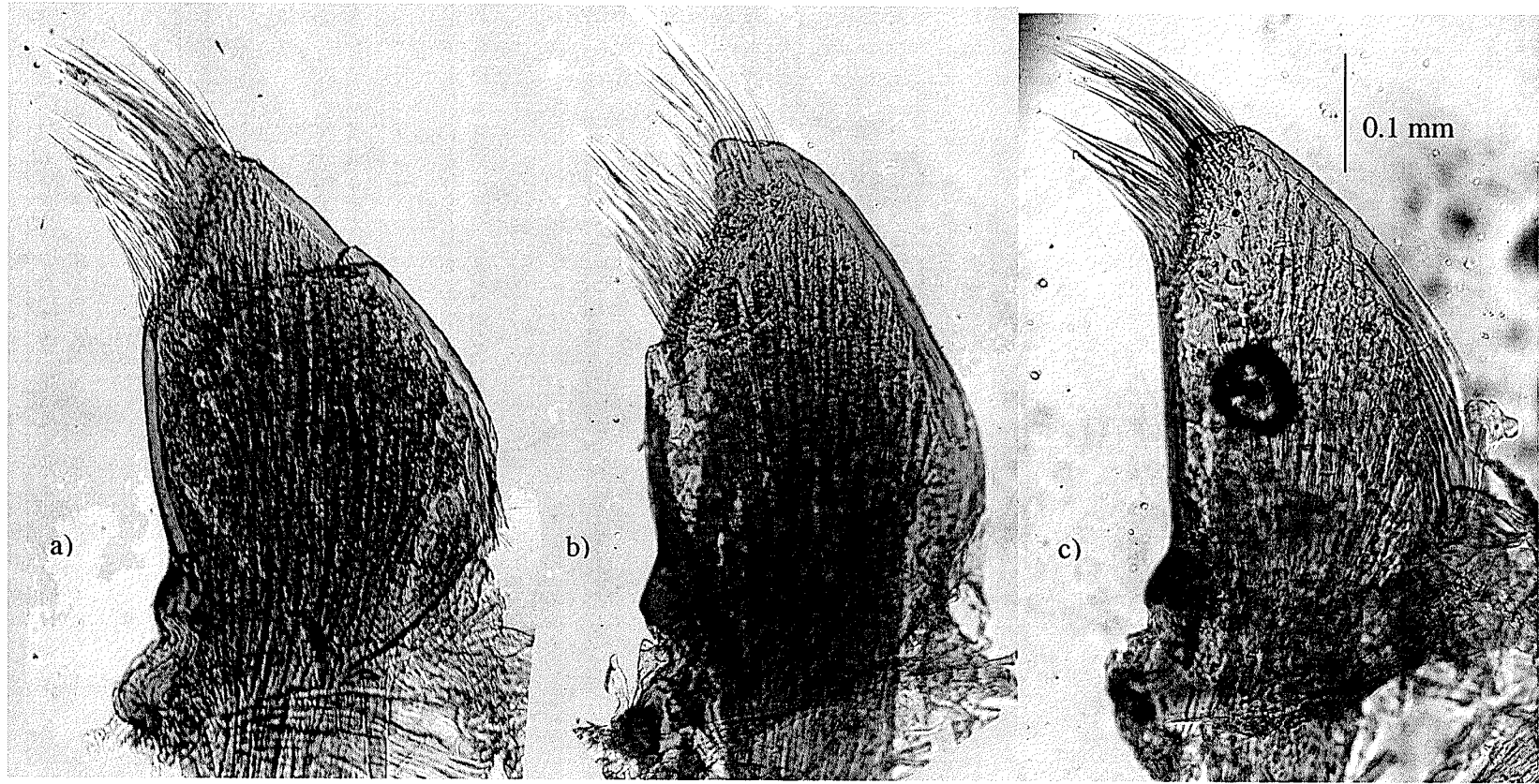


Figure 17. Right paramere of Nearctic *Brychius* spp. (Coleoptera: Haliplidae); a) *B. hornii* Crotch; b) *B. hungerfordi* Spangler; c) *B. pacificus* Carr.

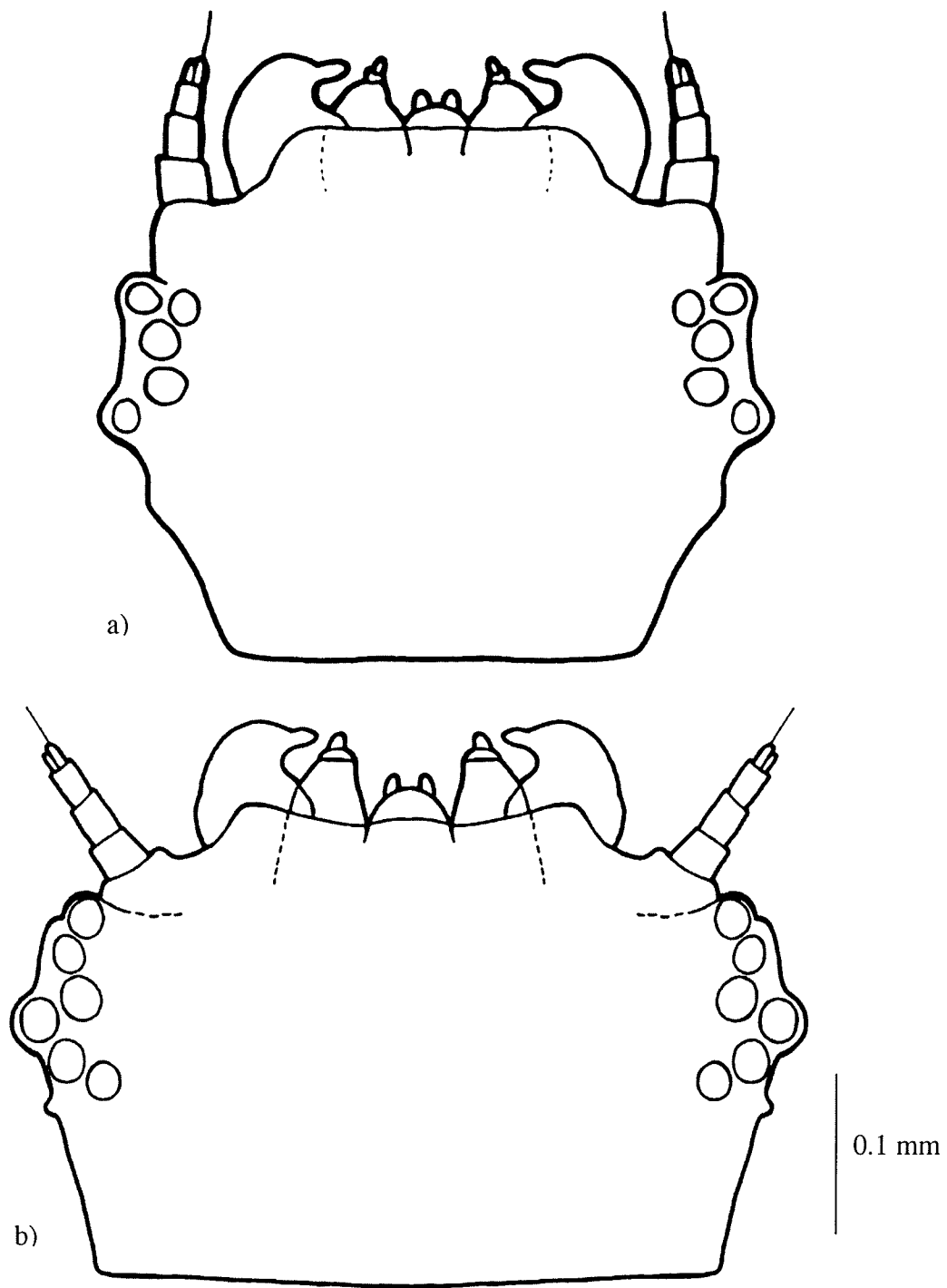


Figure 18. Dorsal view of the head of: a) *Brychius hornii* Crotch; b) *Brychius hungerfordi* Spangler (Coleoptera: Haliplidae), third instar.

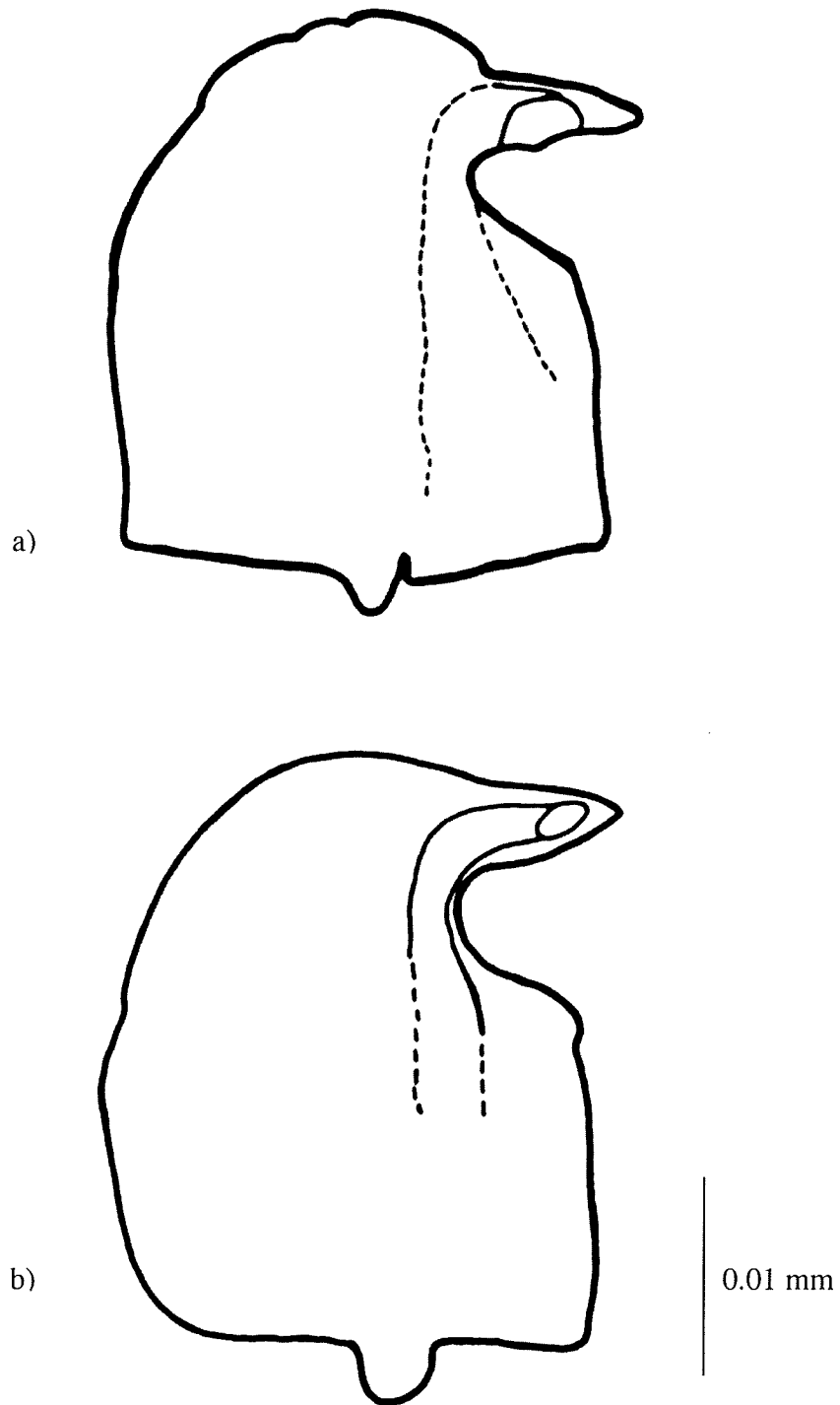


Figure 19. Ventral view of the right mandible of: a) *Brychius hornii* Crotch; b) *Brychius hungerfordi* Spangler (Coleoptera: Haliplidae), third instar.

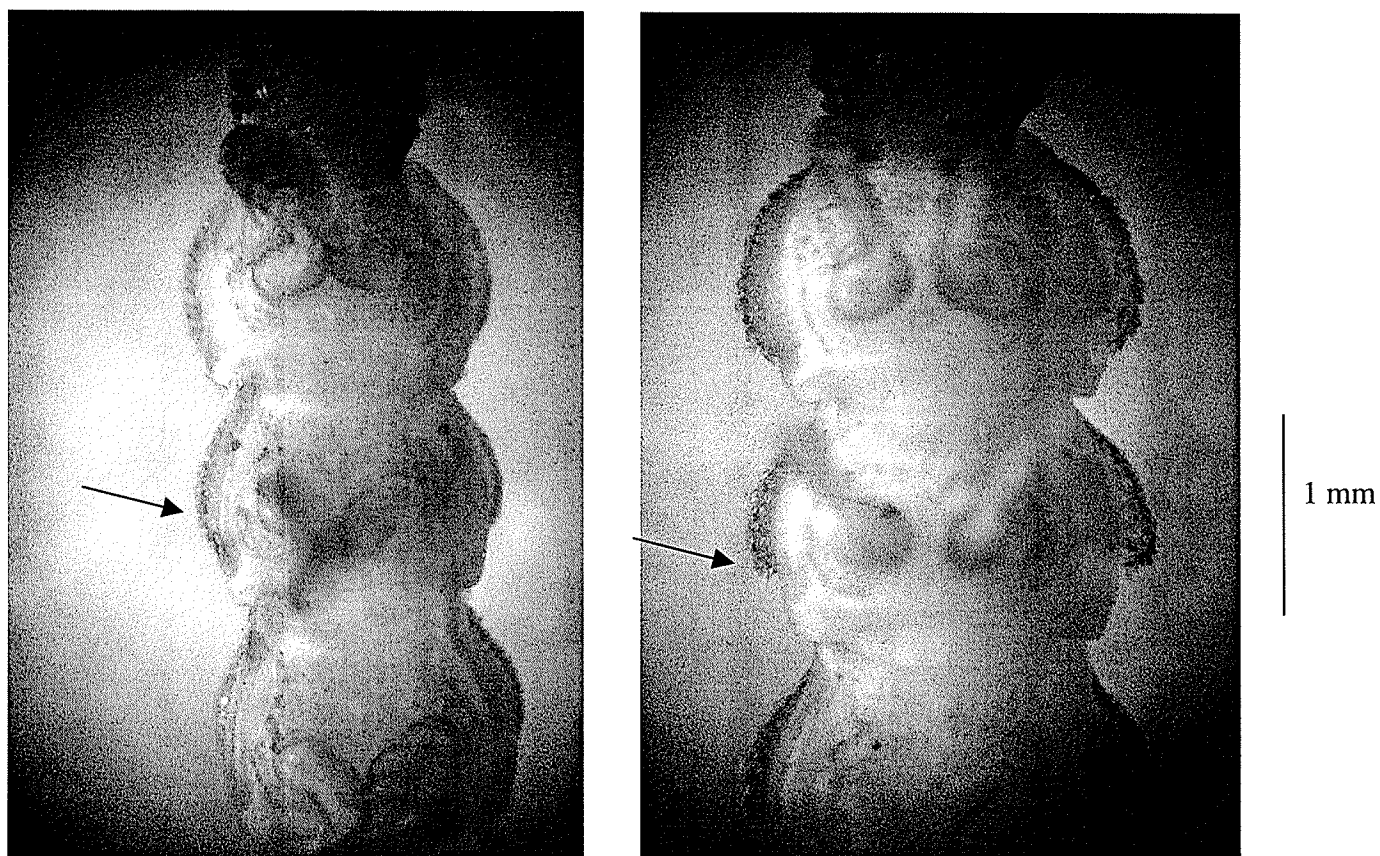


Figure 20. Ventral view of the thorax showing tergal extensions: a) *Brychius hornii* Crotch; b) *Brychius hungerfordi* Spangler (Coleoptera: Haliplidae), third instar.

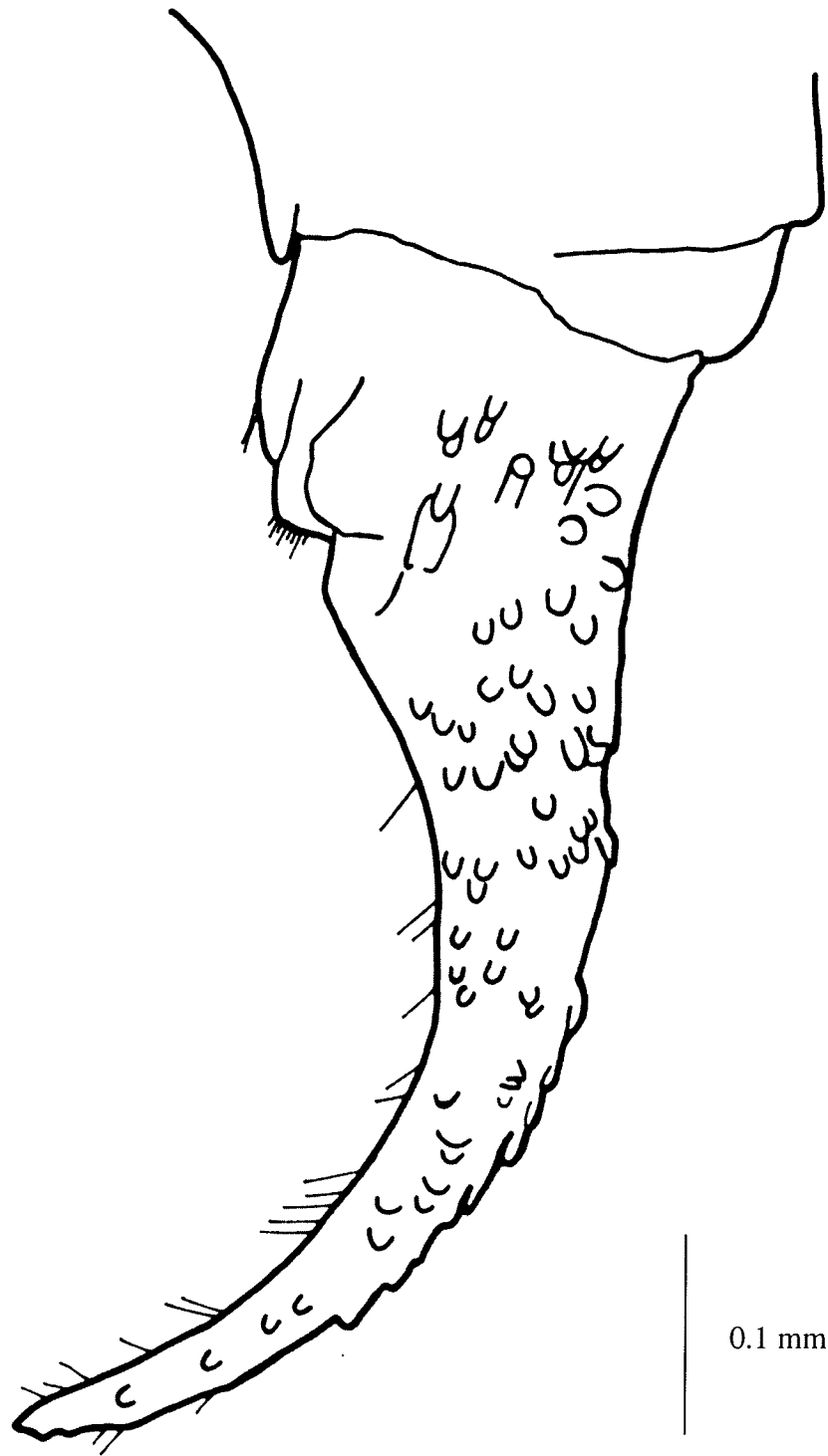


Figure 21. Urogomphus of third instar larva of *Brychius hornii* Crotch (Coleoptera: Haliplidae).

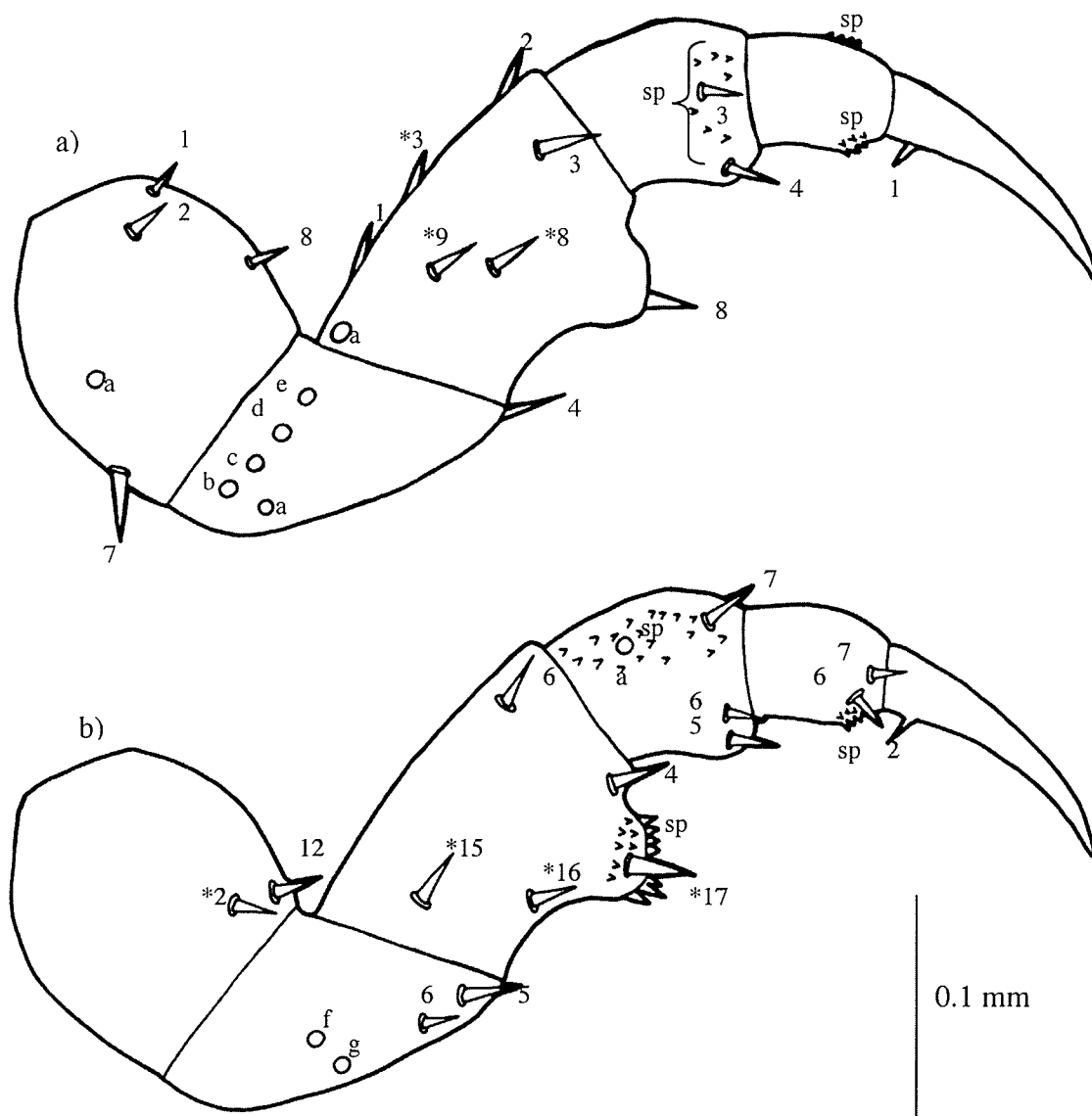


Figure 22. Leg chaetotaxy of right prothoracic leg of the larva of *Brychius hornii* Crotch (Coleoptera: Haliplidae), second instar: a) anterior; b) posterior; numbers refer to setae, letters refer to campaniform sensillae, *=secondary setae, sp=spinulae.

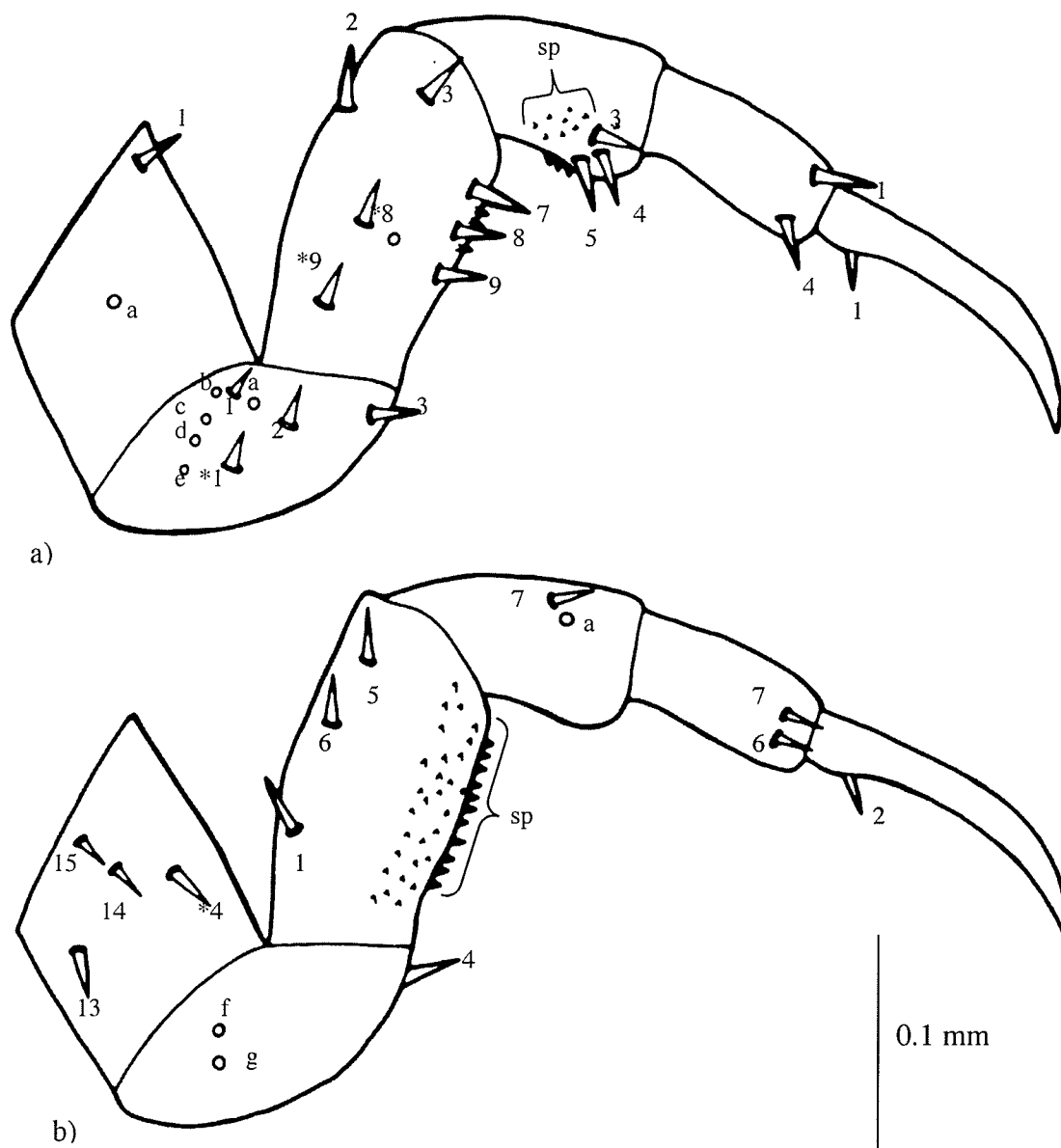


Figure 23. Leg chaetotaxy of right mesothoracic leg of the larva of *Brychius hornii* Crotch (Coleoptera: Halipidae), second instar: a) anterior; b) posterior; numbers refer to setae, letters refer to campaniform sensillae, *=secondary setae, sp=spinulae.

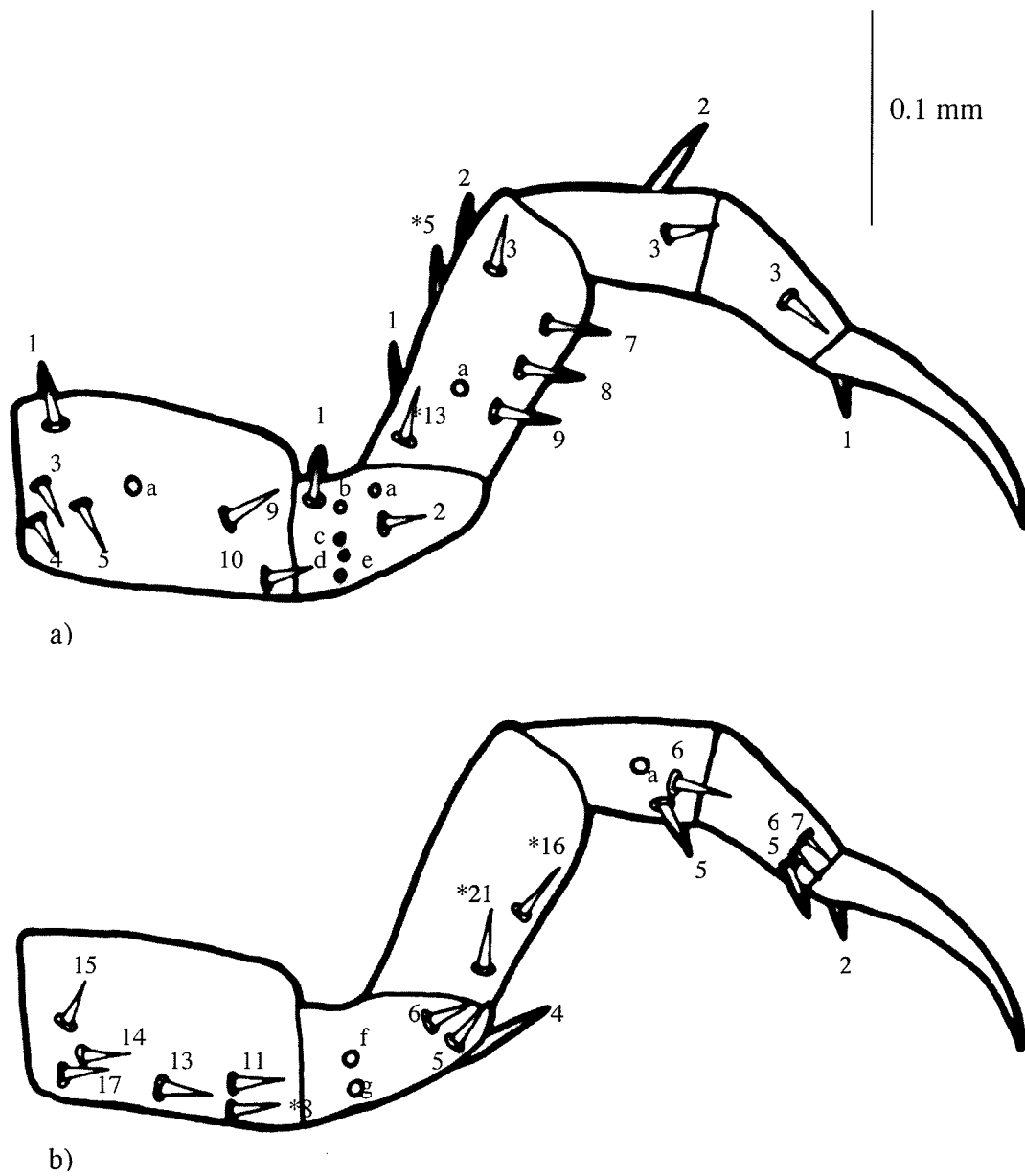


Figure 24. Leg chaetotaxy of right metathoracic leg of the larva of *Brychius hornii* Crotch (Coleoptera: Haliplidae), second instar: a) anterior; b) posterior; numbers refer to setae, letters refer to campaniform sensillae, *=secondary setae, sp=spinulae.

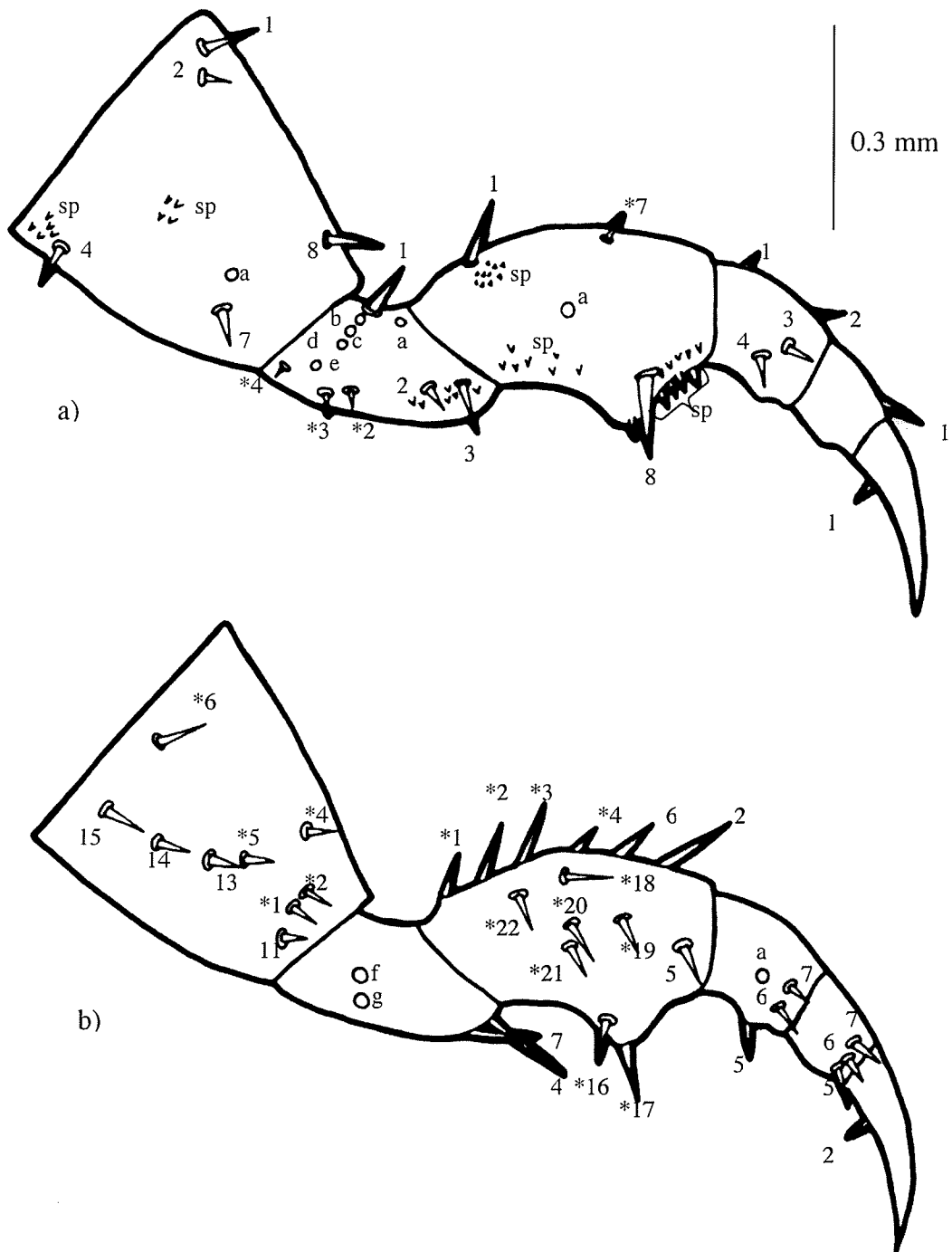


Figure 25. Leg chaetotaxy of right prothoracic leg of the larva of *Brychius hornii* Crotch (Coleoptera: Halipilidae), third instar: a) anterior; b) posterior; numbers refer to setae, letters refer to campaniform sensillae, *=secondary setae, sp=spinulae.

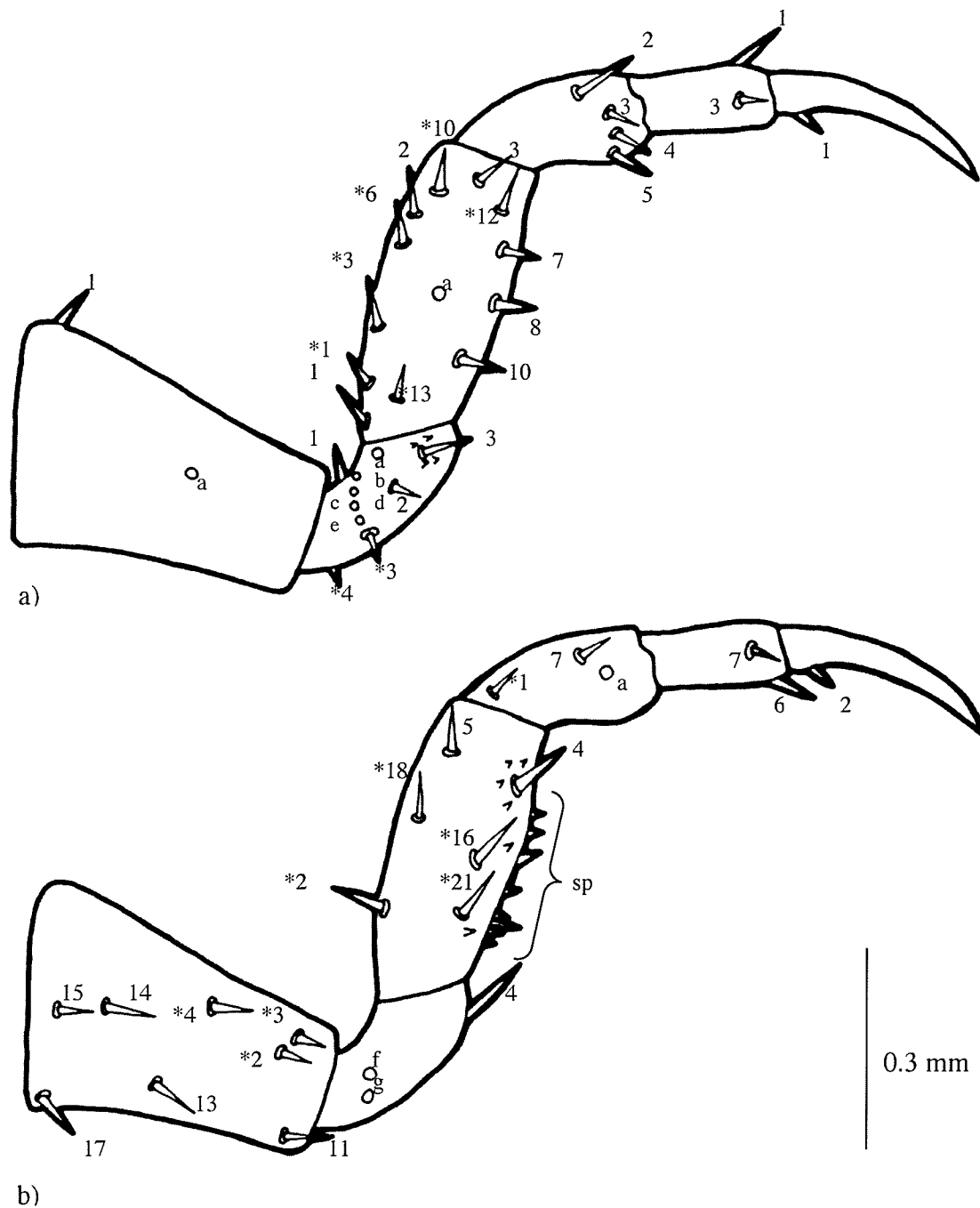


Figure 26. Leg chaetotaxy of right mesothoracic leg of the larva of *Brychius hornii* Crotch (Coleoptera: Halipilidae), third instar: a) anterior; b) posterior; numbers refer to setae, letters refer to campaniform sensillae, *=secondary setae, sp=spinulae.

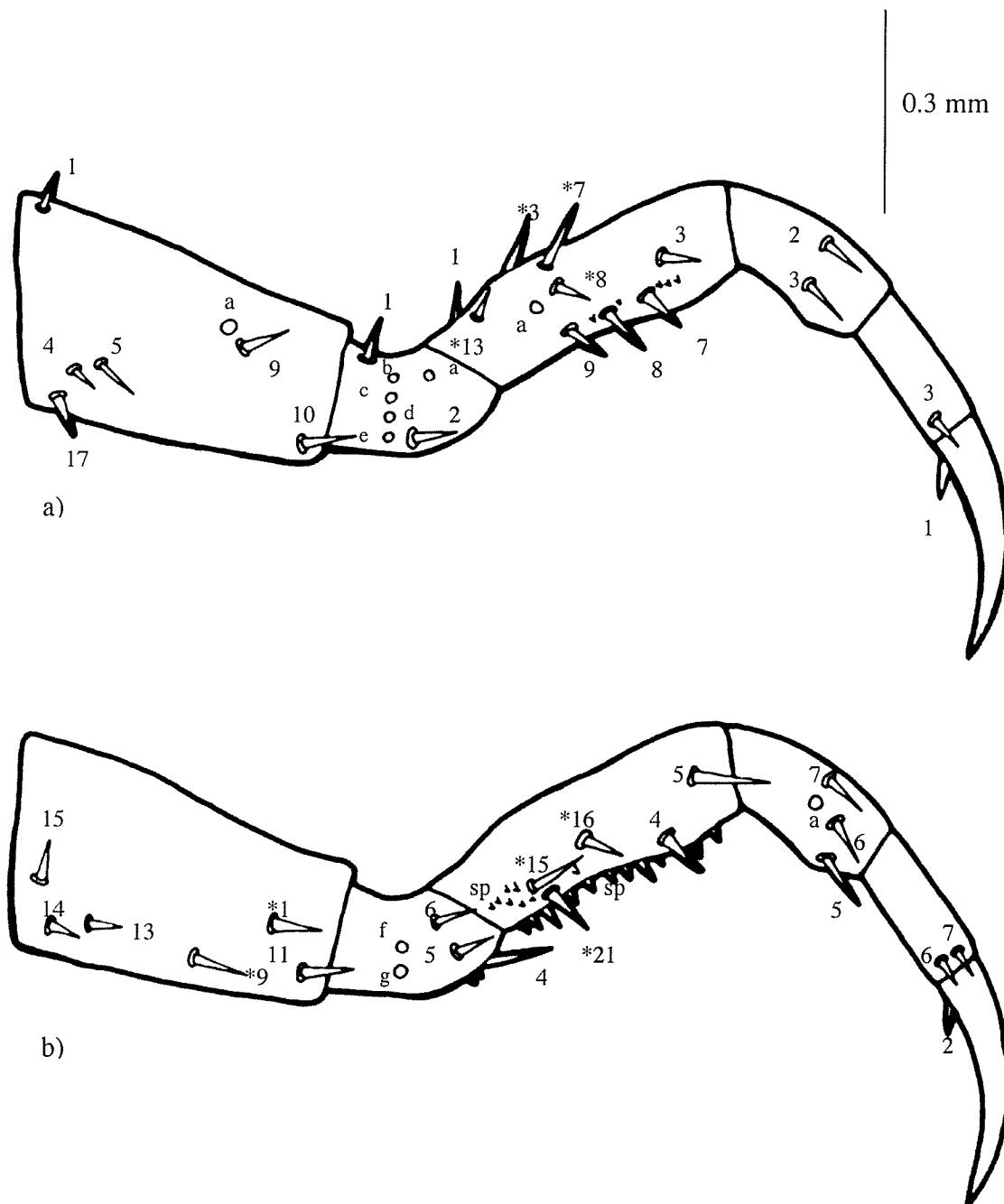


Figure 27. Leg chaetotaxy of right metathoracic leg of the larva of *Brychius hornii* Crotch (Coleoptera: Halipilidae), third instar: a) anterior, b) posterior; numbers refer to setae, letters refer to campaniform sensillae, *=secondary setae, sp=spinulae.

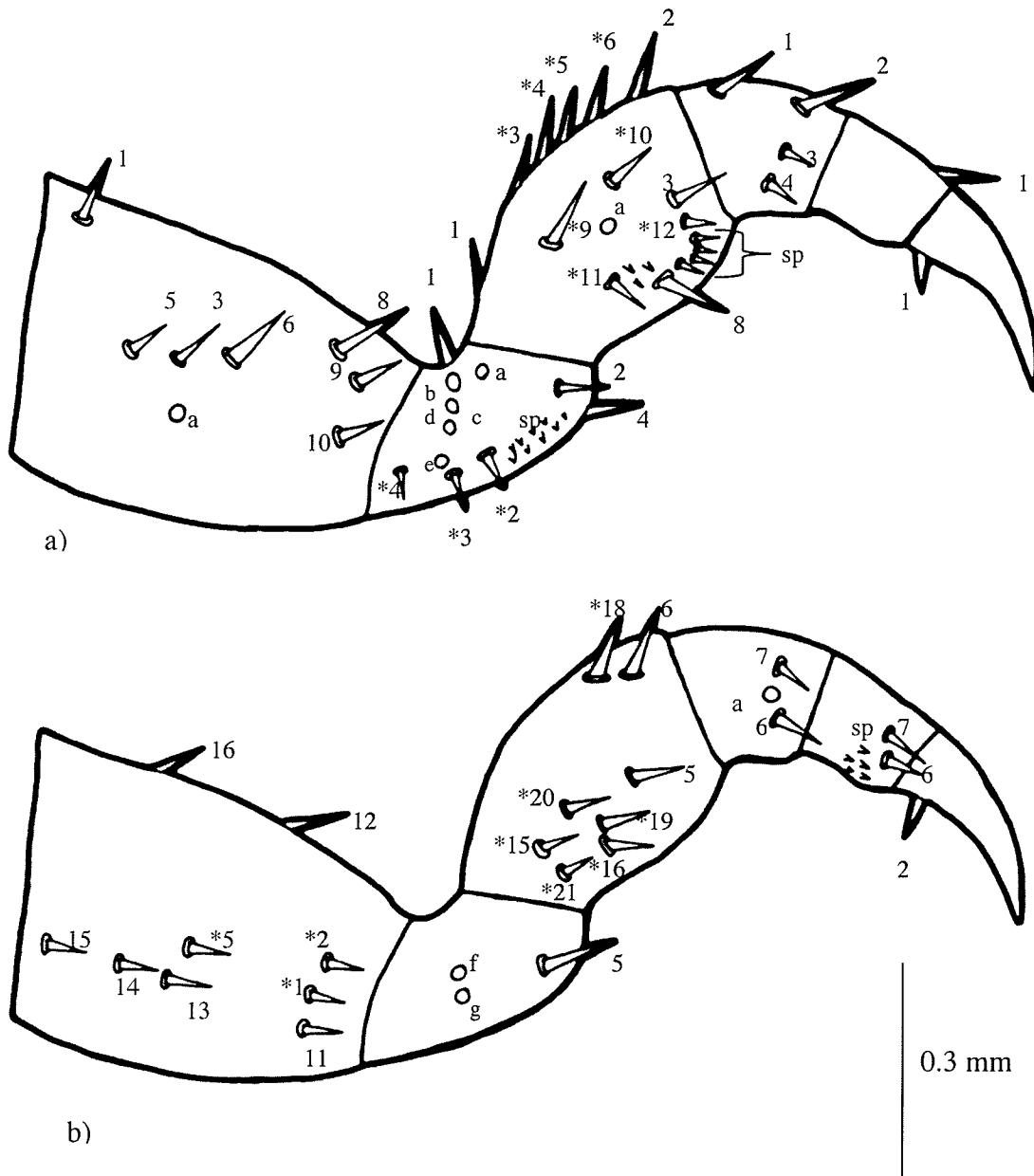


Figure 28. Leg chaetotaxy of right prothoracic leg of the larva of *Brychius hungerfordi* Spangler (Coleoptera: Haliplidae), third instar: a) anterior, b) posterior; numbers refer to setae, letters refer to campaniform sensillae, *=secondary setae, sp=spinulae.

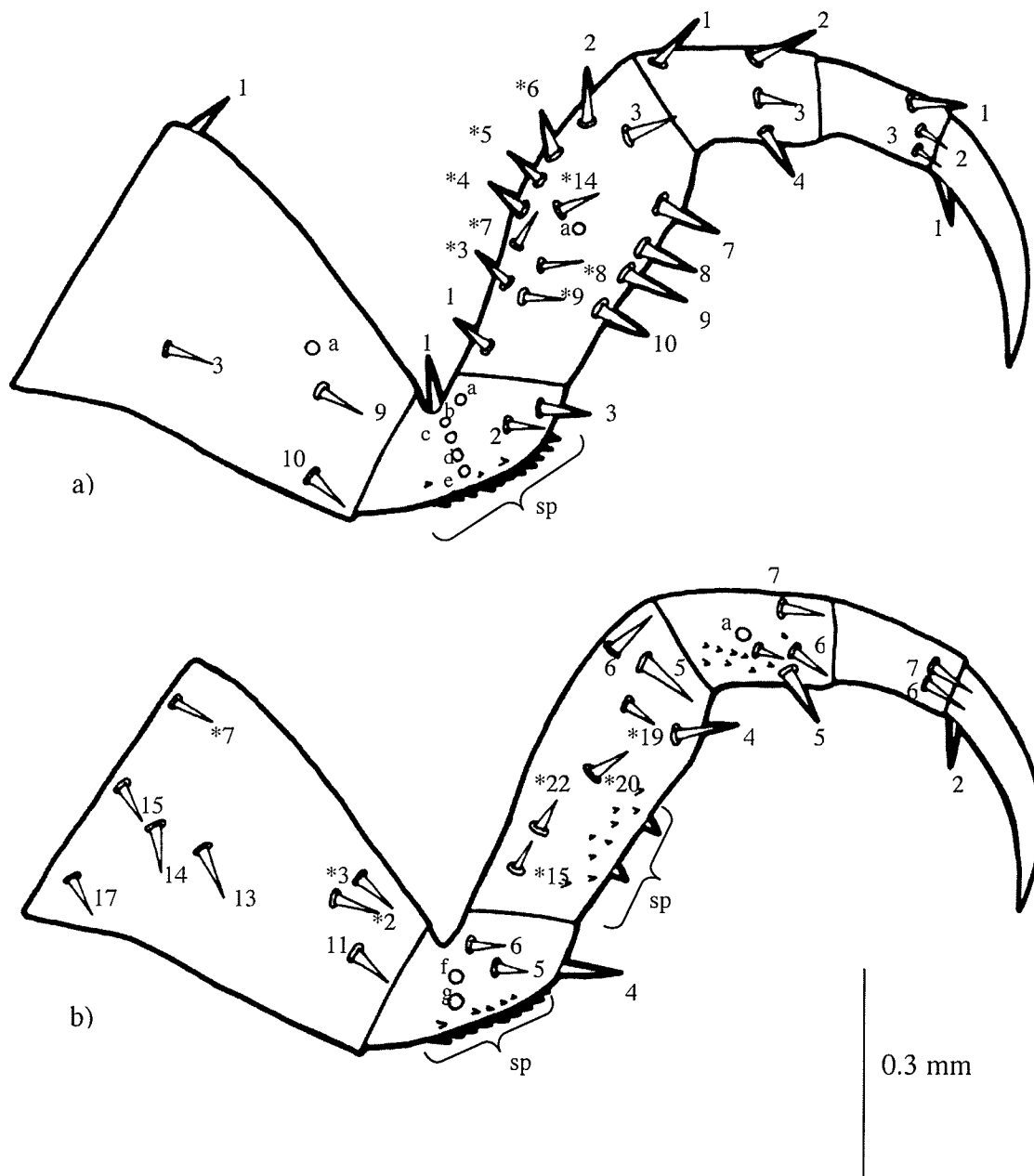


Figure 29. Leg chaetotaxy of right mesothoracic leg of the larva of *Brychius hungerfordi* Spangler (Coleoptera: Haliplidae), third instar: a) anterior; b) posterior; numbers refer to setae, letters refer to campaniform sensillae, *=secondary setae, sp=spinulae.

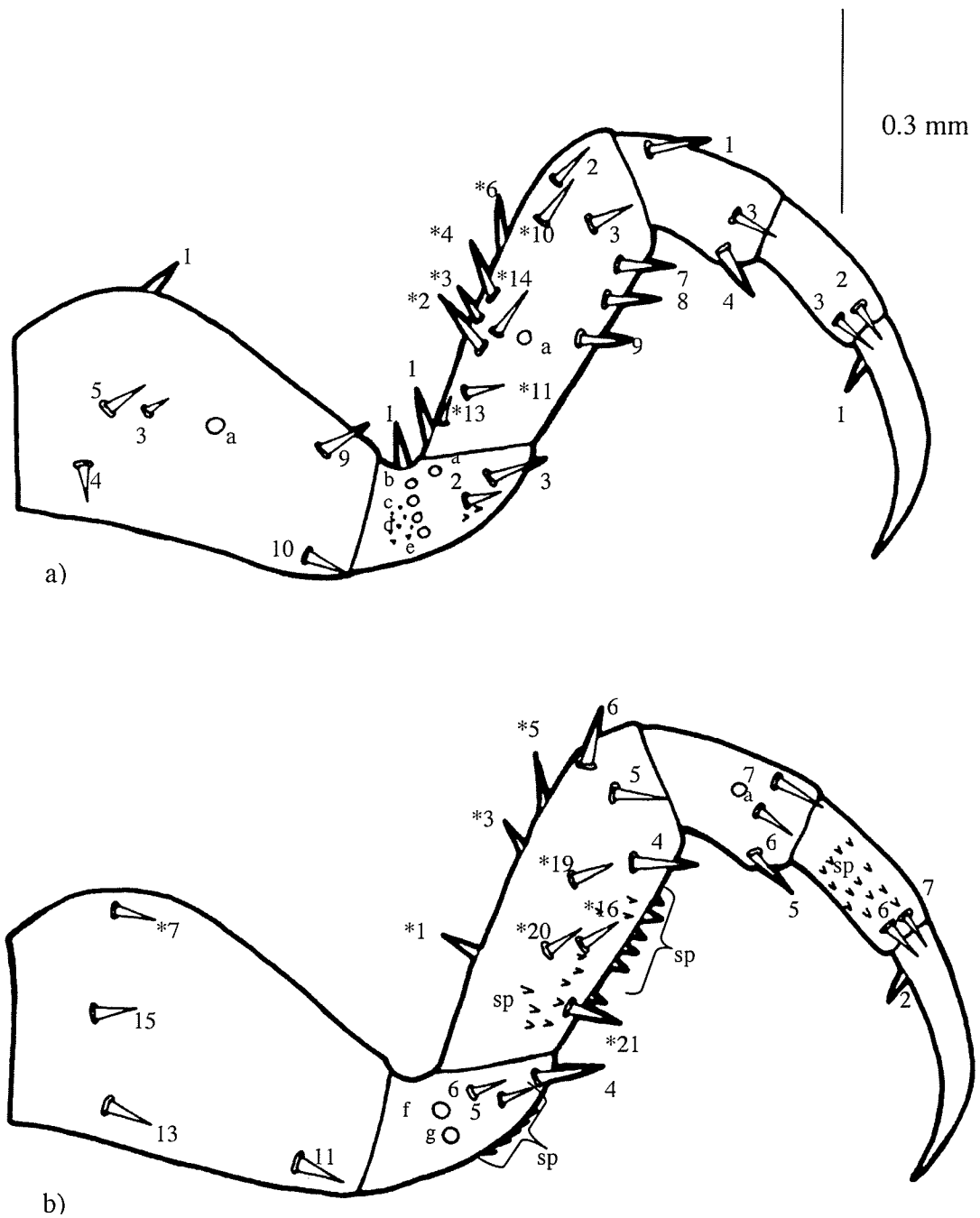


Figure 30. Leg chaetotaxy of right metathoracic leg of the larva of *Brychius hungerfordi* Spangler (Coleoptera: Halipidae), third instar: a) anterior; b) posterior; numbers refer to setae, letters refer to campaniform sensillae, *=secondary setae, sp=spinulae.

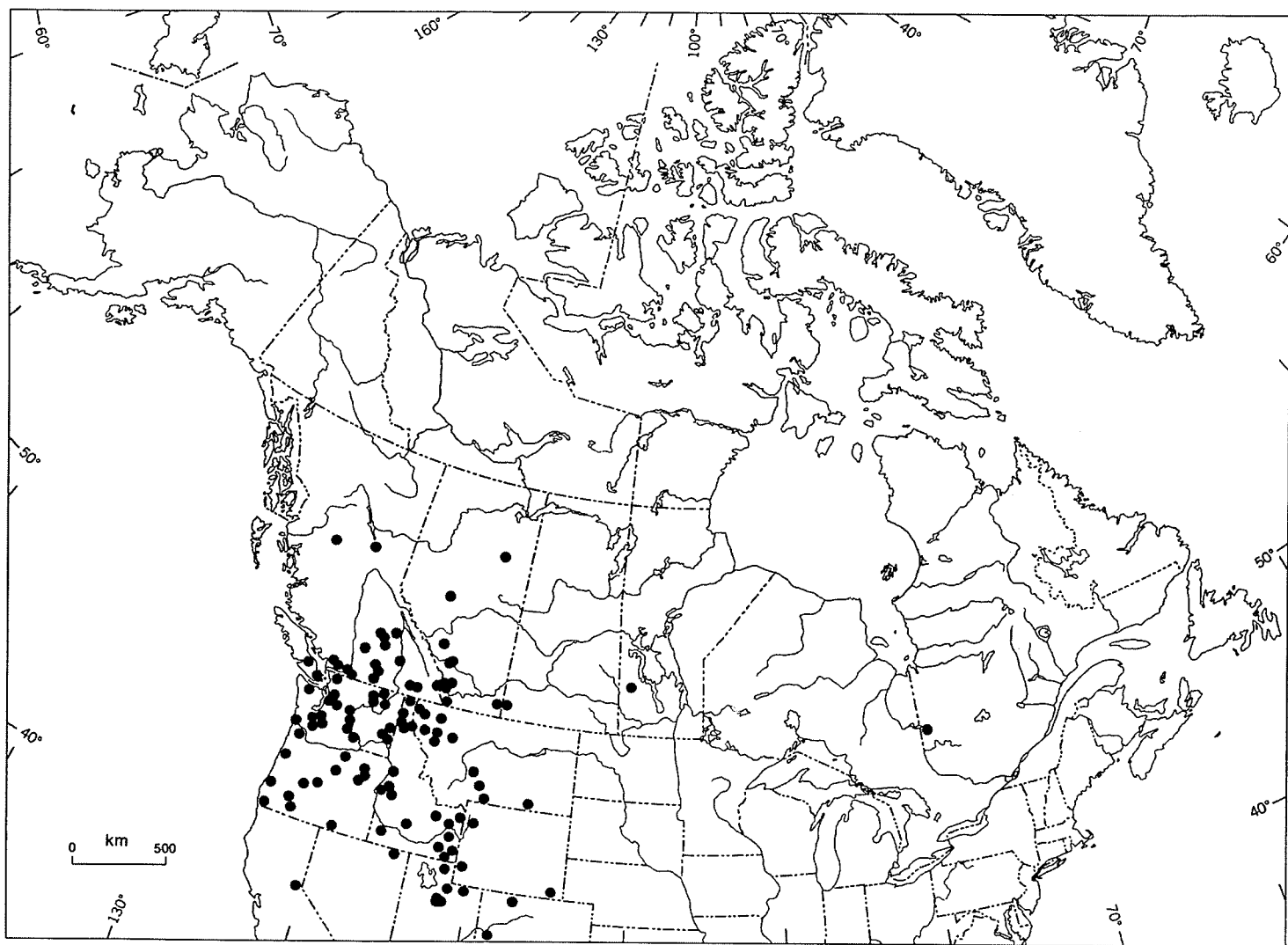


Figure 31. Distribution of *Brychius hornii* Crotch (Coleoptera: Halipidae) based on specimens examined.

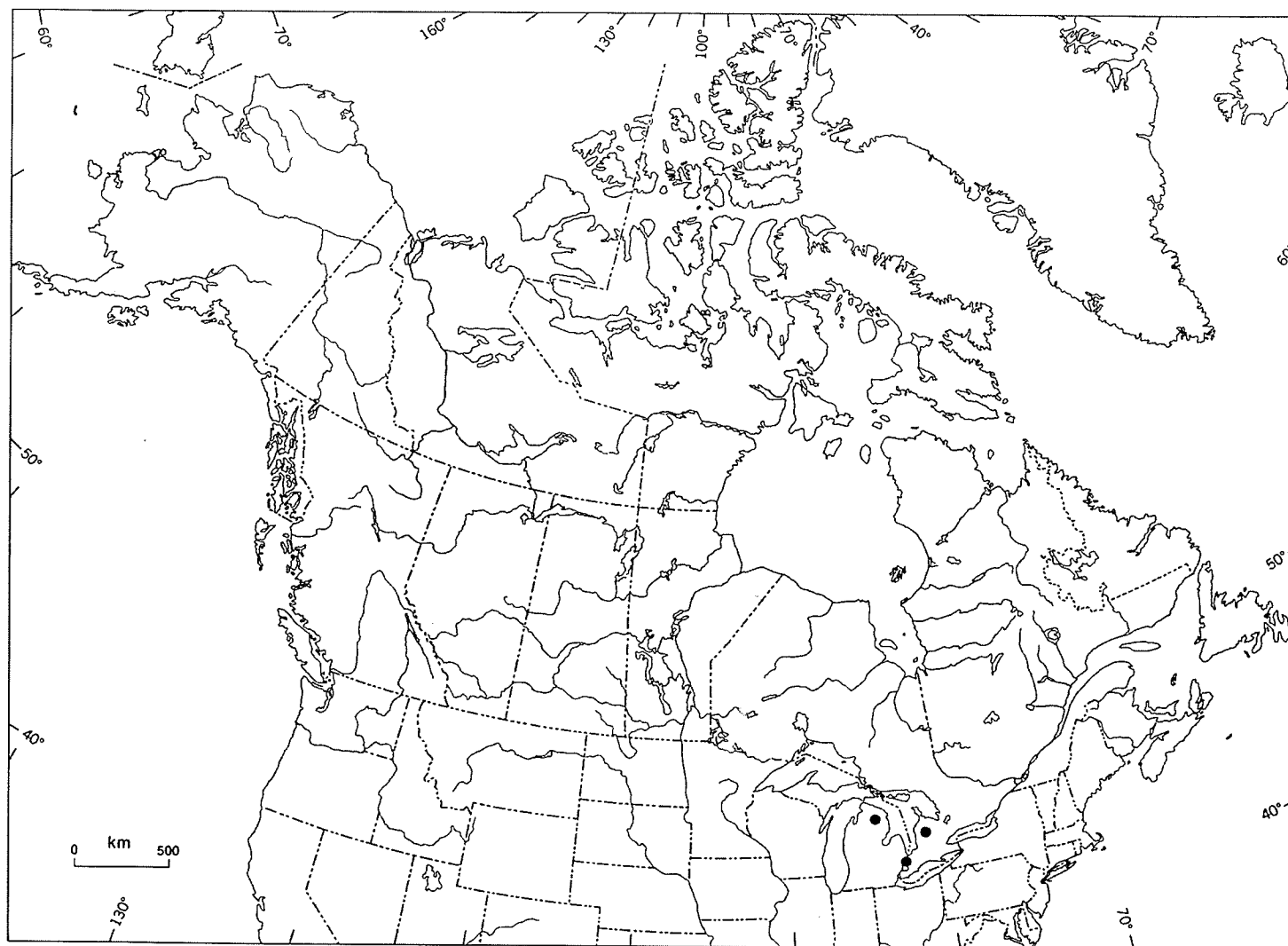


Figure 32. Map of North America, illustrating the distribution of *Brychius hungerfordi* Spangler (Coleoptera: Halipidae) based on specimens examined.

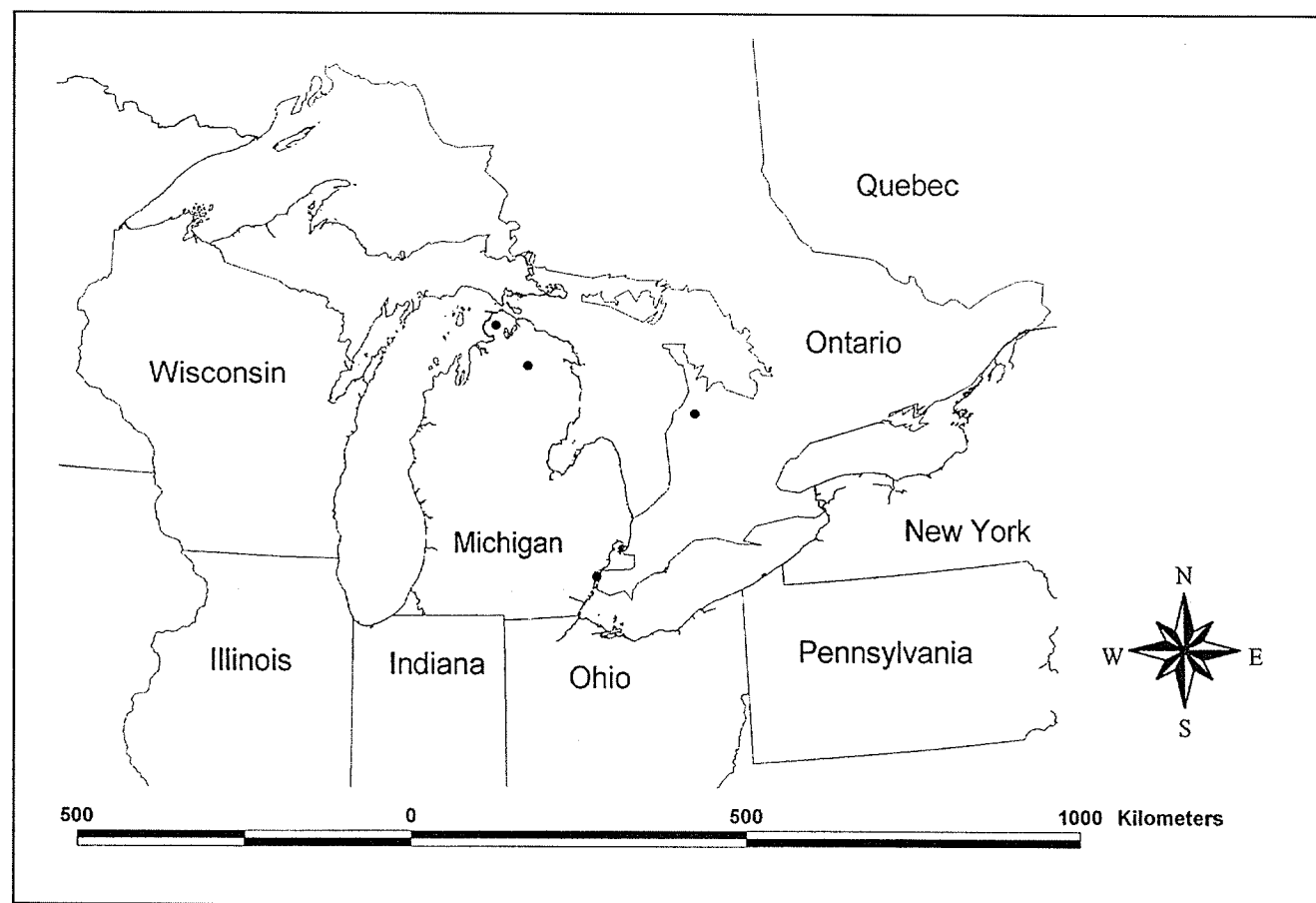


Figure 33. Map of Great Lakes area, illustrating the distribution of *Brychius hungerfordi* Spangler (Coleoptera: Haliplidae) based on specimens examined.

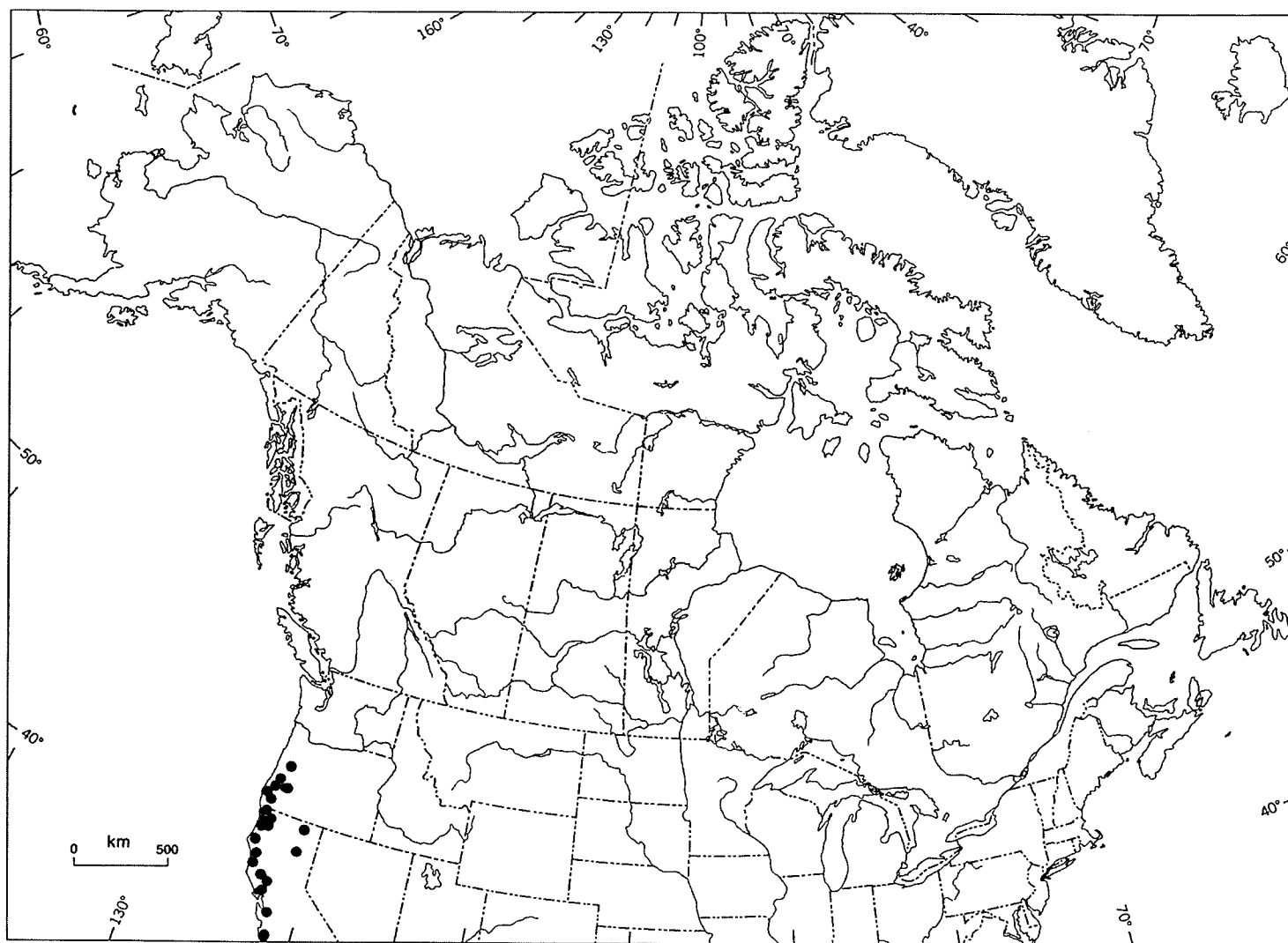


Figure 34. Distribution of *Brychius pacificus* Carr (Coleoptera: Haliplidae) based on specimens examined.

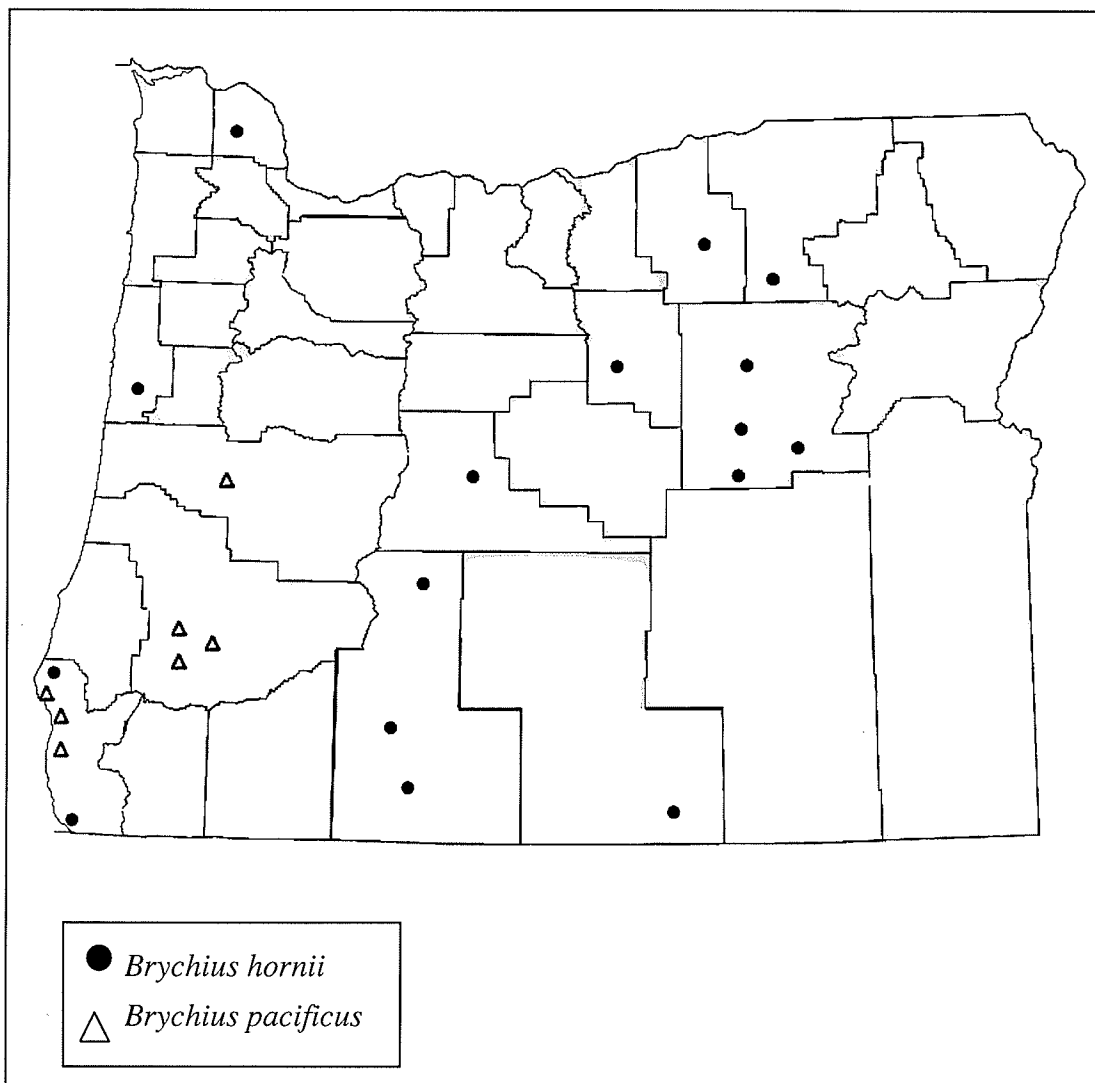


Figure 35. Distribution of *Brychius hornii* Crotch (Coleoptera: Haliplidae) and *Brychius pacificus* Carr (Coleoptera: Haliplidae) in Oregon, U.S.A. based on specimens examined.



Figure 36. Distribution of *Brychius hornii* Crotch (Coleoptera: Halipidae) and *Brychius pacificus* Carr (Coleoptera: Halipidae) in California, U.S.A. based on specimens examined.

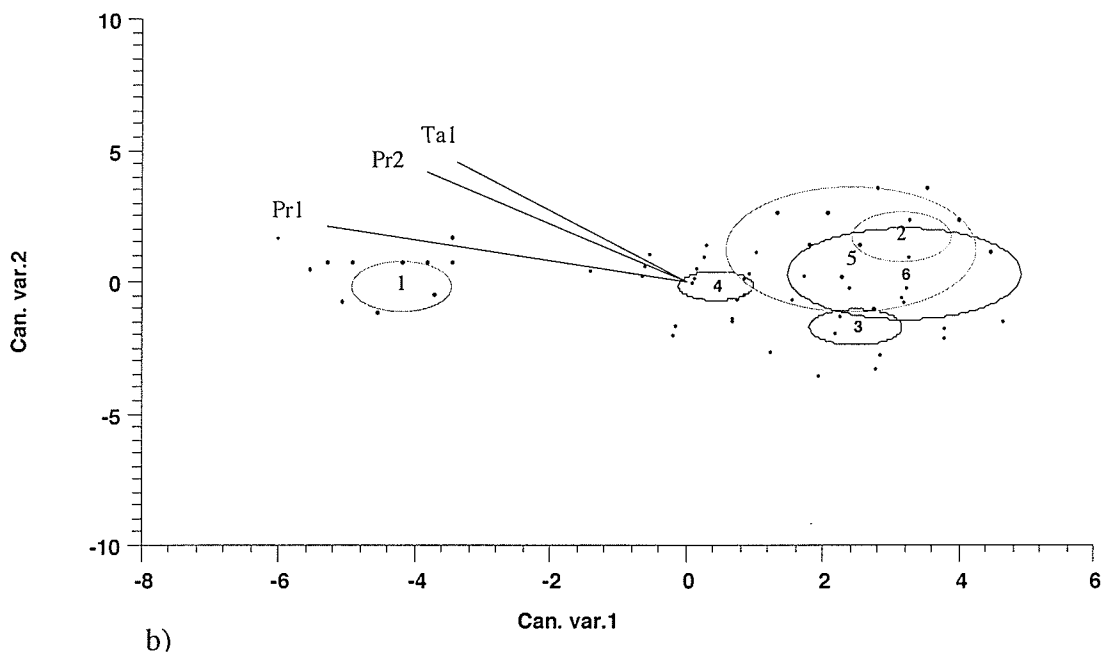
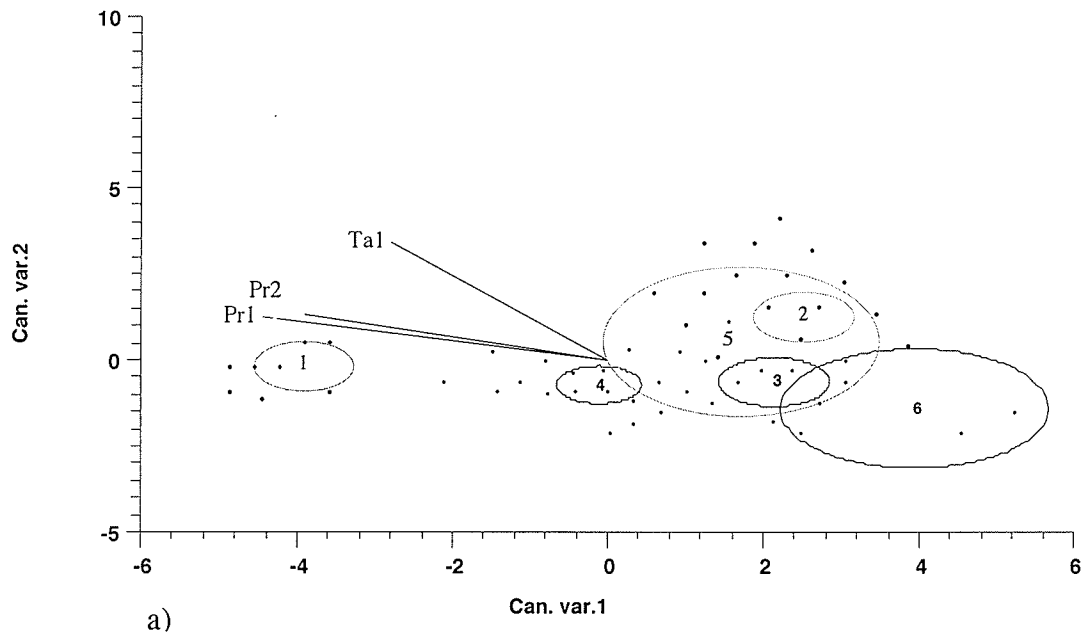


Figure 37. Multiple discriminant analysis of Nearctic species of *Brychius* Thomson (Coleoptera: Haliplidae) based on measurements of adults from selected populations; a) males, b) females. 1= *B. hungerfordi*, 2= *B. pacificus*, 3= *B. hornii* (Creston, BC), 4= *B. hornii* (Cowan, MB), 5= *B. hornii* (Fort McMurray, AB), 6= *B. hornii* (Cypress Hills, AB); Pr1= pronotal width, Pr2= pronotal length, Ta1= tarsomere 1 length.

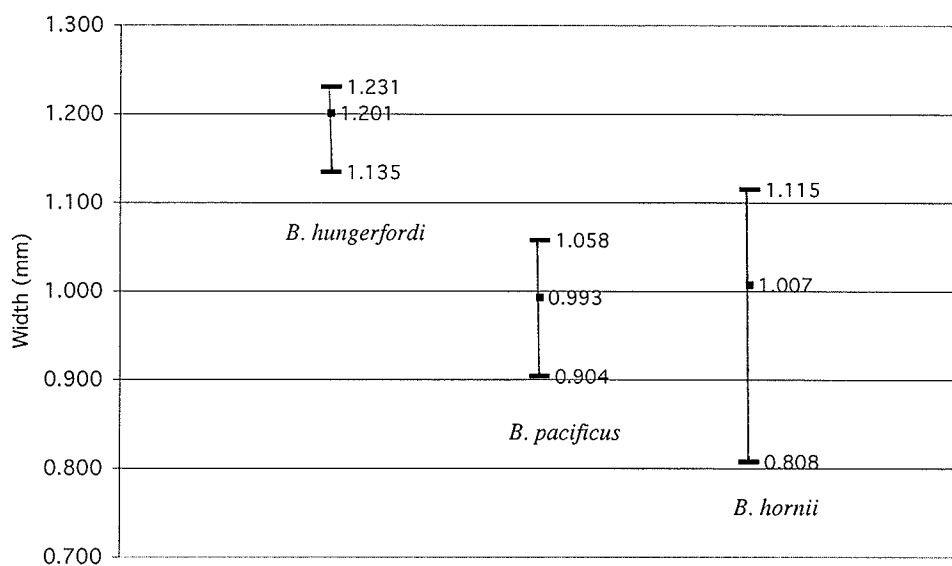


Figure 38. Average pronotal width measurements with the maximum and minimum values for selected samples of male specimens of *Brychius* spp. (Coleoptera: Haliplidae).

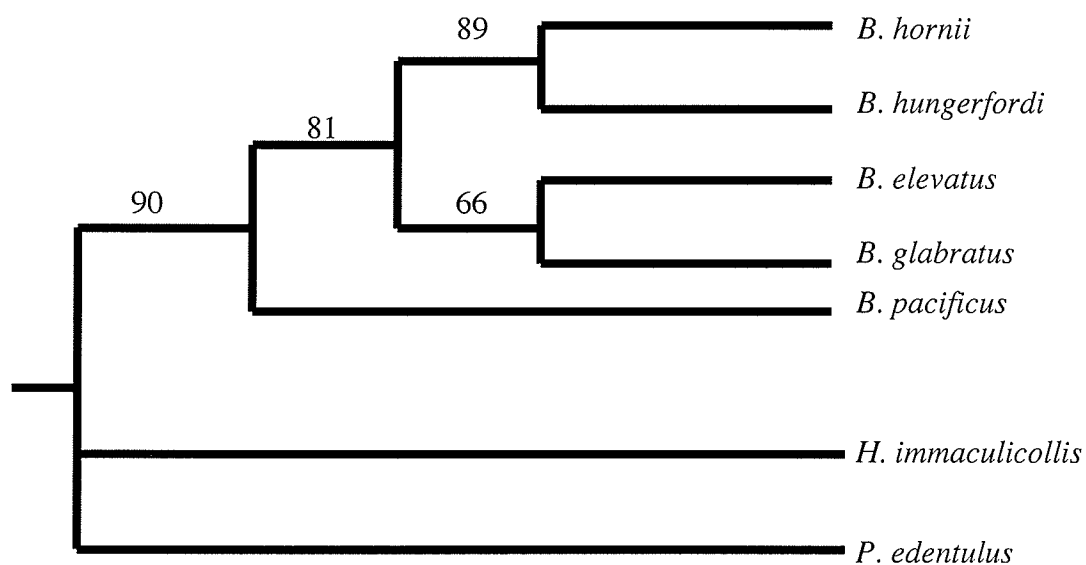


Figure 39. Single parsimonious tree obtained in the analysis of a structural dataset of *Brychius* spp. (Coleoptera: Haliplidae) using an exhaustive search with PAUP. Bootstrap values for 100 branch and bound replicates are listed above the branches.
Tree length 33, CI 0.82, RI 0.71.

CHAPTER IV
OBSERVATIONS ON THE NATURAL HISTORY OF A POPULATION OF
***BRYCHIUS HORNII* CROTCH, 1873 (COLEOPTERA: HALIPLIDAE) FROM**
THE DUCK MOUNTAINS, MANITOBA

Abstract

A population of *Brychius hornii* Crotch 1873 from the Duck Mountains, Manitoba was observed in the field and laboratory to gain insight into the biology and life history of this group of crawling water beetles. Notes were made on the habitat, reproduction, pupation, life cycle, and behaviour. The hydrology of a site seems to play an important role in the habitat requirements. Mating in *B. hornii* was observed in June and, although oviposition was not observed, eggs are thought to be laid in June/July. The larvae of *B. hornii* overwintered in the laboratory, buried in moist sand/ soil. Pupation occurred in the laboratory in March with one adult emerging in May. The natural history of all species of *Brychius* is discussed in light of these new findings.

Introduction

There is little information regarding the natural history of species of *Brychius* Thomson (Coleoptera: Haliplidae). They are found in clear, cool streams with well-aerated riffle segments, a cobble/gravel bottom, an underlying sand substrate, and marginal aquatic plants. Some populations of *Brychius* spp. are disjunct and are often difficult to collect due to patchy distribution and small size. Perhaps because of the difficulties of finding them and the difference in habitat from most other haliplids, there

have been no studies undertaken; there are only few observations available in the literature.

Information on the natural history for the entire family of crawling water beetles is lacking. Life cycles have only been studied for a few species (Falkenström 1926; Matheson 1912; Hickman 1931b; and Seeger 1971a, b, c). Few researchers have maintained laboratory cultures of haliplids; however, there are no studies involving species of *Brychius*. Matheson (1912) reared two species of *Peltodytes* and one species of *Haliphus*. Hickman (1931b) was successful at rearing all species known in Michigan, including *Peltodytes lengi* Roberts, *Peltodytes sexmaculatus* Roberts, *Peltodytes edentulus* LeConte., *Haliphus immaculicollis* Harris, *Haliphus cribrarius* Harris, and *Haliphus triopsis* Say. Falkenström (1926) studied the biology and life history of *Haliphus wehncke* Gerhardt (known as *Haliphus immaculatus* to Falkenström).

The crawling water beetles often make up a significant portion of the diet of fishes, waterfowl, amphibians and other aquatic insects (Hickman 1931b), playing a large role in the ecosystem's food web. The larvae feed almost exclusively upon green algae, based on observations on species of *Haliphus* and *Peltodytes* (Seeger 1971b). Depending on the species, the adults of *Haliphus* and *Peltodytes* may feed on algae, or both algae and animal matter such as chironomid eggs and polyps of *Hydrozoa* (Seeger 1971a).

The purpose of this paper is to provide additional information on the natural history of species of *Brychius*. A population of *B. hornii* found in the Duck Mountains, Manitoba provided an accessible population to study. Observations were made in the field and live specimens were brought back to the laboratory for further study and rearing.

Materials and Methods

Specimen Collection

A number of methods were employed in the collection of specimens of *Brychius* spp. Most of the adults and larvae were collected using a D-frame net with a 1.0 mm diameter mesh. Specimens of *B. hornii* could be found by dislodging rocks from the middle and sides of a stream and catching the loosened material in the net, or by sweeping the net underneath the banks of the stream.

Contents of the nets were then placed into a white sorting tray partially filled with water. Unlike most of the other aquatic Coleoptera that immediately proceeded to hide under pieces of debris in the tray, adult *B. hornii* would swim about, noticeably thrashing their long dangling legs, and therefore they could easily be picked out of the sorting tray. The nets were scanned after sweeping, as adults and larvae would sometimes cling to the mesh.

Adults were collected by gathering aquatic vegetation such as *Chara* spp., squeezing the water from the plants, and placing them on top of a sieve (1.0 cm diameter mesh size), situated above a white sorting tray. As beetles moved about, they would fall through the sieve and into the collecting tray. Larvae also were collected by digging out subsamples of the stream bank and sorting through the sediment and vegetation. After specimens were collected, they were placed in vials with 70% ethanol or placed alive in small buckets with stream water to bring back to the laboratory.

Habitat Description

Observations and measurements of the habitat of *B. hornii* were made at Cowan

Creek, MB (N 51°59'04" W 100°40'49") and the South Duck River, MB (N 51°52'55.5" W 100°36'45.7"). Velocity (centimeters per second) of lotic water was measured with a flowmeter ("Flow Wand" © Edutech Technologies Corp.) where the water was not too shallow or too deep. Temperature (degrees Celsius) was measured with a thermometer. A Hanna Instruments model 9812™ portable pH meter was used to measure pH.

Rearing

Adults

Adult specimens of *B. hornii* were collected into plastic buckets along with water, stones and algae from the collecting site and brought back into the laboratory. These were then placed into a 5 litre aquarium with a magnetized stir function and temperature control (Stir Kool Model sk II). Within this aquarium, water temperature fluctuated from 15-22°C.

Two 8 litre aquaria were set up in a rearing chamber kept at 10-15°C in summer and 5°C in winter (Figure 1). Photoperiod was adjusted during the seasons to mimic natural hours of light and darkness. Each aquarium contained an air stone for adding oxygen to the water.

Larvae

Larvae that were collected alive, were brought back to the laboratory and kept in petri dishes filled with stream water. These dishes were placed in larger petri dishes filled with sand and soil. Twigs were arranged so that the larvae could crawl out of the water and into the sand. Petri dishes with larvae were placed in a rearing chamber kept at 10°C for five months.

Pupa

At the end of March, larvae of *B. hornii* were moved to a pupation terrarium (Figure 2) following similar beetle pupation chamber designs (Seeger 1971b; White and Jennings 1973). This consisted of a 15 litre glass tank partially filled with a mixture of gravel, coarse sand, fine sand, and potting soil. The terrarium was placed on an angle with a small block of wood. The position of the tank provided a moisture gradient throughout the substrate when water was added. Water was added until approximately 15 cm depth had remained on one end of the tank. The terrarium was left to equilibrate before larvae were added the following day.

Results

Habitat Description

Adults of *B. hornii* were collected in Cowan Creek and the South Duck River, MB at nine and 12 sites, respectively in 2001 and 2002 (Appendix 4). Adults were collected from the undercut banks or along the stream margins among vegetation. One adult was found after taking a section of plant roots and mud from underneath an undercut bank. A survey of creeks and streams in Riding Mountain, Duck Mountains, and Porcupine Hills was conducted (Appendix 5); however, no specimens were found other than in the two aforementioned streams.

Cowan Creek and the South Duck River were clear, cold streams with gravel/rock bottoms (Figure 3). The temperature ranged from 2°C (10 November, 2001) to 21.5°C (17 August, 2001) with an average temperature of 10°C. The pH ranged from 8.0-8.2. Velocity in places where specimens were collected ranged from 0.311-0.623 m/s. Trout

were prevalent in both streams. Vegetation and trees line the shores and an abundance of grasses and algae were observed growing within the water. Numerous beaver dams were seen throughout the length of the streams. The water depth fluctuated along the streams. At one point, the depth of the South Duck River reached over 2 metres behind a beaver dam. Where the water was shallow, islands of sand and gravel were seen in the middle of the streams. One of the sites in Cowan Creek was crossed by a ford, which experienced local vehicle traffic. This caused disturbance to the substrate in that part of the creek.

Laboratory Observations

Reproduction

Mating behaviour of adult *B. hornii* was observed on 17, 18, and 19, June, 2001. This consisted of a male positioning itself onto the dorsal surface of the elytra of a female, holding the female with its fore and middle legs. Mating behaviour was first observed after live specimens were collected and placed into a plastic container with stream water. Three pairs of beetles were observed in this position in the container. Over seven hours later, mating behaviour was observed again when beetles were placed into an aquarium in the laboratory. This behaviour was observed in the aquarium 10 times each lasting about two to three seconds and one time lasting over 10 minutes. Eggs were not observed in the aquarium despite the numerous instances of mating behaviour.

Pupation

Seven live III larvae of *B. hornii* were brought back to the laboratory on 10 November, 2001 in an effort to secure a pupae. Larvae stayed underwater until they

became quite restless in late November and moved about the dish frequently. Larvae climbed out of the water at the end of November and remained throughout the winter months half-buried in moist earth and sand.

These larvae were then moved to a pupation terrarium on 25 March, 2002. On 22 May, 2002, one adult was found in the terrarium. No other adults were found. The exact timing of its emergence is uncertain. This is the first recorded incidence of pupation for any species of *Brychius*.

Life Cycle

The life cycle of species of *Brychius* can be deduced from field collections of adult and larval specimens of *B. hornii*, as well as the timing of behaviours observed in the laboratory (Table 1). Adults were collected from June to November. It is assumed from the timing of the mating and collection of second instar larvae, oviposition in *B. hornii* should occur sometime in June and July. Larvae of *B. hornii* were collected from Cowan Creek and South Duck River, MB. Second instar larvae were collected in July, third instars were collected from August until November.

Behaviour

In the laboratory, adults of *B. hornii* spent the majority of their time either: 1) crawling on the surface of rocks and gravel near the bottom of the aquarium; 2) clustering in crevices on the underside of rocks (when disturbed from this position, they would hook themselves together using their tarsal claws and legs and form a tangled "*Brychius* ball" with up to six individuals); 3) digging at the gravel at the bottom of the tank; 4)

swimming to and from the surface to replenish their air supply.

The adults of *B. hornii* were seen to be excellent swimmers. The legs moved alternately when swimming. The hind legs moved backwards with a slightly downward sweep, providing the main thrust. As the adults reached the surface, they positioned their body using the hind legs so that the head was towards the bottom. They then used their hind legs to 'grasp' the tension of the surface water to remain at the surface before placing the tip of the abdomen into the air.

When removed from the water, adults of *B. hornii* exhibited thanatosis and continued to do this for up to one minute. They also walked with considerable ease and agility out of the water, raising the body clear from the surface and placing the weight on the tarsi of all the legs.

Adults of *B. hornii* seemed to be attracted to light in the laboratory. Adults were placed in a white sorting tray filled with water, gravel, and larger rocks. The light of a desk lamp was shone on one corner of the tray. Within minutes, adults had aggregated towards the light.

Discussion

Habitat

Species of *Brychius* require clean, oxygen-rich, running water. In general, species of *Brychius* are collected from well-aerated streams with clear water, a cobble or gravel bottom with an underlying sand substrate and attached aquatic plants. *Brychius hungerfordi* has been found in streams that are slightly alkaline, have an open canopy, and a moderate to fast stream flow (Wilsmann and Strand 1990). In addition, *B. elevatus*

has been found from exposed lake margins (Nilsson 1996).

The larvae of species of *Brychius* live in different microhabitats than the adults. Larval specimens of *B. hornii* were collected only from riffle areas of the stream. As the adults receive their air supply from the surface, highly oxygenated water is probably more important for the survival of the larvae. The larvae continually breathe underwater, respiring through microtracheal gills (Seeger 1971a), although some respiration also occurs through the soft integument, especially in young larvae (Nilsson 1996). White (1986a) suggested the larvae of *B. hungerfordi* live among alder root hairs and submerged aquatic macrophytes. Wilsman and Strand (1990) collected larvae of *B. hungerfordi* in an area of sand and *Chara* spp. (Chlorophyta), stating that the adults and larvae were not usually collected together.

There has been a strong effort to characterize the habitat of *B. hungerfordi* since its federal listing as a U.S. endangered species in 1994. In Michigan, *B. hungerfordi* has been found in a few cold water streams such as the Maple River and Van Hetton Creek. The substrate of the Maple River consists of large rocks (over 25 cm in diameter) covered with a substantial growth of attached green algae such as *Cladophora glomerata* Van den Hoek 1963 (Chlorophyta) (White 1986a). Adults were captured in water greater than 0.5 m deep, where the current velocity was greater than 50 cm per second (White 1986a). In Van Hetton Creek, adults were found in a creek channel composed of sand overlain with a thin layer of detritus (Grant *et al.* 2000).

Stream segments in Michigan with populations of *B. hungerfordi* were characterized using the Michigan Valley Segment Ecological Classification System (MI-VSEC) developed by Seelbach *et al.* 1997 (Hinz and Wiley 1999). The streams were

found to have hardwater, oligotrophic chemistries, fair to high base flows with low to moderate peak flows, cold to cool July temperatures, with low to moderate daily temperature fluctuation, and low valley slope.

In Ontario, *B. hungerfordi* has been found in the North Saugeen River. This site is characterized by heavy deposits of a marl-like substance on stones and rocks (Roughley 1991). Upstream from this collecting site is an impoundment dam with an epilimnion outlet. The North Saugeen River below the Scone dam is a coldwater stream, which includes resident coldwater fish species and migratory species such as rainbow trout and Chinook salmon. Above the dam, it is a coldwater stream system with resident brown and brook trout. There have also been reports of northern pike and smallmouth bass in this area (Bob Gray, Ontario Ministry of Natural Resources, Personal Communication, 2003).

It seems that species of *Brychius* are adapted to cooler environments. The temperature range that they can tolerate is unknown; however, in Manitoba, adults and larvae of *B. hornii* have been collected in stream water ranging in temperature from 2.0-21.5°C and in Michigan, adults of *B. hungerfordi* have been collected in stream water at temperatures of 15-25°C, while the larvae have been collected at temperatures of 8°C (Wilsmann and Strand 1990).

The hydrology of a site seems to play an important role in the habitat requirements of *B. hornii* and *B. hungerfordi*. Specimens are collected near beaver dams, culverts, and stream fords. The backwater of beaver dams stabilizes water levels, and the downstream margins often provide well-aerated riffle areas (Wilsmann and Strand 1990). Human-made structures that create similar conditions, such as wing dams and culverts,

may be important for these reasons.

From label data on museum specimens of *B. hornii*, some specimens were caught from places other than streams and creeks. Two specimens were caught in a pitfall trap beside a river, one specimen was collected in a ditch beside a road, one from a beaver pond, and one specimen from a malaise trap, although the label on the malaise trap specimen is questionable as it contains unlikely and/or incomplete data.

Life Cycle

Adult

Reproduction

There is no published information for any aspect of reproduction for any species of *Brychius*. I observed possible mating behaviour of *B. hornii* occurring in late June in Manitoba. Grant *et al.* (2000) suggested that several cohorts of *B. hungerfordi* are present during one season. An increase in the relative abundance of *B. hungerfordi* seen in May, followed by a second increase in October may be an indication that a second brood of adults emerges late in the season (Grant *et al.* 2000).

The timing of reproduction in species of *Brychius* is probably similar to other haliplids. Reproduction in species of *Haliphus* and *Peltodytes* occurs in the spring and early summer, though there can be another generation that begins in the fall and extends over to spring (Hickman 1931b; Zaitsev 1972). Females may delay laying fertilized eggs until conditions are favourable. For instance, a female of *Peltodytes edentulus* LeConte, isolated in a culture in November, laid eggs in mid May with normal larvae hatching from them; therefore, copulation may have taken place as early as the fall before

(Hickman 1931b).

Life Expectancy of Adults

The life expectancy of adult species of *Brychius* is unknown. White (1986b p. 2) stated "adults of *Brychius* are expected to be long lived (1 year?)". I have kept adult *B. hornii* from Manitoba alive in the lab for over two years; however, this longevity may not be seen in the natural environment. Holmen (1987) found that individual adults of some species of *Haliphus* live for at least two years, while Hickman (1931b) kept species of *Haliphus* and *Peltodytes* alive for eighteen months.

Eggs

Although mating behaviour of *B. hornii* was observed in the laboratory, eggs were not. It is assumed from the timing of the mating and collection of second instar larvae, that oviposition in *B. hornii* should occur in June and July. Oviposition is not known for species of *Brychius*; however, it has been inferred to be endophytic and similar to species of *Haliphus* (Galewski 1972; Beutel and Ruhnau 1990).

Species of *Haliphus* and *Peltodytes* have unique oviposition strategies. Females of *Haliphus* spp. lay a white egg (0.3-0.5 mm) into a plant either by piercing it with the ovipositor or by gnawing a hole into it (Zaitsev 1972). The eggs are laid into various plants, mainly filamentous algae such as species of *Chara* (Chlorophyta) and *Fontinales* (Chlorophyta) (Zaitsev 1972). Females of *Haliphus ruficollis* De Geer, 1774 have been recorded to lay eggs in the stalks of species of *Juncus* (Juncaceae) and *Phragmites* (Gramineae) (Zaitsev 1972). Adult females of *Peltodytes* scatter their brown eggs onto

the surface of aquatic plants (Zaitsev 1972).

Oviposition for species of *Haliphus* and *Peltodytes* occurs in May, June, and the early part of July (Hickman 1931b). There may be another one in the fall months (Hickman 1931b). The number of eggs deposited by one female varies from 30 to 40 (Zaitsev 1972) but this is an approximation, as they are not all laid at one time, but scattered over the period of a week or more (Hickman 1931b). Embryonic development lasts 8-12 days (Zaitsev 1972). Diapausing eggs are unknown among the Haliplidae (Nilsson 1996).

Larva

Larvae of *B. hornii* and *B. hungerfordi* were collected in the fall (Strand and Spangler 1994). Larvae of *B. elevatus* have been collected in the summer and autumn (Holmen 1987). In the lab, larvae of *B. hornii* emerged from the water in November and remained throughout the winter months half-buried in moist earth and sand. This is consistent with Strand and Spangler's (1994) hypothesis that the larvae of *B. hungerfordi* overwinter in damp sand above the water-line in position for spring pupation.

The larval stage of all Haliplidae passes through three instars before the pupal stage (Matheson 1912). The first and second instar larvae receive their oxygen by cutaneous respiration (Hickman 1931a). The time needed for larval development has been found to vary considerably, even within the same species, perhaps due to fluctuating temperatures (Seeger 1971a). Holmen (1987) stated that under natural conditions, the larvae of species of *Haliphus* usually develop within one year. The first two larval instars of species of *Haliphus* and *Peltodytes* may last for one or two weeks each, whereas the

second and third instar of many other species overwinter (Nilsson 1996). Some larvae repeatedly overwinter, remaining in dormancy for as long as three years under experimental conditions (Zaitsev 1972).

Pupa

The haliplid pupa is a typical exarate type and the process of changing into an adult is very similar to that of other beetles (Hickman 1931b). Haliplid larvae come out of the water for pupation and dig a shallow pit in the soil (Zaitsev 1972). Pupation occurs in moist soil a few centimeters above the water line (Zaitsev 1972).

The pupal stage of *Haliphus* and *Peltodytes* can last between nine and fourteen days (Hickman 1931b), whereas Holmen (1987) added that the time spent in the pupal stage is longer for larger species than for smaller species. The time required by the pupa of species of *Haliphus* to shed the exuvia is about twelve hours from the first apparent sign of activity to the end of the process (Hickman 1931b).

It is unclear why only one larva of *B. hornii* pupated in the laboratory. Perhaps the temperature, type of soil, or moisture gradient was inappropriate. Hickman (1931b) stated that the pupa of haliplids is the most difficult stage to obtain because the larva will not pupate unless conditions are right; instead, it will remain as a larva or die.

Overwintering strategies

Adults of haliplids are known to overwinter either out of the water, buried in the mud (Zaitsev 1972; Holmen 1987), or by remaining active in the water (Hickman 1931b). Adults of *B. hungerfordi* were found beneath a 24 cm cover of ice in February in the East

Branch of the Maple River (Grant *et al.* 2000). Species of *Haliphus* and *Peltodytes* are very resistant to freezing; in the laboratory, they could be frozen solid in ice and still live (Hickman 1931b). Adults remained alive even after being alternately frozen during the night and thawed out during the day over a period of twelve days (Hickman 1931b). There seems to be no diapause in haliplids (Seeger 1971b).

The larvae of many species are also capable of overwintering either onshore or in the water (Hickman 1931b; Vondel 1995). *Brychius hornii* larvae overwintered in the laboratory in sand substrate. Strand and Spangler (1994) also suggested *B. hungerfordi* overwinters in the larval stage in position for spring pupation. Second and third instar larvae of species of *Haliphus* were collected from under ice in December (Hickman 1931b). However, Zaitsev (1972) states that the larvae of species of *Peltodytes* rarely overwinter in the water (Zaitsev 1972).

Nutrition and Feeding

Adults

Although I was able to keep adults of *B. hornii* alive in the laboratory for over two years, I was not able to determine what they were feeding on. As I was continually adding stream water from the collection site, I could have been renewing their food supply. Also the aquaria in the rearing chamber contained a number of algal species from the stream that had established themselves in the tank over the years.

In preliminary feeding studies, adults of *B. hungerfordi* excreted frass containing the red algae, *Audouinella* sp. (Rhodophyceae), and on the diatom, *Cocconeis* sp. (Bacillariophyceae) (Brian Scholtens, University of Michigan Biological Station,

Personal communication, 2003). *Audouinella* sp. is a small alga which forms a reddish or brownish coating on stones or on other algae. Red algal species such as *Audouinella pygmaea* Kutz. are widespread throughout stream systems. *Cocconeis* sp. diatoms are single-celled, grow on substrates, usually as an epiphyte, and are found in flowing and still waters. This may confirm observations of adults of *B. hungerfordi* appearing to feed by scraping biofilm from algae (Strand and Spangler 1994) and White's (1986b) hypothesis of *B. hungerfordi* feeding on periphytic diatoms growing on algae.

Adults of species of *Haliphus* and *Peltodytes* may be herbivorous, carnivorous, or both. Seeger (1971b) examined the contents of the gut of several species and discovered a large differentiation in the diet of the separate species. Certain species have been shown to have a more selective diet (Hickman 1931b; Seeger 1971b), and this may be an important factor in explaining their distribution.

The animal food may consist of insect eggs and larvae, hydrozoans, worms, and crustaceans (Seeger 1971b). Species of *Haliphus* may be cannibalistic as dead specimens had the soft parts immediately eaten by remaining adults (Vondel 1995). Younger beetles tend to be more carnivorous than older ones as it seems that animal food is essential for gonadal development (Nilsson 1996). Haliplids prey only on very small animals; however, in aquaria, *Haliphus fulvus* Fabricius, 1801 captured large mayfly nymphs (Nilsson 1996).

Algae are the most common component of plant material eaten by adults. *Peltodytes edentulus*, *P. lengi*, *P. muticus*, *P. shermani*, and *H. triopsis* were observed to be feeding on *Spirogyra* sp. (Chlorophyceae) (Polilli and Shoup 1997). All species were eating the cell contents, and not scraping bacteria or anything else from the algae.

Chloroplasts are believed to be the main substance taken from the cells.

Larvae

Generally, it is assumed that all species of Haliplidae feed on algae in the larval stage. There are two types of algal feeders: filamentous feeders and plant feeders.

Larvae that feed on filamentous algae have the first pair of legs modified for grasping (Hickman 1931b). By means of these legs, they hold the filament, passing it back in a hand-over-hand fashion until the end is reached. They then push it forward while puncturing each cell and sucking out the contents (Hickman 1931b).

Other species, such as *Haliphus cribrarius* Lec. and *H. triopsis* Say, feed upon *Chara* spp. and *Nitella* spp. After selecting a place to feed, the larvae scrape off the outside layer of the branches with the mandibles by means of a downward movement of the head, at the same time drawing in the loosened material through the suction canals (Hickman 1931b). They usually feed in patches anywhere on the branches and make no effort to remove the entire layer (Hickman 1931b). This leads me to believe that they could be feeding on any organism attached to these plants.

Strand and Spangler (1994) found larvae of *B. hungerfordi* in association with *Chara* spp. and assumed this, or the epiphyton associated with these plants, to be their probable food source. *Brychius* larvae have the forelegs modified and therefore this could be an adaptation for feeding on filamentous algae.

Behaviour

Adults

While in water, haliplids spend most of their time walking over the vegetation and swimming short distances (Hickman 1931b). In general, most species of *Haliphus* and *Peltodytes* are regarded as poor swimmers (Hickman 1931b; Zaitsev 1972); however, *A. parvulus* (Chandler 1943; Kitayama 1981), and *B. hungerfordi* (White 1986b) are regarded as strong swimmers. I also observed *B. hornii* to be a strong and fast swimmer.

A strong swimming behaviour and torpedo-shaped body is important for the respiratory needs of species of *Brychius* (White 1986b). Most insects that live in swift flowing water respire by means of a plastron or trans-cutaneously (Eriksen *et al.* 1996). This allows them to cling to the substrate without having to rise to the surface for oxygen. However, in a simple and elegant experiment, Hickman (1931a) showed that *Haliphus triopsis* and *Peltodytes edentulus* cannot survive if prohibited from reaching the surface to obtain oxygen. I observed adults of *B. hornii* periodically rising to the surface to renew their air supply in the laboratory, even with constant air supplied to the aquaria, and White (1986b) observed *B. hungerfordi* swimming to the surface. Therefore, like other haliplids, I would conclude that species of *Brychius* renew their air at the surface and use their strong swimming capabilities to get there.

Not only must individuals of species of *Brychius* fight against the current to renew their air supply, they have to be strong enough swimmers to find their preferred microhabitat without being swept away by the current. White (1986b) observed *B. hungerfordi* rapidly swimming to the surface in less than four seconds and, while the current was over 50 cm per sec., individuals were only swept downstream by 20 cm, and

were able to return to the same rock.

It is uncertain as to whether species of *Brychius* have a dispersal flight. Adults of *B. hungerfordi* seemed unusually reluctant to fly when deprived of water (Wilsmann and Strand 1990). I have dissected full wings from specimens of all Nearctic species of *Brychius*; however, I did not study the flight muscles or sclerites, which can also be an indication of flight capability (Jackson 1952). The specimen label from one adult of *B. hornii* reads "Arizona / Cocconina [sic] Co. / At. light / W.J. Hanson / Malaise trap" (USNM 1 male). Because the label data are incomplete and there is only one specimen, it is possible that this specimen was mislabeled. Although flight is quite rare in most species of Haliplidae, except in *Haliphus lineatocollis* (Marsh.), most are capable of flight (Nilsson 1996).

Larvae

The larvae of species of Haliplidae are adapted only for crawling, and are very slow in their movements (Hickman 1931b). The larvae of *B. elevatus* have been found in the middle of the stream current among immersed stones (Rousseau 1919). They held themselves solidly to the rocks by using their protarsal claws and the hooked urogomphus as a grapple, in order to resist the current (Rousseau 1919). When disturbed, they will curl up for three to six minutes (Hickman 1931b).

Conclusion

The information in this paper is based on observations of *B. hornii* from a population in the Duck Mountains of Manitoba. *Brychius hornii* is collected from similar

habitats to *B. hungerfordi*, in clear, slightly alkaline streams with gravel/rock bottoms and an average temperature of 10°C. The life cycle of *B. hornii* can be deduced from observing reproductive and pupation behaviours, as well as the timing of collection of different life stages. Reproduction occurs in late June and oviposition is thought to occur in June/July. Larvae and adults probably overwinter in undercut banks of the stream. Pupation occurs in the spring, in May.

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Table 1. Preliminary life cycle of *B. hornii* Crotch from the Duck Mountains, Manitoba, based on specimen collection and laboratory observations in 2001/2002; (F) field collection, (L) laboratory observations.

NOVEMBER	Adults and late-instar larvae collected (F)
DECEMBER-MARCH	Larvae overwintered partly in soil (L)
MARCH	Larvae burrowed into soil (L)
APRIL	Pupal stage (L)
MAY	Adult emerged from pupa (L)
JUNE	Mating behaviour (L), teneral adults collected (F)
JULY	Adults and early instar-larvae collected (F)
AUGUST	Adults and early instar-larvae collected (F)
SEPTEMBER	Adults and early instar-larvae collected (F)
OCTOBER	Adults and early instar-larvae collected (F)

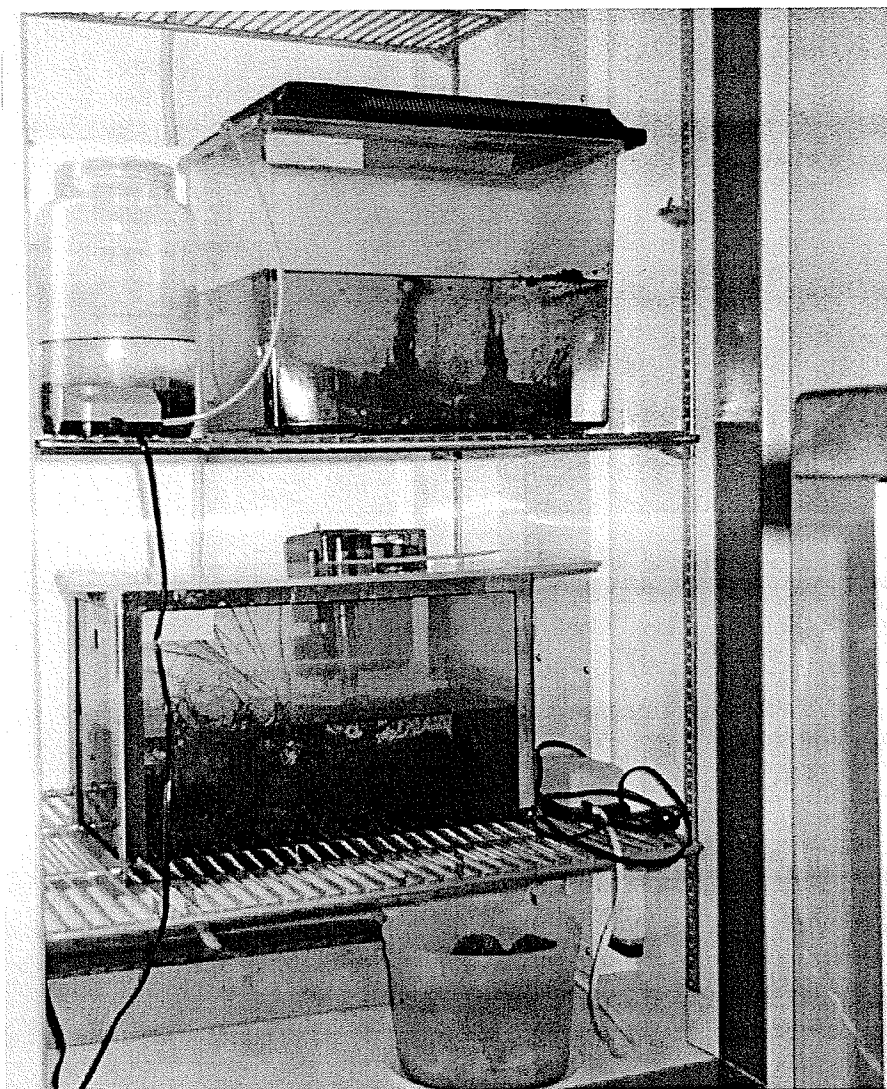


Figure 1. Aquaria containing gravel, small rocks, stream water, air stones, and various aquatic plants and algae in temperature and photoperiod controlled rearing chamber, used for housing live specimens of *B. hornii* Crotch (Coleoptera: Haliplidae).

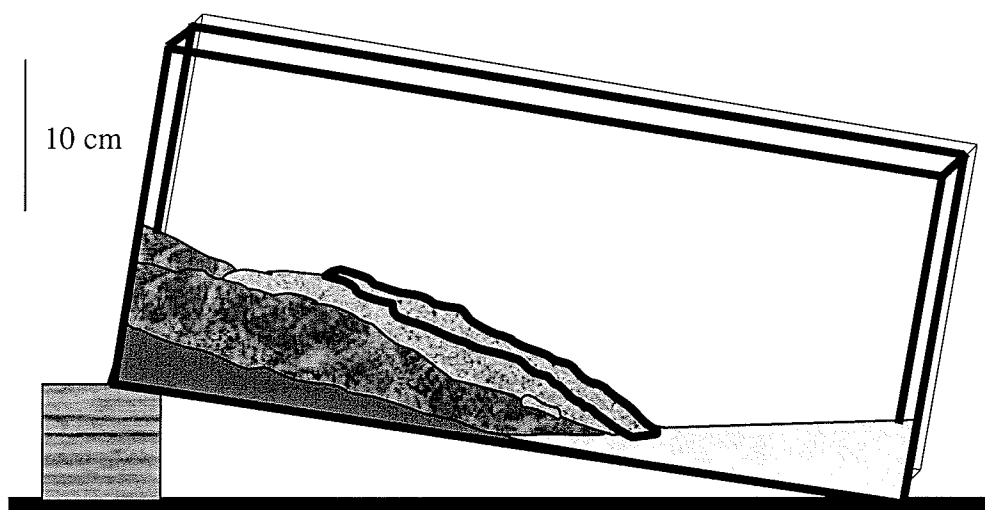


Figure 2. Schematic diagram of pupation terrarium for rearing adults of *B. hornii* Crotch (Coleoptera: Haliplidae). Terrarium was angled with a small block of wood under one end to provide a moisture gradient. Substrate included gravel, coarse sand, fine sand, and potting soil.



Figure 3. Habitat of *Brychius hornii* Crotch (Coleoptera: Haliplidae); Cowan Creek, Manitoba, showing beaver dam, cobble substrate, and riffle area.

CHAPTER V

GENERAL DISCUSSION

The investigations in this thesis have provided a revised classification for the Nearctic species of *Brychius* and insights into the natural history of this group. Before this project was started, it was thought there could be more than one undescribed species (Beutel and Ruhna 1990; Brigham 1978, 1982; Matta 1976). However I conclude there are fewer species in North America than previously described.

Populations of species of *Brychius* display disjunct geographical distributions. *Brychius pacificus* is endemic to the west coast of Oregon and California, and *B. hungerfordi* is endemic to Ontario and Michigan. Perhaps further collecting will reveal additional populations. However, because populations tend to be isolated and vulnerable to localized extinction, there is a concern with respect to conservation.

Action has already been taken for *B. hungerfordi*. This species was listed as state endangered in 1987 by the Michigan Department of Natural Resources (Michigan Dept. Nat. Res. 1989). It was then determined as federally endangered under the US Endangered Species Act in 1994 by the U.S. Fish and Wildlife Service (USFWS 1994). It is currently undergoing a review of its recovery plan (Carrie Tansy, U.S. Fish and Wildlife Service, Personal communication, 2004). A status report (Mousseau and Roughley 2003) has also been prepared on *B. hungerfordi* for the Committee on the Status of Species at Risk in Ontario (COSSARO) and is waiting further recommendation.

Populations that are geographically isolated tend to be vulnerable to localized extinction, depending on the size of population and the extend of the range. Localized extinction may be caused by human alterations of the habitat, and also by stochastic changes in the environment. A species may be rare because its populations contain few individuals, it occurs at few locations, or it has high habitat specificity (Rabinowitz *et al.* 1986). Most rare and threatened invertebrates are associated with fragmented habitats that either occur naturally (e.g., small wetlands, cold spring brooks) or have resulted from human activities (Hafernik 1992). However, as a result of small size, short generation times, and relatively high fecundities, many invertebrate species can maintain viable populations in these small habitats (Wilson 1987). These conditions suggest that viable populations of rare species may be geographically isolated, restricted to small areas, or have low population densities, therefore being difficult to locate.

Attempts have been made to determine population sizes for *B. hungerfordi*. The population in the East Branch of the Maple River was estimated to be 200-500 adults in 1986 (White 1986a). Roughley (1991) collected 42 adults of *B. hungerfordi* from Scone, Ontario in 1986. Marshall (Steve Marshall, Personal communication, 2002) collected specimens at this site in 2001; however, in 2002 he did not find any specimens. To assess the temporal variation in beetle abundance, Grant *et al.* (2000) sampled *B. hungerfordi* in a large pool located on the East Branch of the Maple River, Emmet County monthly from March through December, 1999. They found the greatest number of adults occurred in October.

It is difficult to determine whether population estimates are indicative of a declining population; however, as all species of *Brychius* tend to be highly localized and very

difficult to collect, it is possible to sample an area with individuals and collect few to no specimens.

It is also important to identify specific causes of population decline. Wilsmann and Strand (1990) identified the following potential threats for the population of *B. hungerfordi* in Michigan: dredging for stream bed modification or for sand traps, stream-side logging, channelization, bank stabilization with structures creating an artificial shoreline, and impoundment. The *B. hungerfordi* site in Scone, Ontario has been impounded upstream (Roughley 1991) and the population has survived localized disturbance of bridge construction.

The greatest predators of all species of *Brychius* are probably fish, especially the minnows that live among algae. (Hickman 1931b). Other predators (in the laboratory) include carnivorous insect larvae and frogs (Hickman 1931b).

Beaver impoundments (Strand 1989) and similar structures, such as culverts or mill races (Roughley 1991) appear to be important for maintaining the habitat of this beetle. These structures may decrease the severity of environmental disturbances, such as minimizing fluctuations in downstream flow, thereby reducing the frequency and magnitude of flooding and drying episodes (Naiman *et al.* 1986). Riffles are created on the downstream side of the structures, which may be preferred environments for adult beetles. As well, larvae and adults apparently require the clean gravel substrata with high algal growth that beaver dams and human-made impoundments set up and maintain (Strand and Spangler 1994).

Yet without a species name for an organism and the means to identify it, we cannot even begin to think about conservation programs. For instance, a species cannot

be legally protected if it does not have a name. Before this study, researchers had no reliable means to distinguish species of *Brychius*. The conclusions reached in this work provide a more complete picture of the classification of a small, yet intrinsically interesting group of beetles in North America.

Future Research

Classification

A revision of the Palearctic species of *Brychius*, similar to this study, is needed to clarify the taxonomic status of species in Europe.

Surveys

In order to understand the distribution range and habitat requirements, additional surveys should be conducted for all species of *Brychius*. Results should also be presented for areas that have been surveyed with negative results, as I have done with streams in Manitoba (Appendix 5).

In Manitoba, the Pine River, Hwy. 20 should be surveyed again for specimens of *B. hornii*. As it is difficult to access the river because of its steep banks, I was able to collect there only once and did not find any specimens. However, it is in the same watershed as Cowan Creek and South Duck River and has similar attributes.

In Quebec, collecting should be done in Duparquet to verify if a population exists. Collecting should also be done in the area between Manitoba

and Quebec.

Habitat

Specific habitat requirements should be further investigated. Separate microhabitats of adults and larvae need to be confirmed. Overwintering sites, whether buried in the soil, among root hairs, or within the water column, should be determined.

Natural History

This study touched upon the life history and ecology of *B. hornii*. Further studies are needed to confirm the life cycle, including the timing of the four stages of development, oviposition and pupation sites, and basic biology, including food sources.

The respiration of species of *Brychius* should be further investigated. Although adults have been observed swimming to the surface to renew their air supply in both laboratory and natural environmental settings, individuals of *B. hungerfordi* can withhold renewing air supply at the surface for over two hours (B. Scholtens, University of Michigan Biological Station, Personal communication, 2002). Perhaps there are other ways species of *Brychius* obtain air from the surrounding water such as utilizing oxygen generated by submerged aquatic plants (Hickman 1931a).

The respiration of the larvae should also be studied. The oxygen consumption of larval species of *Haliphus* and *Peltodytes* is generally low (Nilsson 1996); however, this can differ significantly between species (Nilsson 1996). For instance, *Haliphus lineolatus*

larvae have high respiratory activity and are more common in waters with a high percentage of oxygen, whereas larvae of *H. immaculatus*, have a lower respiratory activity and live in water with a limited oxygen supply (Seeger 1971c). It would be interesting to determine the respiratory activity in larval species of *Brychius*, in relation to other species of Haliplidae.

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Appendix 1: Locality information for specimens of *Brychius hornii* Crotch 1873 examined (Coleoptera: Haliplidae). M=male, F=female, ex=male or female specimen.

ADULTS

CANADA

British Columbia

Vancouver Island

Koksilah River; 24.vii.1928; F.S. Carr (1M. JBWM).
Wellington; [no date]; C.S. Papp (2 M. NHM).

Vancouver Region

Vancouver; 2.viii.1939; H.B. Leech (1 M. CNC).
Abbotsford; 29.v.1940; H.B. Leech (1 M. CNC) (1 ex. CAS).
Huntington & LaFoure Roads; near Vancouver; 25.vi.1986; G.L. Challet (1 ex. USNM).
New Westminster; Nicomekl River; Tribune of Boundary Bay; ?.vii.1990 [sic]; R.W. Wisseman Donator (1 F, JBWM).
Mission City; 5.vii.1953; G.J. Spencer (1 F. CNC).

Cariboo Region

Salmon Valley; 19.vii.1969; Lot 1; B.F. & J.L. Carr (4 M, 1 F. CNC).
McLeod Lake; 23.vii.1969; Lot 2; B.F. & J.L. Carr (1 F. CNC).

Range 5 Coastal Region

Topley; Hwy 16; small stream; 25.vi.1987; D. Larson (2 M, 10 exs. Larson Coll.).

Kamloops Region

Three Valley; 2.ix.1992; Lot 1; B.F. & J.L. Carr (1 M. CNC).
Coldwater River; Coquihalla Hwy; 16.ix.1988; Lot 1; B.F. & J.L. Carr (1 F. CNC).
Enderby; Shuswap River; 11.x.1946; H.B. Leech (1 M. CNC) (3 ex. CAS).
Tappen; White Lake Creek; 9.x.1933; H. Leech (1 M. CNC).

Osoyoos Region

Lumby; 19.ix.1937; H. Leech (1 ex. CNC). Bessette Creek; 3.x.1946; H.B. Leech (1 M. CAS). Duteau Creek; 5 km W Lumby; 27.vii.1980; R.E. Roughley (19 exs. JBWM), 31.v.1992 (5 exs. JBWM), 15.ix.1986; low gradient stream; R.G. Beutel & R.E. Roughley (10 M, 78 exs. JBWM).
Vernon; 9.viii.1929; J.F. Brimley Collection Bequeathed 1976 (1M, 3 exs. CNC), 10.viii.1929 (2 M, 1 F. CNC), 9.viii.1929; H.B. Leech (3 exs. CNC) (15 exs. JBWM) (3 exs. CAS), 14.viii.1929; H.B. Leech (2 F, 26 exs. CNC) (3 exs. JBWM) (1 F, 2 exs. USNM) (4 exs. CAS), 8.viii.1929; H.B. Leech (7 exs. NHM), [?] 1929; H.B. Leech (3 exs. NHM), 8.viii.1929; [no collector] (8 exs. AMNH), 8.viii.1929; G.P. MacKenzie Collection (2 exs. UCRC), 10.viii.1929; H.B. Leech

(5 exs. CUIC [Cornell]) (5 exs. USNM) (3 exs. RBCM) (1 ex. CAS), 9.viii.1929;
R. Hopping (1 F, 2 exs. CNC) (9 exs JBWM) (4 exs. (USNM).
Summerland; 10.ix.1931; A.N. Gartrell (1 M, 1 F. CNC).
Similkameen River; 20 km S Keremeos; 1.x.1987; D.J. Larson (2 M, 10 exs Larson
Coll.)
Shingle Creek; 10 km W Penticton; 2.x.1987; D. Larson (1 M, 2 exs. Larson Coll.)

Kootenay Region

Creston; 12.viii.64; Lot 1; BF & JL Carr (2 M, 6 exs. CNC), 29.vii.1956; G. Stace Smith
(1 M. CNC), 22.ix.1957; G. Stace Smith (1 M, 2 F, 7 exs. CNC). Goat River;
edge; 22.ix.1969; J. Schuh (3 M, 4 exs. AMNH), Goat River; 4.viii.1946; G. Stace
Smith (3 exs. CAS).
Ferne; Big Elk River; 14.ix.1986; R.E. Roughley (10 exs. JBWM). Elk River at Hwy 3;
bridge in Fernie; 14.ix.1986; gravel & silt along edge of river; R.G. Beutel & R.E.
Roughley (3M, 2 F, 5 exs. JBWM), 29.v.1992; gravel pool backwater; R.E.
Roughley (2 exs. JBWM).

Alberta

Calgary Region

Tp. 24, Rge. 2, W. 5; 25.viii.1982; C.V. Nidek (2 exs. JBWM).
Tp. 20, Rge. 28, W. 4, Mer.; 30.vii.1973; Lot 1; BF & JL Carr (2 M, 1 F. CNC) (1 M, 2
exs. Cornell).
Tp. 31, Rge. 6, W. 5, Mer.; 29.viii.1972; D. & M. Larson (1 M. Larson Coll.).
Elbow R.; 4.8 km West of Calgary on Hwy. 8; 11.x.1990; R.E. Roughley (1 M. JBWM),
28.vii.1984; R.E. Roughley, D.A. Pollock, & J&B. Carr (1 M. JBWM), 1.ix.1994;
J. Carr, X. Weiping, & R.E. Roughley (2 exs. JBWM), 3.0 mi. W. Calgary; Hwy.
8; Elbow R.; 28.vii.1984; R.E. Roughley coll. (108 exs JBWM); 4.8 km W.
Calgary; Elbow River (1 ex JBWM).
Calgary; 14.ix.1958; Lot 1; BF & JL Carr (1 M CNC), 4.viii.1977 (1 ex. CNC),
29.vii.1973 (1 ex. CNC), 10.viii.1958 (4 exs. CNC), 31.viii.1958 (3 M, 2 exs.
CNC), 1.ix.1973 (3 exs. CNC), 31.viii.1973 (6 exs. CAS), 17.viii.1958 (1 M, 5
exs. CNC) (1 ex. UASM),
Jumpingpound Cr.; 24.viii.1958; Lot 2; BF & JL Carr (2 M, 1 ex. CNC), 12.vii.1959;
Lot 1 (1 F. CNC).

Fort McMurray Region

Hwy. #63; +/- 55 km S. Ft. McMurray; T84, R11, W.4; 28.vii.1984; Lot 2; BF & JL Carr
(2 M, 3 F. JBWM)
Tp. 84, Rge. 11, W. 4, Mer.; 28.vii.1984; Lot 2; BF & JL Carr (7 M, 5 F, 37 exs. CNC).

Southwestern Region

Beaver Mines Creek; Tp. 5, Rge. 2.W., W.4 Mer.; 30.vi.1961; B&J Carr (1 M. CNC).
Beaver Creek; 25.v.1928; F.S. Carr (3 M, 8 exs. JBWM) (1 ex. CNC),(3 F, 4 exs.
UASM) (1 M. Cornell) (1 ex. CAS).
Lundbreck Falls off Hwy. 3 near Lundbreck; 12.ix.1986; gravel & stones below falls,

sticks & silt; R.G. Beutel & R.E. Roughley (5 M, 50 exs. JBWM), 12.vii.1981; RE & ML Roughley (3 M, 25 exs. JBWM).
 Crowsnest River; Lundbreck Falls Prov. Rec. Area; 49°35.03.8"N 114°12'18.0"W; 30.viii.2003; M. Alperyn (4 M, 5 F. JBWM).
 Dungarvon Creek at Hwy. 6; b/n Twinn Butte & Park Union; 49°33'16.5"N 113°43'56.9"W; 31.viii.2003; M. Alperyn (2 M, 2 F. JBWM).
 Tp. 6, Rge. 25, W. 4, Mer.; 24.viii.1985; Lot 1; B.F. & J.L. Carr (2 M. CNC).
 Tp. 6, Rge. 2, W. 5, Mer.; 30.vi.1961; Lot 1; B.F. & J.L. Carr (2 M, 3 F. CNC).
 Tp. 5, Rge. 2, W. 5, Mer.; 30.vi.1961; Lot 1; B.F. & J.L. Carr (1 M, 3 F. CNC).
 Old Man River nr. Cowley; 27.vii.1980; D.J. Larson (3 M, 1 F, 6 exs. Larson Coll.)
 Mill Creek, 4 mi. N. Beauvis Lake; 10.vii.1971; #6; D. & M. Larson (2 M, 1 F. Larson Coll.)
 Waterton National Park, Jct. Hwy. 6 & Crooked Creek; 7.vii.1971; #2; D. & M. Larson (1 F. Larson Coll.).

Cypress Hills Region

Cypress Hills; Battle Cr.; under bridge; nr. Battle Cr. Campground; 6.vii.2001; T. Mousseau (3 M, 2 F. JBWM).

Whitecourt Region

Groat Creek, ca. 20 mi. S. Whitecourt; 8.vii.1970; #1; D. & M. Larson (1 F. Larson Coll.).

Uncertain/Inexact Localities

Tp. [blank], Rge. [blank], W. 5, Mer.; vii.1973; B.F. & J.L. Carr (5 exs USNM).

Saskatchewan

Cypress Hills

Tp. 5, Rge. 29, W. 3, Mer.; 16.viii.1986; Lot 1; BF & JL Carr (5 M. CNC), (1 ex. JBWM). 19.viii.1986 [?] (1 M, CNC).

Manitoba

Cowan Creek

Cowan Creek, 4 km S. & 2 km W. Cowan; UTM grid: 14ULN855612; 9.ix.1986; R.G. Beutel & R.E. Roughley (1 M, 13 exs. JBWM), (51°51'04"N 100°40'49"W); 30.vi.2002; T. Mousseau (10 exs JBWM)
 Near Cowan; 51°59'04"N 100°40'49"W; at fiord over Cowan Creek; 11.vii.1998; R.E. Roughley (4 M, 17 exs. JBWM), 15.ix.2001; T. Mousseau (8 exs. JBWM), 10.ix.2001; T. Mousseau (4 exs. JBWM), 28.vii.2001; T. Mousseau (3 exs. JBWM), 18.viii.2001; T. Mousseau (4 M, 4 exs. JBWM), 5.viii.1998; R.E. Roughley (6 exs. JBWM), 1.vii.2000; R.E. Roughley (3 exs. JBWM), 16.vi.2001; T. Mousseau (2 exs. JBWM), 2.vi.2001; T. Mousseau (1 M, 3 exs. JBWM).

South Duck River

South Duck River, Hwy. 10; under bridge; (51°52'55.5"N 100°36'45.7"W); 15.ix.2001;

384 m elev.; T.Mousseau (11 exs. JBWM), 28.vii.2001; T.Mousseau (2 M, 4 exs. JBWM), 29.vi.2002; T. Mousseau (10 exs JBWM).

Quebec

Duparquet; 1.vii.1944; G. Stace Smith (1 M. insert name of museum).

UNITED STATES OF AMERICA

Washington

Asotin County

South Fork of Asotin Creek; 14 mi SW. Asotin; 26.v.1986; R.S. & V.L. Zack (3 M, 1 F. Zack).

Chelan County

Nason Creek; T27N R17 E Sec 34; Rt. 207; ca 14 mi N Leavenworth; 16.ix.1988; R.S. Zack (1 M, 3 exs. Zack), ca 3 mi N. Coles Corner; 13.ix.1990; R.S. Zack (3 exs Zack), Rt. 2; 5.5 mi E. Coles Corner; 13.ix.1990; R.S. Zack (1 ex. Zack).

Clallam County

Clallam River; Rt. 112; 0.8 mi S. of Clallam Bay; 24.vi.1992; R.S. Zack (1 F. Zack)
Pysht River; Rt. 112; ca 10 mi SE. of Clallam Bay; 24.vi.1992; R.S. Zack (3 F. Zack)

Ferry County

Sanpoil River; Rt. 21; 2.3 mi N. of Keller; 11.ix.1990; R.S. Zack (3 M, 3 F. Zack)
Sanpoli River; ca 1 mi S. Republic; 1.vi.1988; T36N R33E; R.S. Zack (3 M, 2 F, 1 ex. Zack).

Garfield County

Deadman Creek; nr. Central Ferry; T13N R40E, Sec. 14; 27.vi.1990; R.S. Zack (1 M. Zack).

King County

Bothell; North Creek; 17.v.1928; Trevor Kincaid (1 M, 1 ex. JBWM).
North Bend; 31.vii.1927; Darlington (2 M, 1 ex. JBWM), (4 exs. CNC), (1 ex. USNM)
Seattle; 17.v.1928; [no collector data] (1 M. Cornell), (3 exs. USNM).
Carnation; 29.ix.1992; Lot 1; BF&JL Carr (1 M. CNC)
High Point Wy.; T24N R7E Sec. 30; 20.iii.1988; J. Pearson (1 F. Zack)

Kittitas County

Little Naches River; ca 5 mi N. of Cliffdell; FS Rt. 19; 31.vii.1990; R.S. Zack (1 M, 1 F. Zack).
Squaw Creek; ca 13 mi S. of Ellensburg; Rt. 821; 1.viii.1990; R.S. Zack (2 F. Zack).

Lewis County

Bunker Creek; Site 28 near Adna; 46°38'37"N 123°06'19"W; 13.viii.1997; R.W. Wisseman (2 M, 3 exs. JBWM)

Okanogan County

Bonaparte Creek; 7.2 mi ESE. Tonasket; Rt. 20; 11.ix.1990; R.S. Zack (2 M, 1 F, 9 exs. Zack).

Methow River; ca 8.3 mi NW. Winthrop; Rt. 20; 12.ix.1990; R.S. Zack (1 M. Zack).

Pacific County

Naselle River; Rt. 4; T10N R9W Sec. 10; 21.vi.1989; R.S. Zack (1 M, 3 F. Zack).

Pierce County

North Fork Muck Creek; ca 3 mi SW of Graham; 25.ix.1992; R.S. Zack (1 M. Zack).

Snohomish County

Lake Stevens; Catherine Creek; 48°00'29"N 122°02'40"W; 25&30.ix.1997; R.W.

Wisseman Donator (1 ex. JBWM)

Quilceda/Allen Watershed; all sites; ?.ix.1995[sic]; R.W. Wisseman Donator (1 M, 1 ex. JBWM).

Thurston County

Deschutes River at Boe spurs; 47°01'07"N 122°54'08"W; 24.x.1997; R.W. Wisseman Donator (1 ex. JBWM).

Chehalis River at Fagurnus; 46°57'30"N 123°50'00"W; 25.ix.1997; R.W. Wisseman Donator (1 M. JBWM).

Wahkiakum County

Elochoman River; Rt. 407; ca 3 mi ENE Cathlamet; 21.vi.1989; R.S. Zack (1 F. Zack)

Whatcom County

South Fork of Nooksack River; at Hwy. 9; near Acme; 48°43'13.4"N 122°12'02.6"W; 24.vi.2004; R.E. Roughley & R.D. Kenner (1 ex. JBWM, 1 ex. SMDV).

Whitman County

Willow Creek; Rt. 26; ca 1.6 mi W of La Crosse; 24.viii.1992; R.S. Zack (2 M, 4 F. Zack).

Yakima County

Milk Creek; FS Rt. 12; T13N R14E Sec. 5; 1.viii.1990; R.S. Zack (4 F. Zack).

Wenas Rd; ca 14 mi SW Ellensburg; 13.vi.1989; R.S. Zack (2 M, 2 F, 3 exs. Zack).

Dry Creek; Rt. 97; ca 10 mi SW Toppenish; 18.viii.1989; R.S. Zack (3 M, 3 F. Zack).

Skagit County

Montborne; 23.vii.1980; P.&P. Spangler (5 M, 115 exs. USNM)

Cowlitz County

Ridgefield; Gee Creek & tribs.; all sites; 21.vi.1995; R.W. Wisseman Donator (2 F. JBWM).

Uncertain/Inexact Localities

Salmon Creek; Site 25; 26.viii.1997; R.W. Wisseman donator (1 M. JBWM).
Dayton; 2.ix.1957; A.&H. Dietrich (1 F. Cornell).

Idaho**Adams County**

Mud Creek; Rt 95; 3 mi WNW of New Meadows; 10.vii.1992; R.S. Zack (3 M, 8 F. Zack), ca 3.3 mi N Tamarack; 20.vii.1988; R.S. Zack (5 exs. Zack).

Bannock County

Dempsey Creek; Lower R1-3; 13.vii.1994; R.W. Wisseman donator (1 F. JBWM)

Benewah County

Benewah Creek; 12 mi E Plummer; slow water; 13.ix.1981; R.S. Zack (2 M. Zack), 5 mi W St. Maries; 15.vi.1986; R.S. Zack (1 F. Zack)
Charlies Creek; 4 mi SE Emida; 27.viii.1986; R.S. Zack (1 M, 1 F, 6 exs. Zack), East Fork of Charlies Crk.; 5-6 mi SE Emida; 29.vii.1987; R.S. Zack (2 M, 1 F. Zack), 2.ix.1986; R.S. Zack (1 ex. Zack)

Bingham County

Willow Creek; ca 6 mi S Bone; 10.ix.1986; R.S. Zack (1 M. Zack)
Rawlins Creek; Upper; 43°06'41"N 111°53'09"W; T3S R39E S22 SW 1/4; 10.viii.1995; 6083m elev.; M. Stute and J. Wagner (1 F. JBWM)

Blaine County

Wood River; 10.ix.1969; J. Schuh, F. Phippe, J. Coulson (2 M, 3 F, 7 exs. AMNH)

Boundary County

Deep Creek; 5 mi N Naples; 15.ix.1987; R.S. Zack (4 F. Zack)
Brown Creek; 48°37'18"N 116°23'21"W; T61N R1E S30; 27.vii.1995; J. Gilbert (1 M. JBWM)

Butte County

Little Lost River; 10.6 mi N of Howe; 25.ix.1991; R.S. Zack (2 F. Zack)

Caribou County

Tincup Creek; Rt 34; 7.7 mi E of Wayan; 24.ix.1991; R.S. Zack (3 M, 2 F, 7 exs. Zack)
Slug Creek; Lower Valley; South fork of Blackfoot River; 42°46'05" N 111°25'01"W; 14.vii.1994; R.W. Wisseman donator (1 M, 1 ex. JBWM)
Dry Creek; Thatcher Hill; 42°28'53" N 111°47'28"W; T7S R44E S25 SW 1/4; 2.viii.1995; 6109m elev.; J. Wagner (1 M, 1 ex. JBWM)

Owyhee County

Castle Creek; Rt 78; ca 11 mi NW Grand View; 22.ix.1988; R.S. Zack (1 F. Zack)

Franklin County

Maple Creek; 42°01'41"N 111°48'02"W; T16S R40E S15 SE 1/4; 4760m elev.;

14.vii.1994; M.Stute and S. Haris (1 M. JBWM)

Cub River; near Franklin; 23.iv.1955; S. Jewett, Jr. (1 ex. CAS)

Shoshone County

Beaver Creek; 26.vii.1964; B.F. Edmunds, Jr. (1 M. USNM)

Coeur d'Alene River; North fork; near Enaville; 16.vi.1998; R.W. Wisseman donator (1 F. JBWM)

Kootenai County

Trout Creek; 5 mi S Coeur d'Alene; 2.viii.1964; B.P. Edmunds, Jr. (1 F. USNM)

Latah County

Bear Creek; Rt 8; ca 1.9 mi E of Deary; 28.viii.1990; R.S. Zack (3 M, 2 F, 44 exs. Zack)

East Fork Potlatch River; ca 3 mi E Bovill; 28.viii.1987; R.S. Zack (2 M, 1 F, 70 exs. Zack)

Gold Creek; Rt 6; ca 1 mi E of Potlatch; 6.ix.1990; R.S. Zack (2 M, 17 exs. Zack),
30.vii.1991 (1 M, 1 ex. Zack)

Palouse River; FS Rt 447; ca 6 mi ENE of Harvard; 6.ix.1990; R.S. Zack (36 exs. Zack),
1 mi N Harvard; 21.ix.1969; J. Schuh (2 M, 4 F. AMNH), North fork Palouse
River; ca 11 mi NE Harvard; 19.v.1987; R.S. Zack (2 M, 1 F, 38 exs. Zack)

East fork Emerald Creek; FS Rt 447; ca 20 mi E of Harvard; 6.ix.1990; R.S. Zack (1 M, 2 F. Zack)

Valley County

Johnson Creek; Jct. FS Rts. 579 & 447; R8E T15N Sec 7; 22.ix.1991; R.S. Zack (3 M, 1 F, 74 exs. Zack)

Corral Creek; Rt 55; ca 3 mi S Cascade; 23.ix.1988; R.S. Zack (3 M, 3 F, 4 exs. Zack)

Gold Fork River; Rt 55; ca 2 mi S Donnelly; 23.ix.1988; R.S. Zack (3 M, 9 F. Zack)

Big Creek; T13N R4E S9 SW 1/4; 3.viii.1995; 4730m elev.; J. Allison (1 M. JBWM)

Washington County

Weiser River; Rt 95; ca 7.5 mi NE of Midvale; 10.vii.1992; R.S. Zack (2 M, 1 ex. Zack),
17.viii.1989; C.B. Barr (2 F. Barr), (1 F. Berkeley)

Power County

Bannock Creek; Arbon Valley Rd.; 14 mi S of I-86 Jct.; T8S R33E Sec 27; 23.ix.1991;
R.S. Zack (3 M, 4 F, 22 exs. Zack)

Jefferson County

Willow Creek; near Ririe; Snake River & tribs.; 43°37'55"N 111°46'22"W; 7.viii.1996;

R.W. Wisseman donator (1 F. JBWM)

Fremont County

Cave Falls Road; Targhee National Forest; 13 km W Wyoming border; 17.vi.1986; Lot 2;
BF & JL Carr (1 M, 7 F. CNC)

Henry's Fork River; Hwy. 20; Macks Inn; 44°30'N 111°20'W; 23.iii.2003; R.W.
Baumann & S.M. Clarke (5 M, 3 F. BYUC)

Uncertain/Inexact Localities

Eight Mile Creek; 8.viii.1994; R.W. Wisseman donator (1 M, 2 F. JBWM)

Cedar Creek; 19.vii.1994; R.W. Wisseman donator (1 M, 10 exs. JBWM)

Dairy Creek; 17.viii.1994; R.W. Wisseman donator (2 F. JBWM)

Wright Creek; 15.viii.1993; R.W. Wisseman donator (1 F. JBWM)

Pinehurst; 4.viii.1977; Lot 2; B.F. & J.L. Carr (5 M, 2 F, 4 exs. CNC)

Corral R.; 21.vii.1994; R. Wisseman coll. (3 exs. JBWM)

Dempsey R.; 13.vii.1994; R. Wisseman coll. (7 exs. JBWM)

Oregon

Columbia County

East Fork Nehalem River; Rt. 47; ca 3.5 mi N of Vernonia (Pittsburg); 23.ix.1992; R.S.
Zack (2 M, 1 F. Zack)

Grant County

Long Creek; Rt. 395; 1.5 mi N of Long Creek; 17. vii.1990; R.S. Zack (3 M, 12 F. Zack)

Utley Creek; 4.v.1992; R.W. Wisseman (1 M, 1 ex. JBWM), 8.vi.1993 (1 ex. JBWM),
9.ix.1993 (1 M, 1 ex. JBWM)

Dark Canyon Creek; Logan Valley West; 44°12'17"N 118°43'54"W; 22.vi.1993; R.W.
Wisseman (1 M, 1 ex. JBWM)

Rt. 395; beaver pond; ca 9 mi N of Mt. Vernon; 17.vii.1990; R.S. Zack (1 F. Zack)

Klamath County

Little Deschutes River; ca 3 mi N of La Pine; 23.viii.1992; R.S. Zack & M.A. Valenti (3
M, 9 F, 23 exs. Zack), Crescent; 8.ix.1993; R.S. Zack & M.A. Vanlenti (2 exs.
Zack)

Kamath Falls; Barkley Springs; 2.v.1957; J. Schuh (1 M, 1 F. AMNH), 8.v.1967 (2 M,
7 F. AMNH)

Williamson River; edge; 7 mi N Chiloquin; 21.ix.1965; J.Schuh (1 M, 1 ex AMNH),
23.ix.1966; J. Schuh (2 M, 2 F, 18 exs. AMNH), 28.ix.1967; J. Schuh (2 F, 8 exs.
AMNH)

Curry County

Chetko River; near Brookings; south forth; 42°02'45"N 124°16'13"W; 11.vii.1995; R.W.
Wisseman (1 F. JBWM)

Sixes River; 13.vi.1991; Lot 1; BF & JL Carr (1 M. CNC)

Lake County

Camas Creek; Rt. 140; ca 16 mi W of Adel; 16.vii.1990; R.S. Zack (2 M, 3 F, 4 exs. Zack)
Adel; 25.vi.1984; Lot 3; BF & JL Carr (1 M. CNC)

Morrow County

Willow Creek; 8.4 mi SE of Heppner; 18.vi.1991; R.S. Zack (1 M, 1 F. Zack)
Little Butter Creek; Rt. 74; 15.7 mi ENE of Heppner; 19.vi.1991; R.S. Zack (1 M, 2 F. Zack)

Lincoln County

Tidewater; 1.viii.1934; J. Schuh (1 M, 1 ex. USNM)

Wheeler County

10 mi E Mitchell; 4.vii.1984; Lot 1: BF & JL Carr (3 M, 6 F, 7 exs. CNC)

Umatilla County

Owens Creek; Rt. 395; 1 mi W Ukiah; 17.vii.1990; R.S. Zack (2 M, 1 F. 4 exs. Zack)

Deschutes County

20 miles South of Bend; 8.viii.1939; Schuh & Gray (1 F. 1 ex. USNM)

Uncertain/Inexact Localities

Miller Creek; 19.ix.1994; R.W. Wisseman (1 M. JBWM)
Mill Creek; 28.viii.1996; R.W. Wisseman (1 M, 2 exs. JBWM)
Lower McCoy Creek; 28.vii.1997; R.W. Wisseman (1 M. JBWM)
Corral Creek; in riffle; 13.x.1992; R.W. Wisseman (1 M. JBWM), 5.v.1992; R.W. Wisseman (1 M, 1 ex. JBWM), 8.ix.1993; R.W. Wisseman (1 M, 5 exs. JBWM), 21.vii.1994; R.W. Wisseman (1 ex. JBWM)
Blue Creek; Hwy. 140; 25.vi.1984; Lot 1; BF & JL Carr (1 M, 2 F. CNC)
Fox Hollow Creek; 2.viii.1994; R.W. Wisseman donator (3 M, 2 F, 6 exs. JBWM)
Lower McCoy Cr.; 22.vii.1996; R. Wisseman coll. (2 exs. JBWM)

Uncertain identification

Starkey Meadow Creek; 20.ii.1994; R.W. Wisseman (1 F.)
Wallowa County; Whitman National Forest; North Zone Biomon. Station; Upper Chesnimus Creek; 18.viii.1992; R.W. Wisseman (1 F.)
Umatilla County; West Birch Creek; 1 mi W of Pilot Rock; 19.vi.1991; R.S. Zack (1 F. Zack)
Curry County; Mt. Hood National Forest; Tygh Creek; 5-15.vi.1998; R.W. Wisseman (1 F. JBWM)
Bear Creek; 17.ix.1997; R.W. Wisseman (2 F. JBWM)

California

El Dorado County

Upper Truckee River; 2 mi E Meyers; 31.vii.1983; W.D. Shepard (1 ex. CAS)

Nevada**Elko County**

Jackpot; 10.vii.1993; BF & JL Carr (2 M, 2 F. CNC)

Utah**Cache County**

Logan Canyon; 7200 ft.; 28.vii.1973; R. Gordon (2 F. USNM)

Logan; 27.iv.1963; J.L. Hesse (1 F. USNM)

Cache Valley; Porcupine Dam; 14.viii.1987; D.J. Burdick (5 exs. CAS)

Duchesne County

Duchesne River; Hwy. 208; below Tabiona; 13.ix.1990; L.J. Liu (1 M. BYUC)

Emery County

Upper Huntington Creek; 3 mi. abv. Electric Lake; 14.x.2000; M. Gruwell (5 M, 5 F. BYUC).

Salt Lake County

Spring Runs; elev. 4375 ft.; 11.x.1961; D.W. Argyle (2 M. BYUC).

Mill Creek Canyon; elev. 6040 ft.; 13.x.1961; A.D. Stock (2 M, 1 F. BYUC).

Salt Lake City; 16.x.1956; D.J. Rasmussen (1 M. BYUC).

Wasatch County

Strawberry Lake Reservoir; 8.i.1947; R.H. Beaner (1 M, 1 ex. USNM), Bryants Fork; above Strawberry Reservoir; 13.ix.1990; L.J. Liu (3 F. BYUC)

Brown Lake; Uinta Mountains; 30.vi.1986; Lot 1; BF & JL Carr (2 M. CNC)

Weber County

Ogden; 73[sic]; Hubbard & Schwarz (1 M. USNM) (1F. CNC), 73; 712; Horn Coll; H 1217 (1 M. MCZ), 7.6[sic]; Hubbard & Schwarz (1 M. CNC) (1 F. USNM)

Hwy. 39; beaver dams; near Limestone Spring; 14 mi. NE Huntsville; 14.vii.2001; L. Monson (2 M, 1 F. BYUC)

Utah County

Hobble Creek; Kelly's Grove, above Springville; 29.ix.1998; Baumann & Terry (4 F. USNM), 5.ix.2000; K.F. Kuehn (1 M, 3 F. BYUC), 2.x.1986; V. Christman & B. Sargent (1 M, 3 F. BYUC), 5.ix.2000; R.W. Baumann (1 M. BYUC), east of Springville; 29.ix.1998; L.M. Clarke (1 M. BYUC), 5.ix.2000; L. Monson (1 M. BYUC).

Thistle Creek; Hwy. 89; Thistle; 29.ix.1990; R.W. Baumann (2 M. BYUC), Thistle; 29.ix.1990; J.T. Zenger (1 M. BYUC).

Pond at Vivian Park; Provo Canyon; 15.ix.2000; K.T. Jefferies (1 F. BYUC).
17 mi SE Soldier Summit; small stream; 27.vi.1986; RS & VL Zack (1 M, Zack).
American Fork Springs; 59; 1A-16 north (PGPS=57); 18-20.iv.2001; R.W. Baumann (1
M, 1 F. BYUC), 61; 1A-16 (PGPS=61); 18-20.iv.2001; R.W. Baumann (1 F.
BYUC), Mitchells Hollow; 18-20.iv.2001; R.W. Baumann (3 M, 1 F. BYUC).

Mono County

S. Walker, W.Br. Walker R. on Hwy. 395; 6100'; 7.x.1978; R.E. & M.L. Roughley;
backwater debris behind cobbles (4 exs JBWM).

Uncertain/Inexact Localities

Strawberry River; 11.vii.1962; G.F. Knowton, F. Vincent (2 M, 2 ex. UCRC)
Uinta Mountains; Rock Creek; trib. To Green River; ?vi.1998[sic]; R.W. Wisseman (1 F.
JBWM)

Montana

Lincoln County

Lake Creek; near Troy; 48°27'05"N 115°52'37"W; 5.viii.1998; R.W. Wisseman (1 M, 1
F. JBWM)
Fawn Creek; FS Rt 650; ca 20 mi SE Libby; 25.ix.1990; R.S. Zack (2 M, 1 F, 34 exs.
Zack)
Fisher River; FS Rt. 763; T28N R29W Sec 1; ca. 24 mi SE Libby; 25.ix.1990; R.S. Zack
(3 M, 4 exs. Zack)

Flathead County

Thompson River; FS Rt. 56; ca 6.6 mi S Rt. 2; 25.ix.1990; R.S. Zack (2 M, 2 F, 14 exs.
Zack)

Missoula County

Lolo Creek; Rt. 12; 13 mi W of Lolo; 26.ix.1991; R.S. Zack (1 F. Zack)

Gardiner County

Yellowstone National Park; near Gardiner; 16.viii.1962; P. & P. Spangler (1 M.
USNM)

Mineral County

St. Regis River; FS Rt 282; ca 2 mi WSW St. Regis; 26.ix.1990; R.S. Zack (2 M, 1 F, 15
exs. Zack)

Gallatin County

Gallatin River at Hwy. 84; E of Bozeman; 13.viii.1990; R.E. Roughley (1 M, 32 exs.
JBWM), Gallatin River, 4700'; 10.xi.1987; D.L. Gustavson (1 M, 7 exs. USMN)
(2exs. CAS), 20.x.1987; D.L. Gustavson (2 exs CAS), 15.vii.1987; D.L.
Gustavson (2 exs. CAS), 2.iv.1987; D.L. Gustavson (1 ex. CAS), 12.iii.1987;
D.L. Gustavson (2 exs. CAS), 25.xii.1987; D.L. Gustavson (9 exs. CAS), 12.iv-

18.vii.1989; Pitfall Trap; D.L. Gustavson (2 exs. CAS), Gallatin R.; Bozeman; spring seep #2; 12.xi.1990; D.L. Gustafson (1 M, 1 F. BYUC), Gallatin River at Hwy. 347 just W Belgrade; 24.vii.1989; C.B. Barr (2 exs. Barr), (1 ex. Berkeley). Shed's Bridge; 1 mi W Four Corners at Gallatin R.; 5200'; 17.viii.1986; R.S. Miller (7 exs. USMN)
Bear Creek Canyon; SE. Bozeman; 2.ix.1987; D.L. Gustafson (2 exs. CAS), (2 F. BYUC)

Lake County

Flathead Indian Reserve; Jocko River at US Hwy. 93; 2.5 mi N Arlee; 26.vii.1989; C.B. Barr (2 M, 1 F. Berkeley), (2 exs. Barr)
Swan River at N.F; Rd. 129; ca 3 mi S Swan Lake; 22.vii.1989; C.B. Barr (2 exs. Barr)

Saunders County

Camas Creek; Hwy. 382; ca 0.5 mi N of Perma; 6.viii.1989; C.B. Barr (2 M, 1 F. 2 exs. Berkeley), (6 exs. Barr)

Big Horn County

Lime Kiln Creek; mouth; 25.v.1988; D.L. Gustafson (2 exs. CAS)

Broadwater County

Big Spring; Toston; 9.xi.1989; D.L. Gustafson (2 exs. CAS)

Powell County

Blackfoot River; WT 141; 26.vi.1989; D.L. Gustafson (1 ex. CAS)

Uncertain/Inexact Localities

Ardea; 2.viii.1936; [no collector] (3 exs. USNM)
Wolf Creek; 27.ix.1989; Lot 2; BF & JL Carr (1 M, 6 exs CNC)

Wyoming

Lincoln County

Alice Lake Road; 10 mi NE Cokeville; 25.vi.1986; Lot 1; BF & JL Carr (2 M, 1 ex. CNC)

Teton County

Snake River; Rt 26/89; 15.8 mi S of Jackson; 24.ix.1991; R.S. Zack (1 M, 1 F. Zack)

Albany County

Medicine Bow National Forest; Pole Creek Campground; 18.vi.1973; 8300 ft.; D.K. Young (1 F. W.Mad), T25N R71W Sec 19; 6-7.vii.1974; 8300ft; D.K. Young (1 F. W. Mad)

Uncertain**Sheridan County**

Deweese Creek; 1.x.1997; R.W. Wisseman (1 M, 2 exs. JBWM), 8.x.1998; R.W. Wisseman (1 M, 1 ex. JBWM)

Colorado**Gunnison County**

Blue Mesa Reservoir.; 20.vii.1970; Lot 4; BF & JL Carr (1 F. CNC)

Routt County

Steamboat Springs; 29.vii.1940; 6700ft; O.B. (1 ex. CAS)

Arizona**Cocconina County**

Cocconina County; at light; W.J. Hanson; Malaise trap (1 M. USNM)

LARVAE**CANADA****Manitoba****Cowan Creek**

Cowan Creek, 4 km S. & 2 km W. Cowan; 10.xi.2001; T. Mousseau (7 L. JBWM); 1.vii.2001; R.E. Roughley (4 L. JBWM); 24.viii.2001; M. Alperyn (1 L. JBWM); 18.viii.2001; T. Mousseau (2 L. JBWM).

South Duck River

South Duck River, Hwy. 10; under bridge; (51°52'55.5"N 100°36'45.7"W); 15.ix.2001; 384 m elev.; T. Mousseau & L. Capar (1 L. JBWM).

Appendix 2: Locality information for specimens of *Brychius hungerfordi* Spangler 1954 examined (Coleoptera: Haliplidae). M=male, F=female, ex=male or female

ADULTS

CANADA

Ontario

Bruce County

N. Saugeen River at Rd. #25 at Scone; 2.viii.1986; stream nr. dam; R.E.
Roughley (3 M, 4 F, 26 exs. JBWM)

UNITED STATES OF AMERICA

Michigan

Emmet County

McKinley Twp.; Maple River; 1.6 mi E Pellston on C-64; 18.vii.1978; M&R Roughley;
among stones & gravel in backwater (1 M, 10 exs. CNC) (2 M, 1 ex. JBWM) (2
M, 8 exs. CAS), in stones & gravel in pool of small stream (12 M, 20 exs.
JBWM), 17.vii.1984; among stones & gravel in backwater/wdid. Stream; RE &
ML Roughley (18 exs. JBWM).
T.36N. R. 4 W.; 19.vii.1989; R.M. Strand (2 exs. USNM)

Cheboygan County

2.vii.1953; S.E. Neff (2 exs. Cornell), 23.vi.1953; G.J. Lugthart (2 exs. CAS).

LARVAE

CANADA

Lambton County

St. Clair River; Seaway Island; St. Clair cutoff channel; ~0.8 mi SW of E-most tip of
island; ~125 inches offshore; 7 inches H₂O, sandy silt; 12.x.1983; P.Hudson collector;
Det. Eric G. Chapman, 2001 (1 L. USNM).

St. Clair County

Harsens Island; South Channel; St. Clair River; ~half way between Muirs & Voakes
Road; ~175 inches offshore; found in 10 inches H₂O, sandy silty clay w/ org. det
12.x.1983; P.Hudson collector; Det. Eric G. Chapman, 2001 (1 L. USNM).

Appendix 3: Locality information for specimens of *Brychius pacificus* Carr 1928 examined (Coleoptera: Haliplidae). M=male, F=female, ex=male or female

ADULTS

UNITED STATES OF AMERICA

Oregon

Curry County

Siskiyou National Forest; Elk River; 42°47'36"N 124°31'28"W; 25.vii.1995; R.W. Wisseman (1 F. JBWM), 5.xi.1993 (1 F. JBWM).

Brushy Bald Mt.; Lobster Creek; 42°30'25"N 124°17'38"W; 22.viii.1995; R.W. Wisseman (1 F. JBWM).

Humbug Mt.; 24.iv.1988; Lot 1; BF & JL Carr (1 M. CNC)

Douglas County

Berry Creek; near Roseburg; 43°02'05"N 123°32'43"W; 25.x.1991; R.W. Wisseman (1 M. JBWM)

Beals Creek; 42°56'56"N 123°10'16"W; 20.viii.1996; R.W. Wisseman (1 F. JBWM)

Cow Creek; ca 3 mi SW Riddle; 13.viii.1987; R.S. Zack (2 M, 1 F. Zack).

Lane County

Eugene; Willamette River; nr. Beltline Br.; 31.x.1995; R.W. Wisseman (1 M. JBWM)

Uncertain Locality

Bachelor Creek; in riffle; 19.viii.1993; R.W. Wisseman (1 M. JBWM)

California

San Luis Obispo County

Santa Rosa Creek; at Hwy. 1; 20.vi.1981; G. Challet (2 M, 1 ex. CNC), 19.viii.1980; G. Challet (1 ex. CNC), at Cambria; 9.xi.1980; G. Challet (1 ex. CNC), at Hwy. 46; 9.6 mi N. Cambria; 19.viii.1980; G. Challet (1 ex. CNC).

Dairy Creek at El Chorro Reg.; Park Golf Course Drainage; 8.v.1998; [no collector] (1 ex. JBWM)

Humboldt County

Orick; 14.vi.1991; Lot 1; BF & JL Carr (2 M, 10 exs. CNC), Redwood Creek; at Hwy. 101 at Orick; 2.viii.1994; G.L. Challet (1 ex. CNC), 21.vii.1995; G.L. Challet (1 ex. CNC), 2.viii.1996; G.L. Challet (4 exs. CNC), 21.ix.1986; gravel/sand/silt of stream edge; R.G. Beutel & R.E. Roughley (2 M. JBWM), 8 m elev.; 24.iv.1991; Y. Alarie & R.E. Roughley (1 ex. JBWM), 27.iv.1991; R.E. Roughley & Y. Alarie (10 exs. JBWM), Redwood Cr.; 15.ix.1946; H.P. Chandler (1 ex. CAS), 21.vi.2004; R.E. Roughley & R.D. Kenner; 41°17'23.3"N 124°03'25.5"W (33 ex JBWM, 30 ex SMDV)

Dyerville; No. 28 Expo.; 14.ix.1946; H.P. Chandler (1 M. Berkeley)
Willow Creek; Rt 299; ca 6 mi SW of Willow Creek; 21.viii.1992; R.S. Zack & M.A. Valenti (1 F. Zack)
Freshwater; 22.vi.1969; D. Levin (2 F. NHM)
Humboldt Co.; Schaeffer Collection (1 ex. Cornell)

Marin County

Redwood Creek; 1.8 mi S Muir Woods National Mon.; 3.x.1964; H.B. Leech (1 ex. CAS)

Del Norte County

Panther Creek; 18 mi S Crescent City; 25.ix.1959; J. Schuh (1 M. AMNH)
Smith River, Public Fishing Access on Fred Haight Dr.; 21.vi.2004; R.E. Roughley & R.D. Kenner; 41°53'26"N 124°08'49"W (27 ex. JBWM, 27 SMDV).

Mendocino County

1 mi downstream Orrs Hot Springs; 3.ix.1950; H.B. Leech (3 exs. CAS)
Alder creek; 3 mi N Manchester; H.B. Leech (1 ex. CAS)
Mill Creek; just W of Mailliard Redwoods State Park; 6.ix.1964; H.B. Leech (1 ex. CAS)
Branscomb; 18.vii.1965; Lot 3; BF & JL Carr (2 F. CNC)
Westport; 13.vii.1965; Lot 1; BF & JL Carr (1 ex. JBWM) (1 M, 1 F, 9 exs. CNC)
Mendocino Co.; Van Dyke Collection; H. Chandler Collection (1 ex. CAS)

Trinity County

Trinity River; Jct. Rts. 3 & 299; ca 4.4 mi S of Weaverville; 20.viii.1992; R.S. Zack & M.A. Valenti (3 M, 2 F, 6 exs. Zack)
Forest Glen; 23.ix.1992; Lot 3; BF & JL Carr (3 M, 4 F, 5 exs. CNC)

Siskiyou County

Butte Creek; 5 mi S Mt. Hebron; 5.ix.1961; J. Schuh (1 M. AMNH)

Alameda County

Sunol; 23.x.1919; J.O. Martin (2 exs. CAS) (1 M, 1 F. Cornell) (1 M. JBWM)

Tehema County

South Fork Battle Creek; Rt. A-6; ca 7 mi WSW of Manton; 11.ix.1993; R.S. Zack (2 M, 1 F. Zack).

Napa County

Chiles Creek; 2.5 km from Lake Hennessey; 3.x.1976; H.B. Leech (26 exs. CAS),
18.x.1979; H.B. Leech (6 exs. CAS), 14.v.1983; R.E. Roughley & H.B. Leech (1 M, 2 F. JBWM), 2 mi N of Highway No. 128; 30.viii.1964; H.B. Leech (2 exs. CAS), 1.7 mi N Hwy. 128; '430; 3.x.1976; Leech & Schuh (4 F. AMNH)
Soda Creek; at Hwy. 128; 6 mi W jct. Hwy. 121; 20.vi.1985; C.B. Barr (1 F. Barr)

Sonoma County

S. Fork Gualala River at Stewarts Pt.; Healdsburg road; 7.ix.1964; H.B. Leech (1 ex.

CAS)

Uncertain Locality

Elk; 25.vi.1991; Lot 1; BF & JL Carr (1 M. CNC)

Appendix 4: GPS coordinates for collection sites of *B. hornii* Crotch (Coleoptera: Haliplidae) along Cowan Creek and South Duck River, MB in 2001 and 2002.

	Cowan Creek	South Duck River
1	51°58'59.7"N 100°40'49.1"W	51°52'55.5"N 100°36'45.7"W
2	51°58'56.1"N 100°40'49.2"W	51°52'55"N 100°36'45.5"W
3	51°59'04"N 100°40'49"W	51°52'54.3"N 100°36'45.4"W
4	51°58'55.3"N 100°40'49.1"W	51°52'53.7"N 100°36'45"W
5	51°58'55.0"N 100°40'48.7"W	51°52'53"N 100°36'45"W
6	51°58'54.5"N 100°40'49"W	51°52'52.1"N 100°36'45.7"W
7	51°58'53.9"N 100°40'49.1"W	51°52'51.9"N 100°36'45.3"W
8	51°58'52.9"N 100°40'49.1"W	51°52'51"N 100°36'44"W
9	51°58'52.1"N 100°40'47.5"W	51°52'49.4"N 100°36'44.6"W
10		51°52'48.7"N 100°36'45.7"W
11		51°52'48.2"N 100°36'44.5"W
12		51°52'47.6"N 100°36'44.5"W

Appendix 5: Localities surveyed for *B. hornii* Crotch (Coleoptera: Haliplidae) with negative results in Riding Mountain, Duck Mountains, and Porcupine Hills, Manitoba in 2001.

1. Lake Winnipegosis; Camperville; Beach Drive
2. Lake Winnipegosis; Camperville; Archies Creek Rd.
3. Pine River; Hwy. 20
4. Roaring River; Hwy. 10; nr. Swan River
5. Sclater River; Hwy. 10; nr. Cowan
6. Unnamed creek; Hwy. 10; 51°52'40"N 100°36'40"W
7. East Favel River
8. Elk Lake; 51°32'16.5"N 100°48'35.2"W
9. Ochre River; nr. Ste Rose du Lac
10. Edwards Creek; Hwy. 10
11. Vermillion River; Hwy. 10
12. Wilson River; nr. Ashville
13. Valley River
14. Drifting River
15. Mink Creek
16. Fishing River
17. Stone Creek
18. Shanty Creek
19. Fork River
20. Garland Creek
21. Garland River
22. West Favel River
23. Unnamed creek; Hwy. 10; Rd. #200; 51°54'53.7"N 100°38'56.8"W
24. Unnamed creek; Hwy. 10; 51°45'15.6"N 100°31'57"W