University of Alberta

Community ecology of ants (Hymenoptera: Formicidae) in the central sand hills of Alberta, and a key to the ants of Alberta

by

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Abstract

In this study I examined ant biodiversity in Alberta. Over a two-year period, 41,791 ants were captured in pitfall traps on five sand hills in central Alberta and one adjacent aspen parkland community. Using additional collections, I produced a key to the 92 species of ants known from Alberta, Canada. The central Alberta sand hills had the highest recorded species richness ($S = 35$) reported in western Canada with local ant species richness inversely related to canopy cover. Forest fires occurred in the sand hills during both years of sampling, allowing me to examine the response of ants to fire. Species richness did not significantly change following fire, although individual species did change in abundance. Body size was the most influential variable in predicting changes in species abundance. This study underscores that ants in Alberta are more species-rich and have complex adaptations to disturbance.

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Background and Rationale

Ants as focal taxa for biodiversity research

Assessments of biodiversity and its conservation have become important issues given the current rates of habitat destruction (Maguran 2004; Alonso 2010). However, complete surveys of all taxonomic groups in a given area are impractical or even impossible. Thus, it is useful to focus resources on taxa that are ecologically important, diverse, abundant, easy to sample/monitor, taxonomically stable, and indicators of other taxonomic diversity because this allows for a more rapid assessment of diversity (Ellison 2012). Even if diversity of a focal taxon does not always correlate with diversity of other taxa (Olive et al. 1998), surveys of single taxa provide knowledge of that group and increase our understanding of local biodiversity (Alonso 2000; Ellison 2012).

Understanding the natural history of a focal taxon is important in relation to elaborating biodiversity and using the information for conservation purposes (Alonso 2010). In particular, determining the effects of regional and local environments on abundance and distribution of focal taxa is important (Magurran 2004; Alonso 2010).

Ants (Hymenoptera: Formicidae) are an excellent taxon for biodiversity studies because they are conspicuous and important faunistic elements in most ecosystems. For example, ants contribute as much to soil turnover as terrestrial annelids (Hölldobler and Wilson 1990). In areas with no termites, such as northern temperate regions, ants are also major contributors to the breakdown of wood (Hasen and Klotz 2005). In the eastern United States, ants are responsible for dispersal of more than 30% of all seeds from herbaceous plants (Handel et al. 1981). Ants are also important food sources for both invertebrates and vertebrates (Hölldobler and Wilson 1990), and are major predators of arthropods of all sizes, including mites (Hölldobler and Wilson 1990). Ants are also diverse. Over 12,600 species have been described (Agosti and Johnson 2005).

Ants are also excellent focal taxa for study and monitoring since they are found abundantly in most terrestrial ecosystems (Majer 1983; Hölldobler and Wilson 1990). The majority of ground dwelling ants live in perennial, sessile colonies with workers having limited foraging ranges (Hölldobler and Wilson 1990), allowing for reliable sampling and monitoring that is well-linked to characteristics of the local habitat (Alonso et al. 2010). Ants have been used as indicator taxa, most notably in Australia, where their diversity of ants is positively related to biodiversity in arid environments. They have also been used to monitor the effect of disturbances, such as mining, on biodiversity (Andersen et al. 1996; Andersen et al. 2007). Economically, ants are also important, having both positive and negative influences.

In addition to the important ecological factors listed above, ants are also known to reduce the abundance of pests, such as defoliating forest insects (Petal 1978), and in Europe ants are often used as biological controls (Klotz et al. 2008). However, public opinion generally focuses on the negative effects of ants (Klotz et al. 2008). A billion dollar per year industry in the United States focuses on the control of structural pest ants, such as *Camponotus* and *Liometopum* (Klotz et al. 2008). Additional money is spent on controlling invasive ants, such as *Solenopsis invicta* (Fire Ants) and *Linepithema humile* (Argentine Ants), which can have deleterious effects on both natural and agricultural ecosystems and can cause human discomfort (former with painful stings) (Klotz et al. 2008; Lach and Hooper-Bùi 2010).

Diversity of ants in Alberta

Despite their probable ecological importance and potential as ideal study organisms, little is known about Western Canadian ant biodiversity, or what factors may affect that diversity. This is especially true in Alberta were research on ants has been quite sparse. The majority of work to date has focused on the biology of individual species, notably *Formica podzolica* Francoeur 1973, and its relationship with its facultative (*Formica aserva* Forel) and obligate (*Formica integra* Nylander and *Polyergus breviceps* Emery) slave-makers (Deslippe and Savolainen 1994, 1995a,b; Savolainen *et al*. 1996; Savolainen and Deslippe 2001). A study of ants from the genera of *Lasius*, *Myrmica*, *Tapinoma*, and *Temnothorax*, often farmed more than one species of Sternorrhyncha at a time (Newton et al. 2011). Another study looked at indirect mutualisms among *Formica obscuriventris* Mayr and aphids (Heteroptera: Sternorrhyncha) on the Yucca plant, *Yucca glauca* Nutt, which resulted in lower seed predation for the plant (Perry et al. 2004).

The last taxonomic review of ant biodiversity in the province (Sharplin 1966) found 40 species, in 10 genera. Since then, several taxonomic revisions and species descriptions have been published (e.g., Fischer and Cover 2002), laying the ground for a more in-depth survey of ant biodiversity in the province.

Ants in the sand hills of central Alberta

Like ants, the sand hill ecosystems of Alberta have not been extensively surveyed with respect to their biota. Sand hills first formed as aeolian dunes at the end of the Wisconsin glaciation (Wolfe et al. 2004). The majority of northern and central dune fields in Alberta, excluding the Lake Athabasca sand dunes (Wolfe et al. 2001; Acorn 2011), have been stabilized by vegetation for several centuries. These central and northern sand hills are generally covered by jack pine barrens, a heterogeneous environment with variable canopy and ground cover (Lewis and Dowding 1928). Furthermore, sand hills appear to represent distinct regional scale "ecological islands" surrounded by aspen parkland vegetation or cultivated agriculture, making them regionally important for biodiversity and conservation.

The sandy substrate of sand hills allows for easy burrowing and provides thermal benefits. Furthermore, given the topographic heterogeneity of sand hills, these areas contain high invertebrate diversity (Howe et al. 2010; Acorn 2011). Additionally, sand hills with jack pine barrens experience locally high fire frequencies, increasing heterogeneity in vegetation structure (Larsen 1997) and biodiversity (Boulanger and Sirois 2007). Furthermore, sandy soils support higher ant diversity when compared to soils with higher clay content (Boulton et al. 2005). Sand hills are therefore prime environments in which to study ant biodiversity.

Thesis Objectives

In this thesis, I review the ant fauna of Alberta, and investigate the community ecology of ants in the sand hills of central Alberta. The thesis is divided into the following chapters.

In Chapter Two, I provide the first taxonomic review, since Sharplin (1966), of ant diversity in Alberta, Canada. I also present an illustrated key that consolidates and simplifies the process of identifying ants in the province. By doing this I hope to encourage future research on ants in Alberta.

In Chapter Three, I compare the distribution and abundance of ants on sand hills with those in surrounding aspen parkland communities that are common throughout central Alberta. I also examine how different vegetation physiognomies, classified by canopy cover, affect ant species richness on the sand hills of central Alberta. I was generally interested in testing whether sand hills could be viewed as ecological islands containing a distinct and diverse fauna of ants.

In Chapter Four, I assess immediate post-fire effects of fire on individual ant species. Here, I compare changes in abundance of individual ant species, as well as overall species richness, in either the first or second year following wildfire using a control site without fire for comparison. I also examine how life history traits affect observed numerical responses of ants to fire.

Chapter Five is an overview of my research and its importance for both ant diversity and potential impacts on conservation. I discuss the importance of ants in northern temperate regions. Moreover, I argue that sand hills are potential biological hotspots in need of greater conservation. Finally, I assess potential limitations of my research and suggest future research that may enhance our understanding of northern temperate ant biodiversity.

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Chapter 2: Key to the ants (Hymenoptera: Formicidae) of Alberta: based primarily on the worker caste

Introduction

Ants (Hymenoptera: Formicidae) are familiar insects in Alberta, Canada. Despite the important and diverse roles that ants play, it is surprising that little is known about them in the province. The last published work on ant diversity in Alberta (Sharplin 1966) was a preliminary study listing only 40 species. Worldwide, ants are known to be important ecosystem engineers that enhance nutrient cycling, soil turnover, seed dispersal, and invertebrate populations (Briese 1982; Hölldobler and Wilson 1990; Jones et al. 1994; Folgarait 1998). Furthermore, many ants are considered pests because of their abilities to disrupt lawns, infest homes, and their habit of viciously defending their colonies through biting and stinging (Klotz et al.2008).

Although ant taxonomy in North America is well known (Bolton 1995) and well-described (Mackay and Mackay 2002, Wheeler and Wheeler 1963, Creighton 1950), many species within particular genera, such as *Formica*, *Leptothorax* and *Myrmica*, are very similar or taxonomically problematic (Fisher and Cover 2007). Few taxonomic keys focus on ants in Canada, and many lack several common boreal species. Furthermore, many keys are genus or species-group specific. Thus, it has been challenging to identify ants from Alberta.

The following review of the ant fauna of Alberta has more than doubled the number of species known from the province. Sharplin (1966) recorded 10 genera and 40 species. I now record 15 genera and 92 species (Table 2.1).

Materials

Ants were collected at a variety of sites around Alberta. Large numbers of ants were collected and examined from areas associated with three ecological studies: the EMEND project in the Peace River area of Alberta (2002), my own studies of ants on central Albertan sand hills (2009-2010), and a study by Newton et al. (2011), on native fescue grassland from east-central Alberta. Collections were examined at the Royal Alberta Museum, the University of Calgary Entomological Collection, and the E. H. Strickland Entomological Museum of the Department of Biological Sciences at the University of Alberta. The personal collection of John Acorn was also examined. Vouchers of each species I have collected are now deposited in the E. H. Strickland collection, and the remainder of my specimens have been retained in my personal collection

Overview of the Fauna

I have recorded 92 species of ants, in 15 genera and three subfamilies from Alberta (Table 2.1; Figures 2.1-2.95). By far the most speciose genus is *Formica*, with 37 species. Other commonly encountered genera include *Camponotus*, *Lasius*, *Myrmica*, and *Leptothorax*. Several rare or geographically restricted genera include *Dolichoderus*, *Solenopsis*, *Manica*, and *Pogonomyrmex*. There are four putatively endemic species in Alberta, *Leptothorax athabasca* Buschinger and Schulz, *Leptothorax pochahontas* (Buschinger), *Leptothorax faberi* Buschinger, and *Temnothorax fragosus* (Mackay and Buschinger) (all apparently restricted to the Rocky Mountains). Of the 92 species of ants in Alberta, 91 are indigenous and one, *Monomorium pharaonis* (Linnaeus), is introduced.

Species list of Formicidae from Alberta:

*indicates ant species that have been reported to be in Alberta by other publications, but have not encountered by the author.

Subfamily Dolichoderinae

Genus *Dolichoderus*
- *Dolichoderus taschenbergi* (Mayr) 1866

Genus *Tapinoma*
- *Tapinoma sessile* (Say) 1836

Subfamily Formicinae

Genus *Camponotus*
- *Camponotus herculeanus* (Linnaeus) 1758
- *Camponotus laevigatus* (Smith)* 1858
- *Camponotus modoc* Wheeler 1910
- *Camponotus nearcticus* Emery 1893
- *Camponotus novaeboracensis* (Fitch) 1855
- *Camponotus vicinus* Mayr 1870

Genus *Formica*
- *Formica accreta* Francoeur 1973
- *Formica adamsi whymperi* Wheeler 1917
- *Formica aserva* Forel 1901
- *Formica argentea* Wheeler 1902
- *Formica bradleyi* Wheeler 1913
- *Formica canadensis* Santschi 1914
- *Formica dakotensis* Emery 1893
- *Formica densiventris* Viereck 1903
- *Formica emeryi* Krausse 1926
- *Formica fossaceps* Buren 1942
- *Formica fusca* Linnaeus 1758
- *Formica glacialis* Wheeler 1908
- *Formica hewitti* Wheeler 1917
- *Formica impexa* Wheeler 1905
- *Formica integroides* Wheeler 1913
- *Formica lasioides* Emery 1893
- *Formica limata* Wheeler 1913
- *Formica microgyna* Wheeler 1903
- *Formica montana* Wheeler 1910
- *Formica neoclara* Emery 1893
- *Formica neogagates* Viereck 1903
- *Formica neorufibarbis* Emery 1893
- *Formica obscuripes* Forel 1886
- *Formica obscuriventris* Mayr 1870
- *Formica obtusopilosa* Emery 1893
- *Formica opaciventris* Emery 1893

- *Formica oreas* Wheeler 1903
- *Formica oreas comptula* Wheeler 1913
- *Formica perpilosa* Wheeler 1913
- *Formica planipilis* Creighton 1940
- *Formica podzolica* Francoeur 1973
- *Formica puberula* Emery 1893
- *Formica ravida* Creighton 1940
- *Formica rubicunda* Emery 1893
- *Formica subintegra* Wheeler 1908
- *Formica subnitens* Creighton 1940
- *Formica subpolita* Mayr 1886
- *Formica ulkei* Emery 1893

Genus *Lasius*

- *Lasius alienus* (Förster) 1850
- *Lasius coloradensis* Wheeler 1917
- *Lasius crypticus* Wilson 1955
- *Lasius fallax* Wilson 1955
- *Lasius flavus* (Fabricius) 1781
- *Lasius latipes* (Walsh) 1863
- *Lasius neoniger* Emery 1893
- *Lasius niger* (Linnaeus) 1758
- *Lasius pallitarsis* (Provancher) 1881
- *Lasius subglaber* Emery 1893
- *Lasius subumbratus* Viereck 1903
- *Lasius umbratus* (Nylander) 1846

Genus *Polyergus*

- *Polyergus breviceps* Emery 1893

Subfamily Myrmecinae

Genus *Solenopsis*

- *Solenopsis molesta* (Say) 1836

Genus *Formicoxenus*

- *Formicoxenus hirticornis* (Emery) 1895
- *Formicoxenus quebecensis* Francoeur 1985
- *Formicoxenus provancheri* (Emery) 1895

Genus *Harpagoxenus*

- *Harpagoxenus canadensis* Smith 1939

Genus *Leptothorax*

- *Leptothorax athabasca* Buschinger and Schulz 2008
- *Leptothorax faberi* Buschinger* 1983
- *Leptothorax muscorum* (Nylander) 1846
- *Leptothorax pocahontas* (Buschinger)* 1979
- *Leptothorax retractus* Francoeur 1986
- *Leptothorax wilsoni* Heinze* 1989

Genus *Manica*

- *Manica hunteri* (Wheeler) 1914

- *Manica invidia* Bolton* 1895

Genus *Monomorium*
- *Monomorium minimum* (Buckley) 1867
- *Monomorium pharaonis* (Linnaeus) 1758

Genus *Myrmica*
- *Myrmica ab01*(near *Myrmica crassirugis*)
- *Myrmica ab02* (near *Myrmica americana*)
- *Myrmica alaskensis* Wheeler 1917
- *Myrmica americana* Weber 1939
- *Myrmica brevispinosa* Wheeler 1917
- *Myrmica crassirugis* Francoeur 2007
- *Myrmica detritinodis* Emery 1921
- *Myrmica fracticornis* Forel 1901
- *Myrmica incompleta* Provancher 1881
- *Myrmica latifrons* Stärcke 1927
- *Myrmica lobifrons* Pergande 1900
- *Myrmica nearctica* Weber 1939

Genus *Pogonomyrmex*
- *Pogonomyrmex occidentalis* (Cresson) 1865
- *Pogonomyrmex salinus* Olsen 1934

Genus *Temnothorax*
- *Temnothorax ambiguus* (Emery) 1895
- *Temnothorax fragosus* (Mackay and Buschinger) 2002
- *Temnothorax rugatulus* Emery 1895

Taxonomic Problems

Several ant taxa likely contain more species in Alberta than are listed. Some may be undescribed, while others are simply difficult to distinguish and not yet confirmed for the province. However, working out these taxonomic problems is beyond the scope of this thesis.

Leptothorax: *Leptothorax* species are difficult to identify confidently as the diagnostic characteristics for many described species are poorly defined (Fischer and Cover 2007; Buschinger and Schultz 2008). Further research is needed to help clarify the taxonomy of this genus in Alberta (Buschinger and Schultz 2008). In this key, *Leptothorax muscorum* is potentially a mix of several species, referred to under one name. Even among the named species I choose to recognize here, many individuals will be difficult to place correctly.

Temnothorax: Like *Leptothorax*, *Temnothorax* from the northern Nearctic is relatively poorly known (Mackay and Buschinger 2002; Buschinger and Schultz 2008). It is possible there are more species waiting to be recognized in Alberta.

Myrmica: This genus contains several species that are morphologically similar (Fischer and Cover 2007). It is probable that because of limited taxonomic work, and limited collecting, more species exist in Alberta. Two potentially new species *Myrmica ab01* and *Myrmica ab02,* have been deemed significantly different from known species, and were included in the key. *Myrmica ab01* looks similar to *Myrmica crassirugis* but possesses distinctly upturned propodeal spines. *Myrmica ab02* is similar to *Myrmica americana,* but possesses smaller lamina on the basal bend of its scape. As North American *Myrmica* is currently being revised by André Francoeur (personal communication) these potentially new species may be described. For the moment I have considered them as tentative new species and thus recognized as so in this thesis.

Formica: The most species-rich genus in Alberta with 38 species, *Formica* has six species-groups and numerous species that are difficult to separate from one another (Fisher and Cover 2007). Traits that are difficult to see without 50X dissecting microscopes, regional variation within species, and differences relying on setae and/or pubescence often make *Formica* difficult to identify. This key tries to simplify the difficulties, but comparison with identified material, and familiarisation by working with large numbers of specimens is the best way to see the differences present between similar species of this genus.

Preparing Specimens for Use with this Key (Figures 2.1-2.95)

The key is intended to allow identification of any worker caste ant specimen from Alberta, but careful specimen preparation will facilitate identification. The following tips should ensure that adequate material is acquired at the time of collection. A stereo microscope with at least 50X magnification is required to see many of the characteristics mentioned in the key, and careful experimentation with lighting, including diffusion, may be required as well.

- Collect a range of worker sizes and multiple specimens (minimum of five recommended) so identification can be confirmed.
- When pointing specimens make sure the mandibles are open so you can see all mandibular teeth. For the genera *Lasius*, *Temnothorax* and *Leptothorax* this is especially important.

- Specimens in ethanol can be confusing to identify, it is best for the specimens to be pinned, pointed (glued to a triangular card) and dry, so that structures, such as erect setae, are easier to see.
- For the *Formcia fusca* group there is a couplet in the key where some dissection is needed. It works best before the specimen is pointed. For the dissection, remove the posterior four legs including the coxae, and then mount the specimen on its side; this will allow for structures required for identification to be seen.
- For identification of *Camponotus* species, major workers are required; however it is important to collect all castes, especially when dealing with arboreal species, such as *Camponotus nearctica* whose majors can easily be confused with minors from larger *Camponotus* species.

Glossary

Some of the terms used in ant identification may be unfamiliar, even to those who work on other insect groups. Terms used in the key are defined below.

Antenna: paired, segmented sensory appendages attached to the front of the head.

Antennal fossa: depressed area around the antennal socket.

Antennal socket: articulation of the antenna with the head.

Apex: tip, most distal point (plural= apices).

Apical club: antennae have an apical club when the distal (terminal) segments are enlarged relative to more basal segments.

Appressed setae: setae that lie against, or run almost parallel to, the cuticle of an ant.

Basal tooth: the basalmost tooth along the chewing margin of the mandible, closest to the anterior margin of the clypeus.

Carinate: having multiple carinae (ridges).

Clavate setae: setae that are expanded at their apices.

Clypeus: the anterior median sclerite of an ant head. The anterior margin of the clypeus forms the anterior margin of the head in frontal view.

Clypeal fossa: depression near the posterior margin of the clypeus, formed from the lateral “wings” or sides of the clypeus.

Concolourous: head, mesosoma and gaster are all the same colour.

Decumbent setae: setae that stand at an angle of between 10-40 degrees from the cuticle of ant.

Erect setae: setae which stand at higher than a 40 degree angle from the cuticle of ant.

Flexor surfaces: the surfaces of the tibia and femur that can touch each other when the leg bends.

Frontal carinae: a pair of parallel or almost parallel ridges, medial to the antennal sockets, originating directly posterior to the clypeus on the head of an ant.

Frontal lobes: shelf-like lobes formed when frontal carinae extend laterally over the antennal fossae.

Frontal triangle: a triangular area dorsal to the clypeus and between the frontal carina.

Frontal view: anterior view, of the face of an ant.

Funiculus: the apical segments of antenna, after the first basal segment.

Gaster: terminal four or five segments of the abdomen, posterior to the petiole and/or postpetiole.

Gena: the area of the head between the compound eye and the mandible.

Head length: measured from the anterior midline of the clypeus to the posterior midline of the occipital margin; does not include the mandibles.

Infuscated: darkened, with a blackish tinge.

Inquiline: living in another ant’s nest; either commensally or parasitically.

Major: the larger castes of an ant species, excluding the queen.

Mesosomal profile: dorsal profile of the mesosoma, as seen in lateral view.

Mesosoma: the middle of the three main body parts of an ant. Includes the thorax and the propodeum.

Mesonotum: dorsal tergite of the mesothorax.

Metasternum: the posteroventral sclerite of the propodeum.

Metanotal region: the area where mesonotum and propodeum meet, representing the vestiges of a tergite called the metanotum.

Microreticulate: with a network of very fine ridges.

Minor: the smaller castes of an ant species.

Occipital margin: the posterior margin of the head.

Peduncle: an anteriorly elongated narrowing of the petiole.

Petiole: the anterior segment (and sometimes the only segment) of the ant waist, consisting of abdominal segment 2.

Polymorphic: having multiple sizes and/or morphological castes.

Postpetiole: the posterior segment (not present in all ant species) of the ant waist, consisting of abdominal segment 3.

Profemora: the femora of the anterior pair of legs.

Pronotum: the dorsal sclerite of the prothorax.

Propodeal spines: spines on the dorsum of the propodeum.

Propodeum: the first abdominal segment, fused to the thorax. Forms part of the mesosoma.

Prothorax: the first thoracic segment.

Psammophore: an array of long setae, forming a basket, on the ventral side of the head.

Pubescence: short fine setae that are decumbent along the cuticle.

Punctate: with numerous fine pits.

Rugae: wrinkle-like ridges, often in parallel.

Scape: elongate basal segment of antenna.

Sclerite: an integumental plate of the exoskeleton.

Striae: impressed lines.

Tergite: dorsal sclerite of a segment.

Truncate setae: setae that are thick and squared off at the apex.

Format of the Key

The following key has been prepared using the PowerPoint template provided by the Canadian Journal of Arthropod Identification, and intended for online interactive publication, with hyperlinks. As such, each PowerPoint slide is presented below as a figure. Note as well that anterior is to the left in all illustrations showing lateral views. In dorsal views, anterior is either to the left or to the top.

Acknowledgments

Beta-testing of the key was performed by Heather Proctor and John Acorn, although specimens of all species were not available at the time. I also thank Jeffery Newton and Tyler Cobb for also testing the key and giving their comments.

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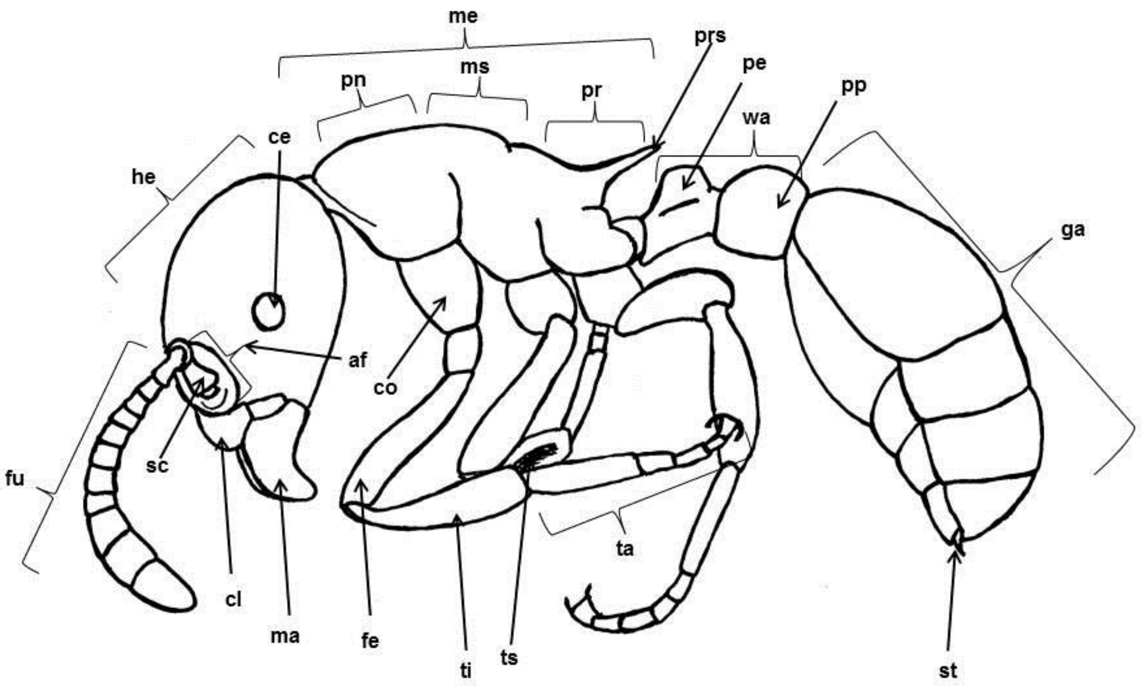
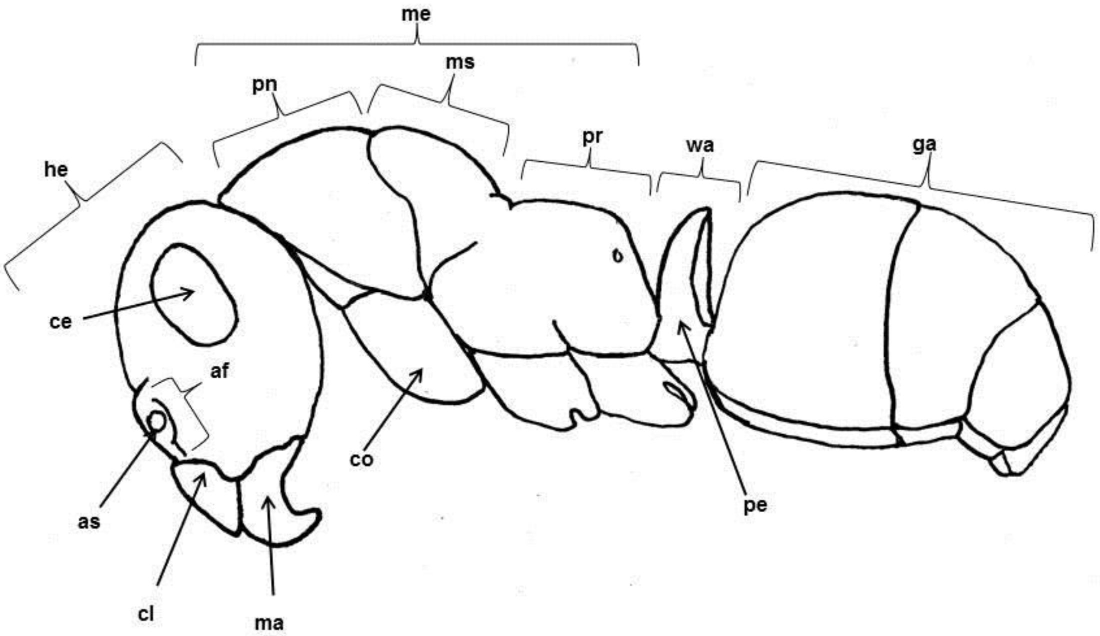
Figures:



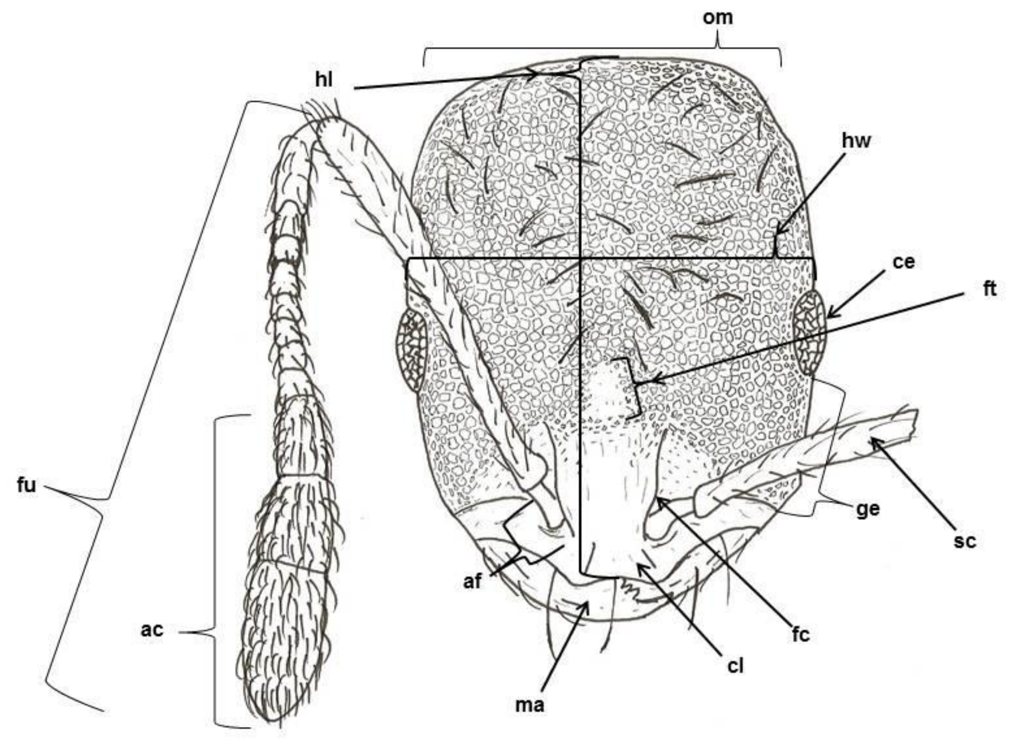
Myrmica alaskensis. Labels: af: antennal fossa. ce: compound eye. cl: clypeus. co: coxa. fe: femur. fu: funiculus. fu+sc: antenna. ga: gaster. ma: mandibles. me: mesosoma; ms: mesonotum. pe: petiole. pp: postpetiole. pn: pronotum. pr: propodeum. prs: prodeal spine. sc: scape. st: stinger. ta: tarsomeres, composed of tarsomeres. ti: tibia. ts: tibial spur. wa: waist.

Figure 2.1: Lateral view of the myrmicine ant, *Myrmica alaskensis*, showing structures used in identification.



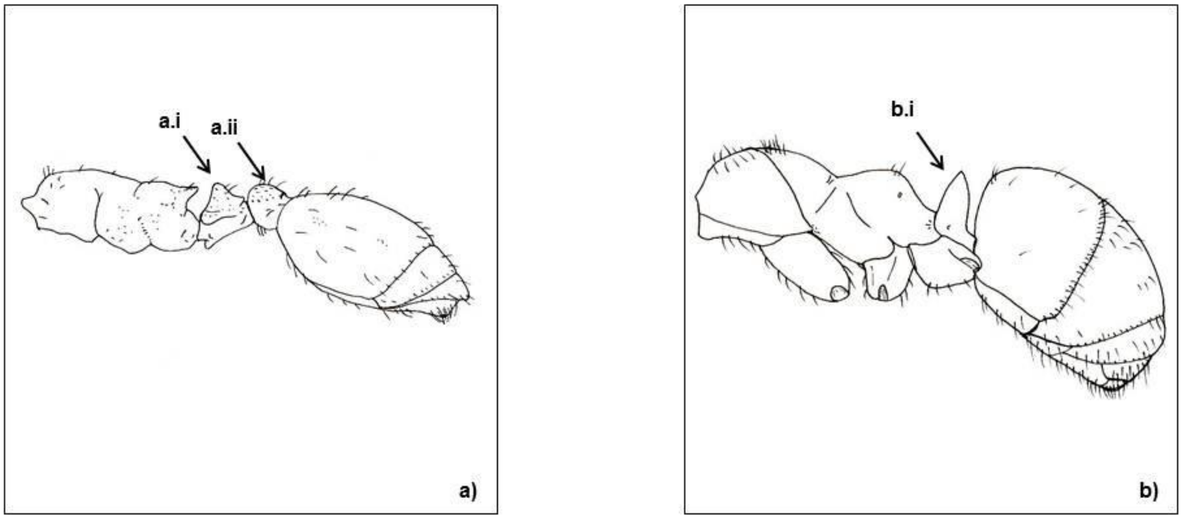
Formica podzolica: antenna and legs not shown. Labels: af: antennal fossa. as: antennal socket. ce: compound eye. cl: clypeus. co: coxa. ga: gaster. ma: mandibles. me: mesosoma. ms: mesonotum. pe: petiole. pn: pronotum. pr: propodeum. wa: waist.

Figure 2.2: Lateral view of the formicine ant, *Formica podzolica*, showing structures used in identification.



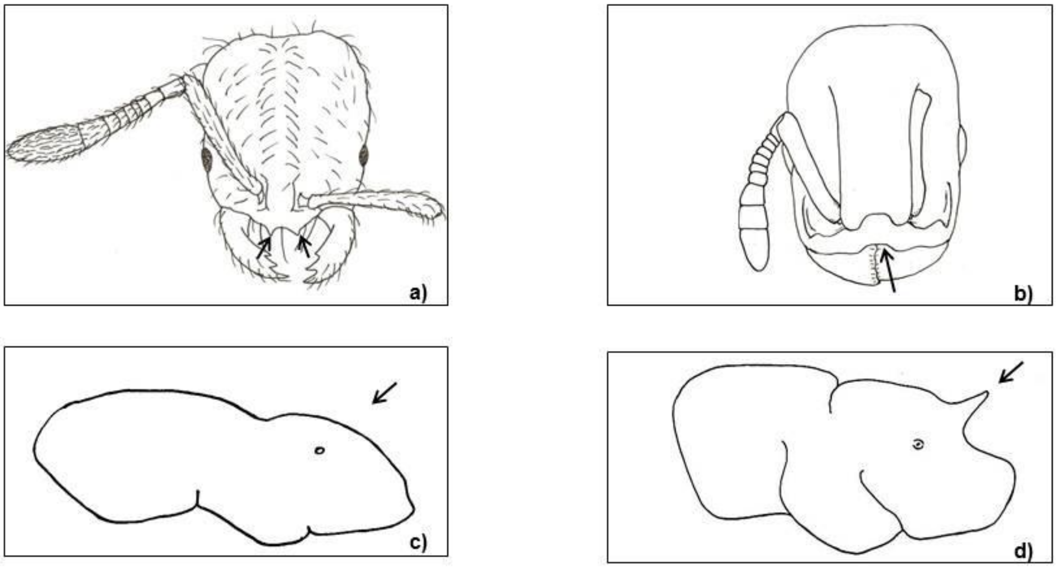
Monmorium pharaonis: left funiculus not shown. Labels. ac: antennal club. af: antennal fossa. ce: compound eye. cl: clypeus. fc: frontal carina. ft: frontal triangle. fu: funiculus. fu+sc: antenna. ge: gena. hl: head length. hw: head width. ma: mandibles. om: occipital margin. sc: scape.

Figure 2.3: Frontal view of the Myrmicinae ant, *Monomorium pharaonis,* showing structures used in identification.



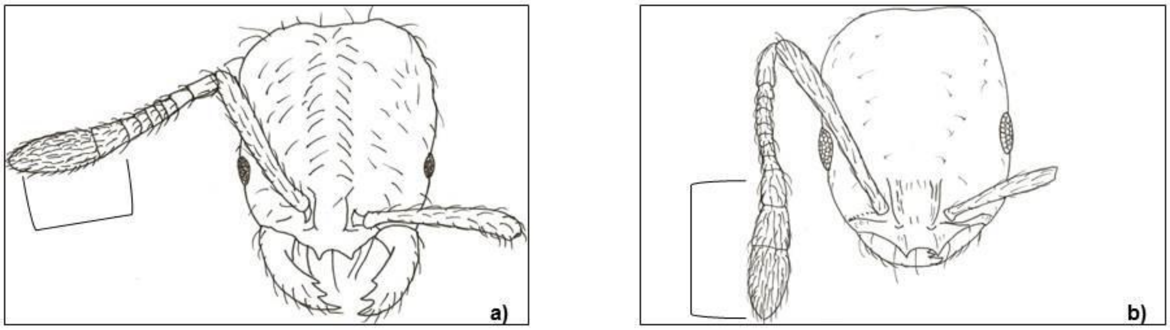
1	Waist consisting of petiole (a.i) (abdominal segment 2) and postpetiole (a.ii) (abdominal segment 3, which is separated from the petiole in front and abdominal segment 4 behind) (a). Stinger present, though not always obvious. (Subfamily: Myrmicinae).	2
1’	Waist consisting of one segment; the petiole (b.i). Postpetiole absent, stinger absent.	33

Figure 2.4: Couplet 1 of the key to the ants of Alberta.



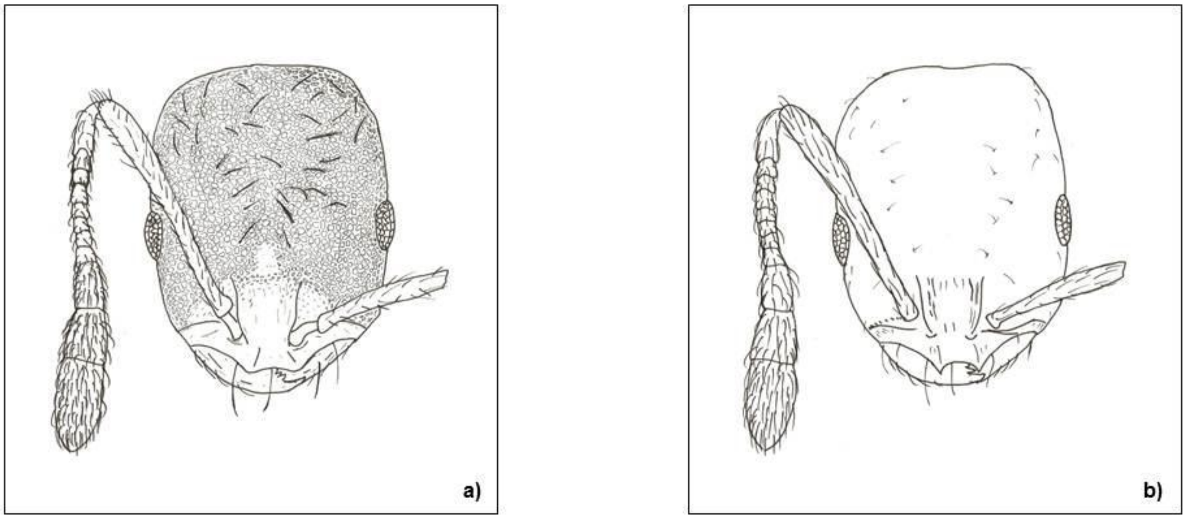
2 (1)	Clypeus bidentate (a). Propodeum without spines (c).	3
2’	Clypeus not bidentate but may be notched (b). Propodeum with or without spines (c or d).	5

Figure 2.5: Couplet 2 of the key to the ants of Alberta.



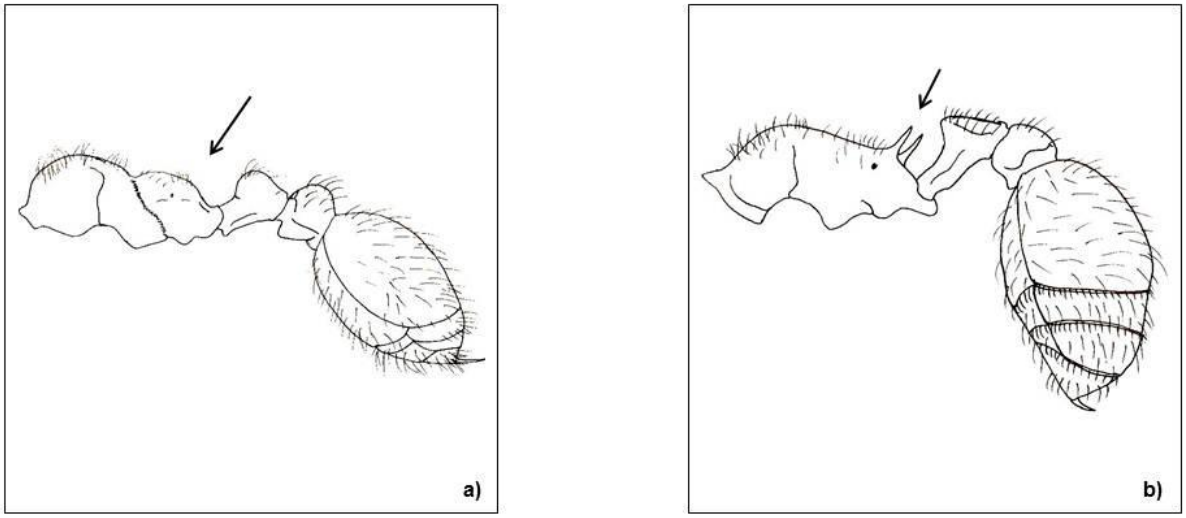
3 (2)	Antennae with 10 segments and last two segments forming the apical club (a). (Genus *Solenopsis*).	*Solenopsis molesta*
3’	Antennae with 12 segments (a) and last three segments forming the apical club (b). (Genus *Monomorium*).	4

Figure 2.6: Couplet 3 of the key to the ants of Alberta.



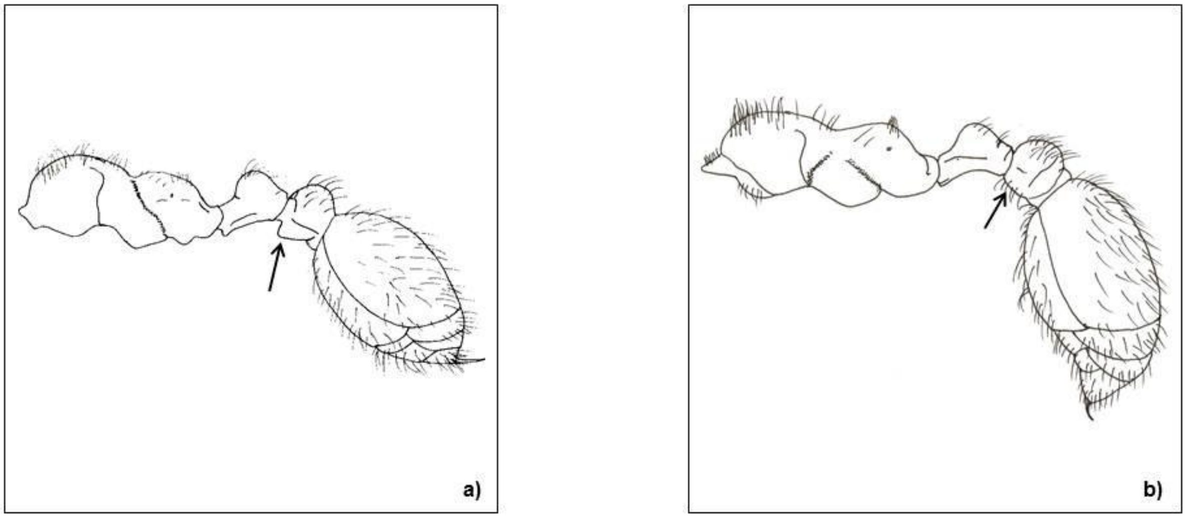
4 (<u>3</u>)	Head and thorax heavily microreticulate and dull (a). Colour reddish yellow with slightly darker gaster.	*Monomorium pharaonis*
4’	Head and thorax smooth and shiny (b). Concolourous dark brown.	*Monomorium minimum*

Figure 2.7: Couplet 4 of the key to the ants of Alberta.



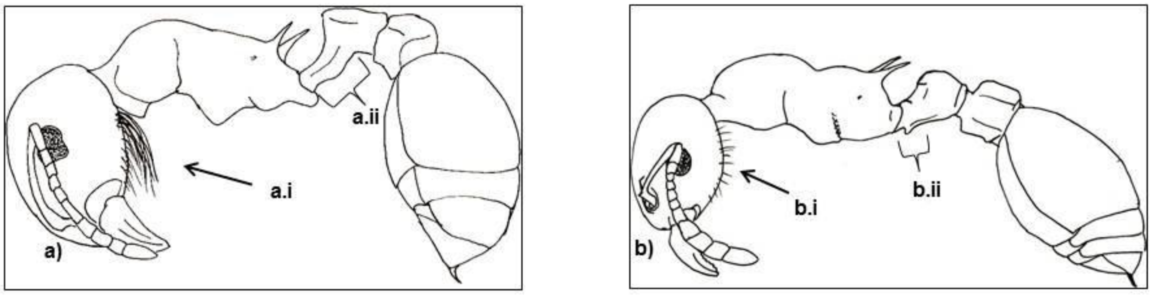
5 (2)	Propodeum without spines (a). (Genus *Manica*).	6
5’	Propodeum with spines (b).	7

Figure 2.8: Couplet 5 of the key to the ants of Alberta.



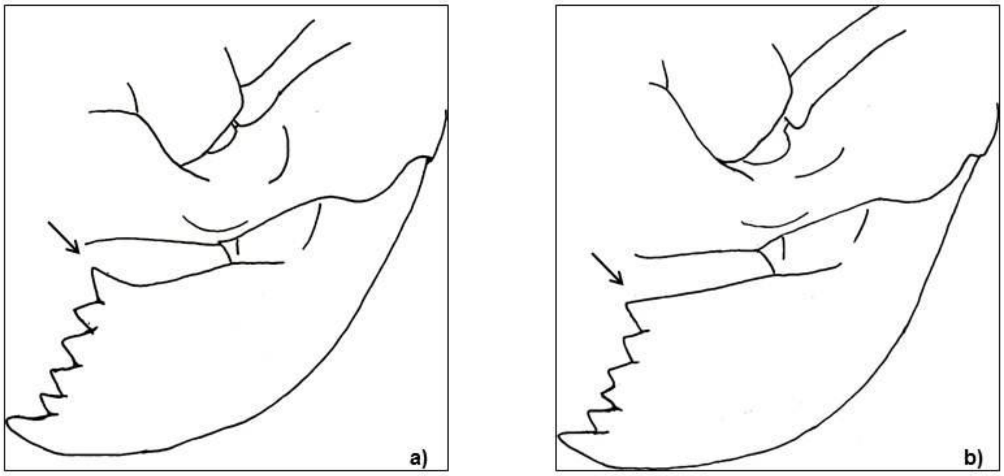
6 (5)	Lobed projection on anterior ventral part of postpetiole (a).	*Manica hunteri*
6’	Postpetiole without ventral projection (b).	*Manica invidia*

Figure 2.9: Couplet 6 of the key to the ants of Alberta.



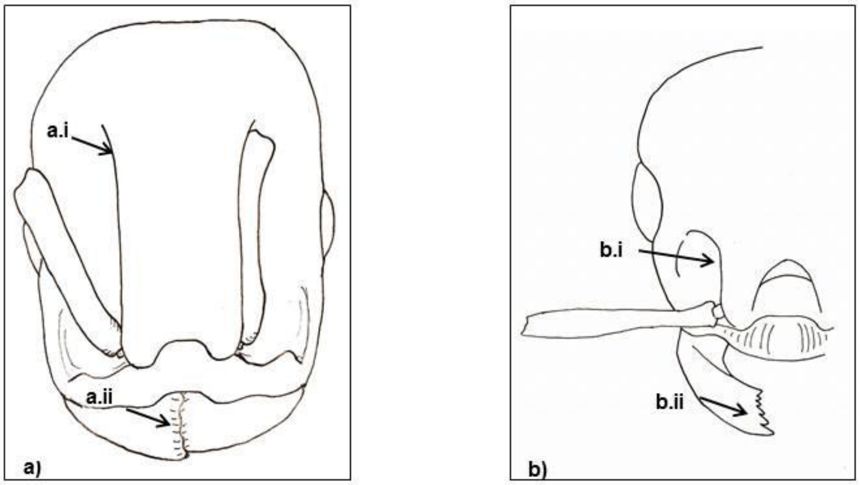
7 (5)	Psammophore present (a.i), petiole with elongate anterior peduncle (a.ii) (Genus *Pogonomyrmex*).	8
7’	Psammophore not present (b.i). Petiole without elongate peduncle (b.ii).	9

Figure 2.10: Couplet 7 of the key to the ants of Alberta.



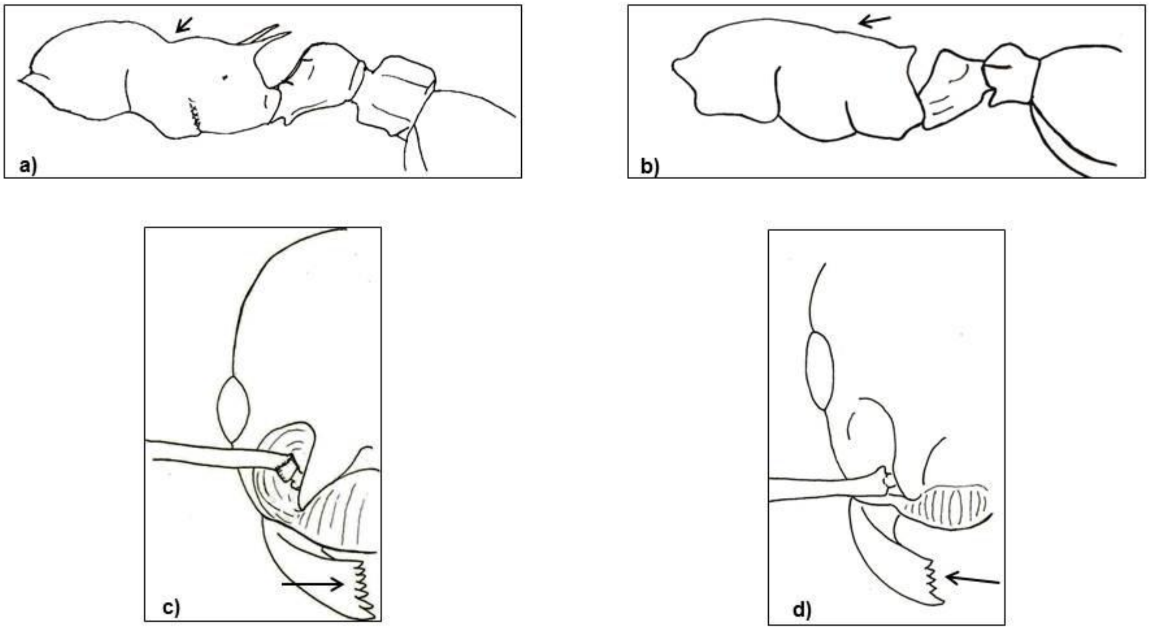
8 (7)	Basal tooth of mandible deflected posteriorly at base of mandible (a).	*Pogonomyrmex occidentalis*
8’	Basal tooth of mandible in line with other teeth (b).	*Pogonomyrmex salinus*

Figure 2.11: Couplet 8 of the key to the ants of Alberta.



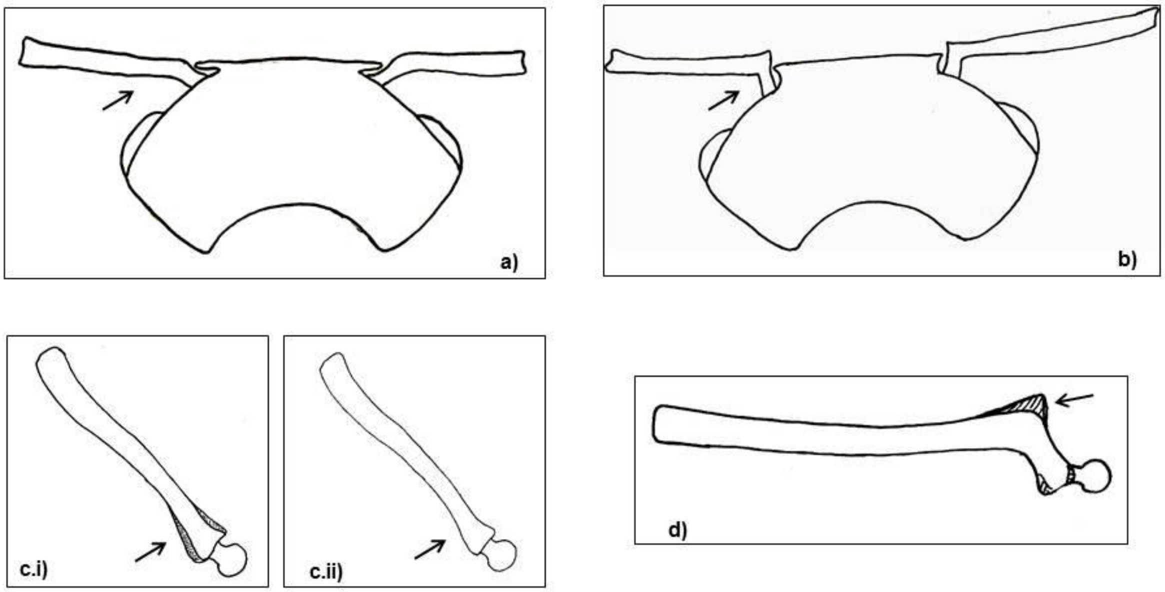
9 (7)	Frontal carinae extending past eyes (a.i). Mandibles without teeth (a.ii). (Genus *Harpagoxenus*)	*Harpagoxenus canadensis*
9’	Frontal carinae not extending past eyes (b.i). Mandibles usually with (but sometimes without) teeth (b.ii).	10

Figure 2.12: Couplet 9 of the key to the ants of Alberta.



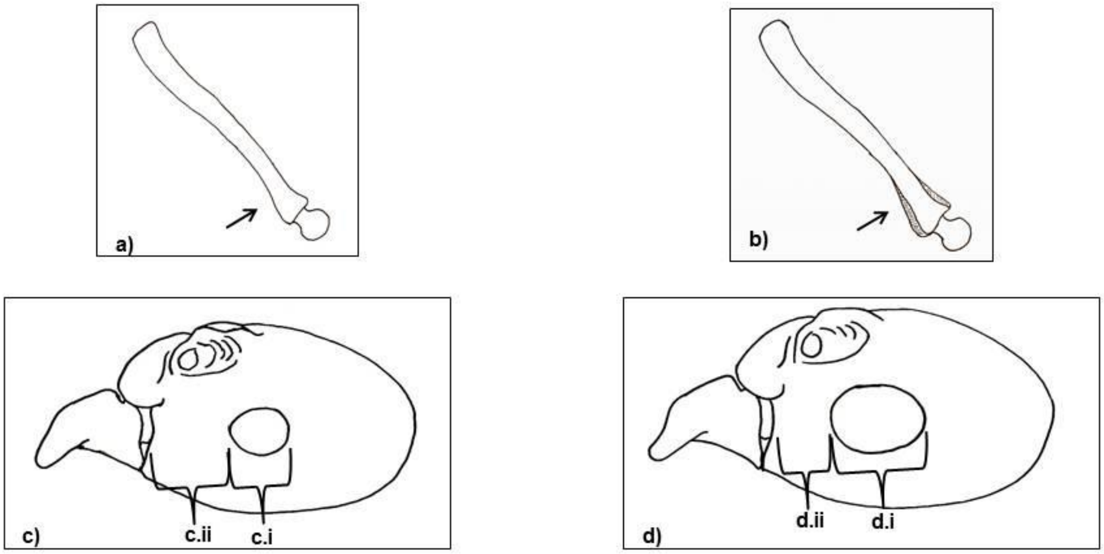
10 (9)	Metanotal region weakly to moderately notched, interrupting mesosomal profile (a). Mandible with seven or more teeth (c). Medium sized ants (usually 4-6mm) (Genus *Myrmica*).	11
10'	Metanotal region not as deeply notched; mesosomal profile flat to convex (b). Mandible with six or fewer teeth (d). Smaller ants (usually ~2mm).	22

Figure 2.13: Couplet 10 of the key to the ants of Alberta.



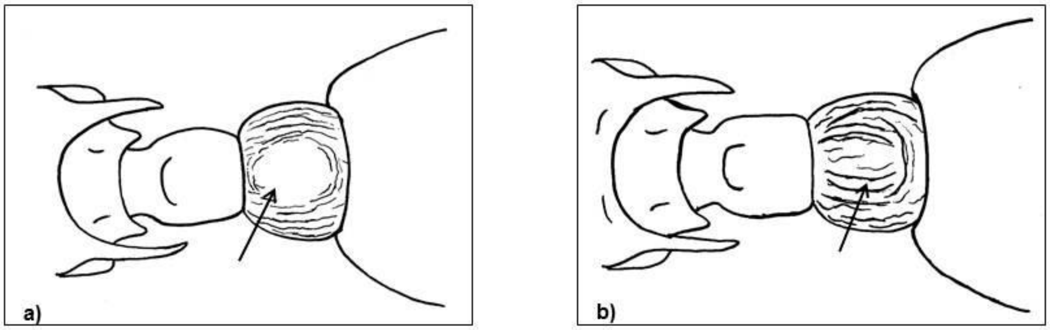
11 (10)	Scape gradually curved posterobasally (a). With (c.i) or without (c.ii) a postero-lateral dark ridge before bend.	12
11'	Scape more angular posterobasally (b). With a lamina, thickening, or ridge (d).	15

Figure 2.14: Couplet 11 of the key to the ants of Alberta.



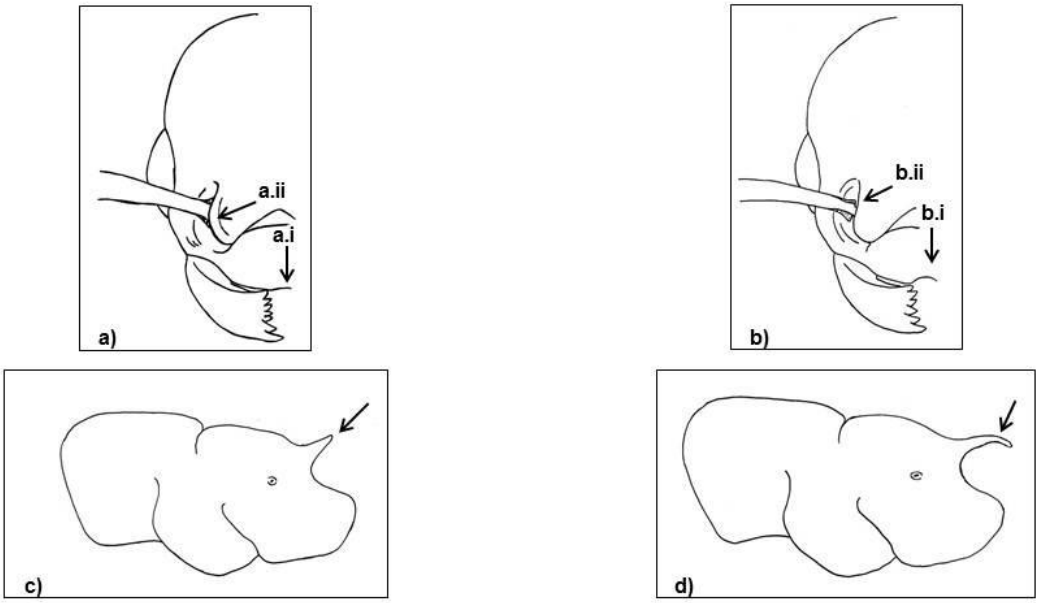
12 (11)	Base of scape without lamina (a). Eye (c.i) shorter than gena (c.ii).	13
12’	Base of scape widens into dark laminal outgrowth (b). Eye (d.i) longer than gena (d.ii).	14

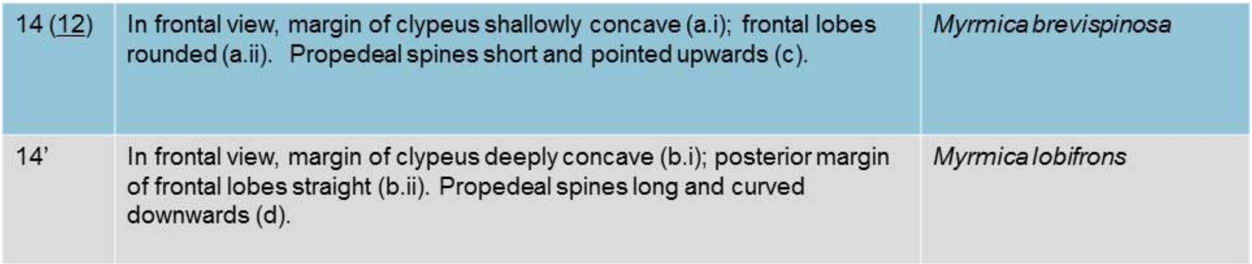
Figure 2.15: Couplet 12 of the key to the ants of Alberta.



13 (12)	Postpetiole with dorsal area mostly lacking rugae (a).	*Myrmica alaskensis*
13’	Entire postpetiole covered in rugae (b).	*Myrmica incompleta*

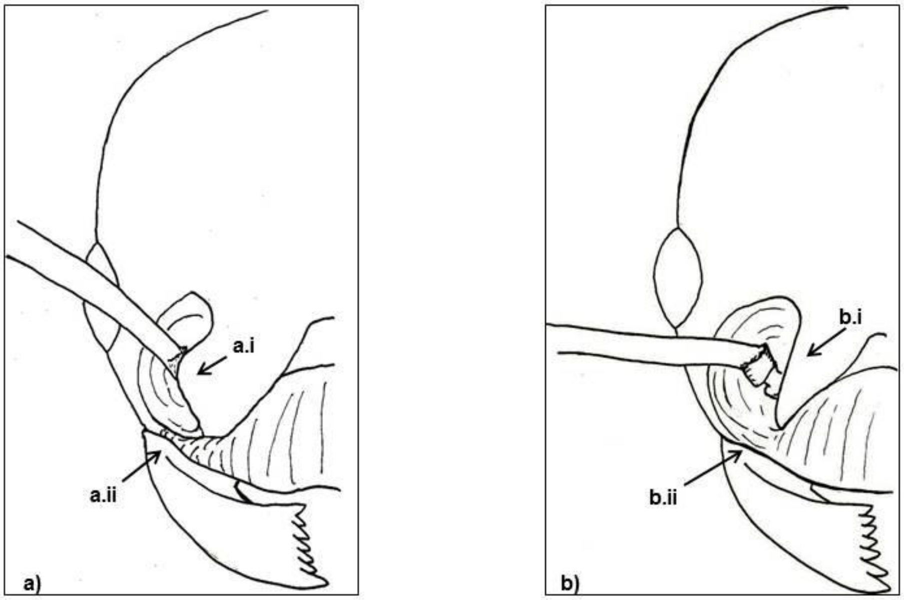
Figure 2.16: Couplet 13 of the key to the ants of Alberta.





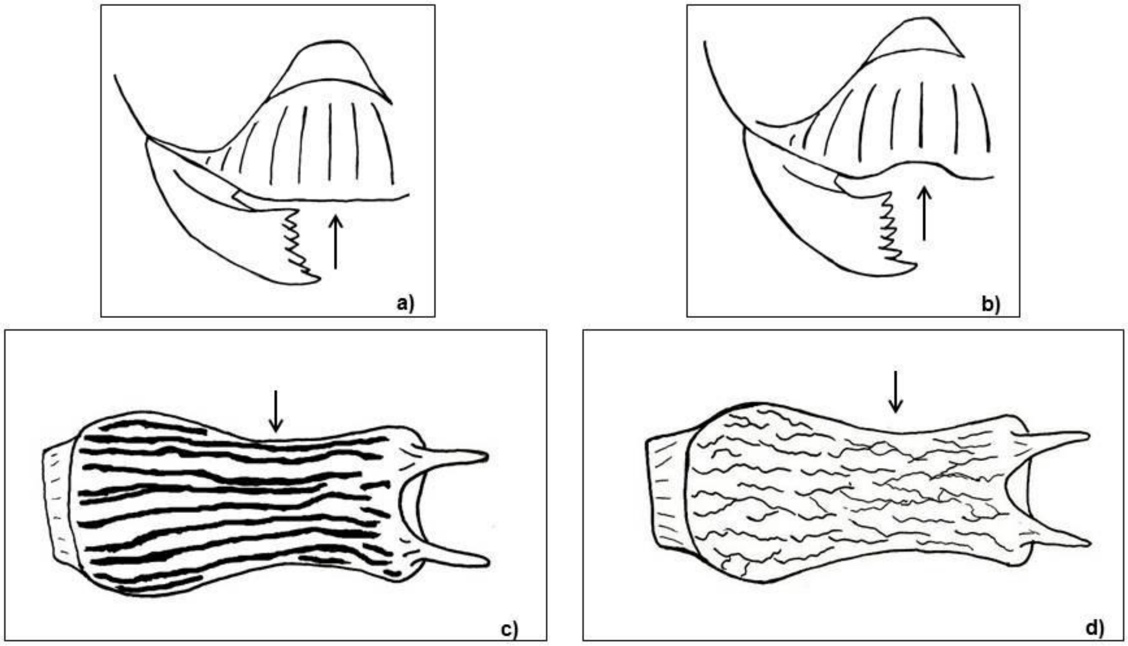
14 (<u>12</u>)	In frontal view, margin of clypeus shallowly concave (a.i); frontal lobes rounded (a.ii). Propedeal spines short and pointed upwards (c).	*Myrmica brevispinosa*
14’	In frontal view, margin of clypeus deeply concave (b.i); posterior margin of frontal lobes straight (b.ii). Propedeal spines long and curved downwards (d).	*Myrmica lobifrons*

Figure 2.17: Couplet 14 of the key to the ants of Alberta.



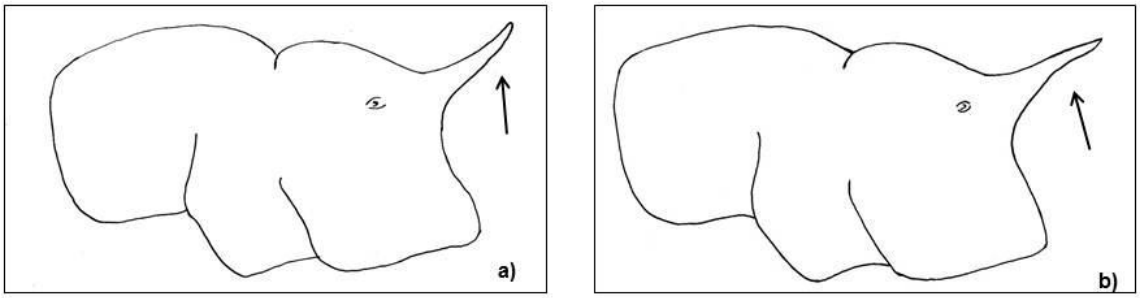
15 (11)	In frontal view, frontal lobes convex and extending over antennal fossae (a.i). Lateral wings of clypeus raised into a ridge closing the antennal fossae (a.ii) (not as prominent in some species, where it is a very thin ridge).	16
15’	In frontal view, frontal lobes straighter and not extending as far over antennal fossae (b.i). Lateral wings of clypeus not forming ridge and not closing antennal fossae (b.ii).	20

Figure 2.18: Couplet 15 of the key to the ants of Alberta.



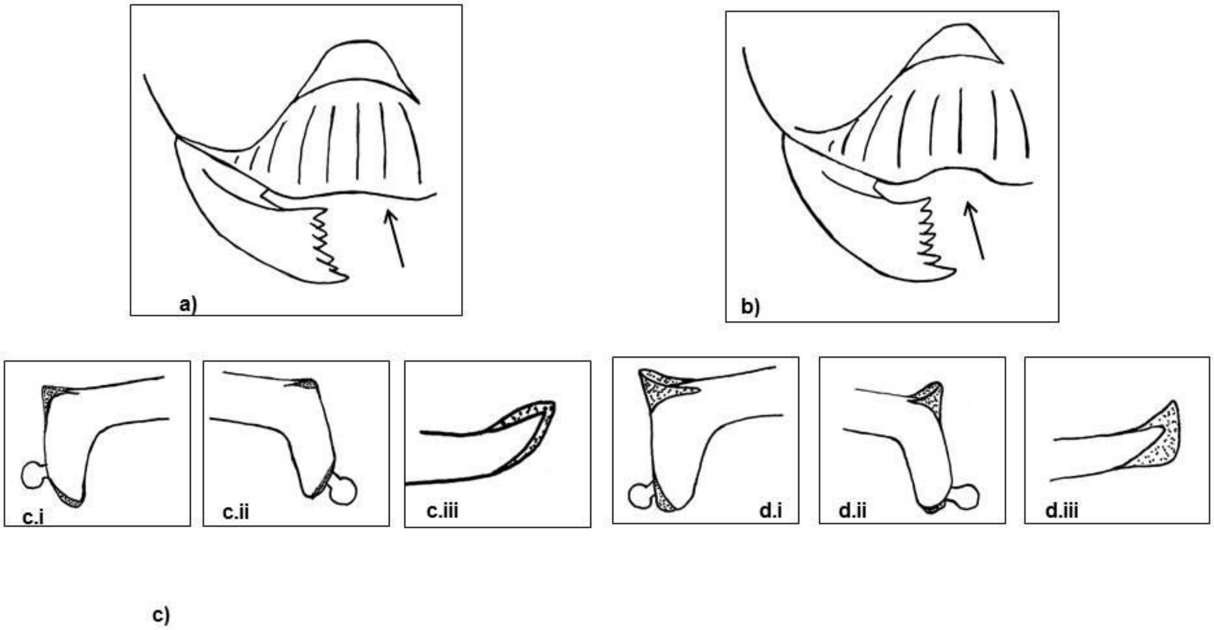
16 (15)	Median margin of clypeus not concave (a). Striae on dorsal part of thorax deep and longitudinal (c).	17
16’	Median margin of clypeus concave (b). Striae on dorsal part of thorax more shallow, undulating and/or anastomizing (d).	18

Figure 2.19: Couplet 16 of the key to the ants of Alberta.



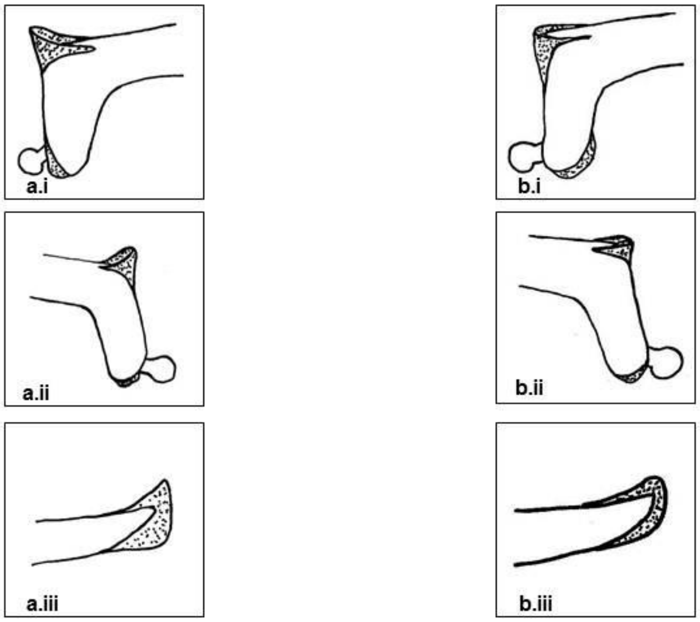
17 (16)	Propodeal spines deflected upwards (a).	*Myrmica ab001*
17’	Propodeal spines straight or slightly deflected downwards (b).	*Myrmica crassirugis*

Figure 2.20: Couplet 17 of the key to the ants of Alberta.



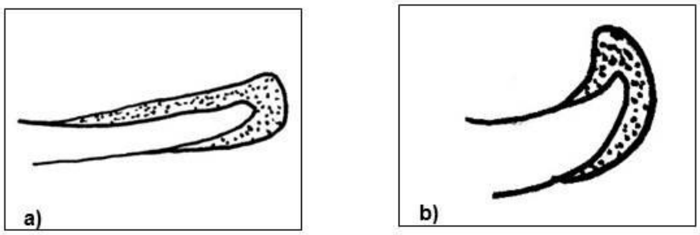
18 (16)	In frontal view, median margin of clypeus shallowly concave (a). Lamina on scape a darkened ridge, without a prominent projection (Right antenna at basal bend: c.i: posterior view; c.ii anterior view; c.iii dorsal view; images of right antenna).	*Myrmica latifrons*
18’	In frontal view, median margin of clypeus distinctly concave (b). Lamina on scape with projection (Right antenna at basal bend: d.i: posterior view; d.ii anterior view; d.iii dorsal view).	19

Figure 2.21: Couplet 18 of the key to the ants of Alberta.



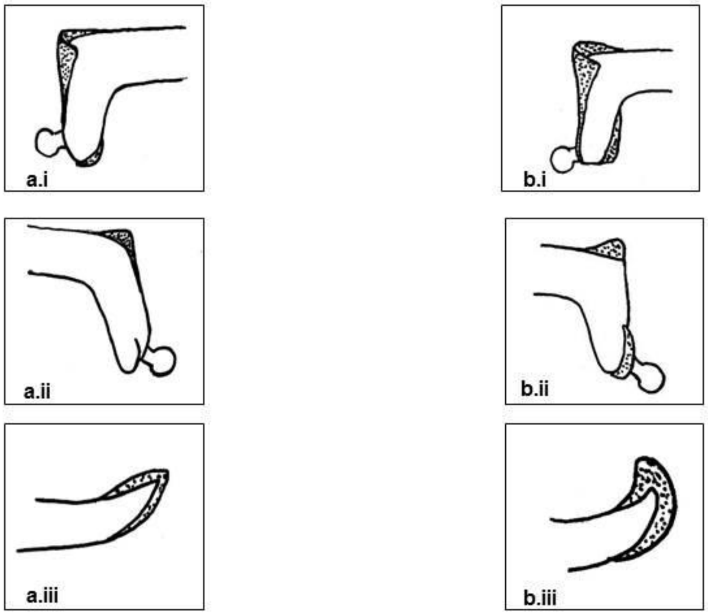
19 (<u>18</u>)	Lamina on scape dish-like and projecting upwards (right antenna at basal bend: a.i: posterior view; a.ii anterior view; a.iii dorsal view).	*Myrmica americana*
19’	Lamina on scape a minor upward projection (right antenna at basal bend: b.i: posterior view; b.ii anterior view; b.iii dorsal view).	*Myrmica ab002*

Figure 2.22: Couplet 19 of the key to the ants of Alberta.



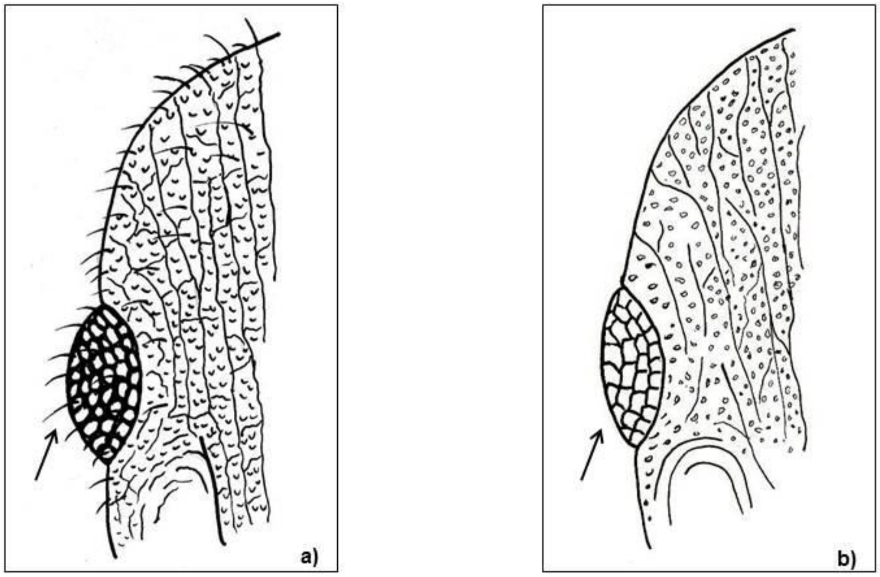
20 (15)	In dorsal view antennal scape with a postero-lateral lamina that narrows as it extends away from basal bend (a). In image distal end of antenna continuing to the left.	*Myrmica nearctica*
20’	In dorsal view antennal scape with lamina restricted to basal bend (b). In image distal end of antenna continuing to the left.	21

Figure 2.23: Couplet 20 of the key to the ants of Alberta.



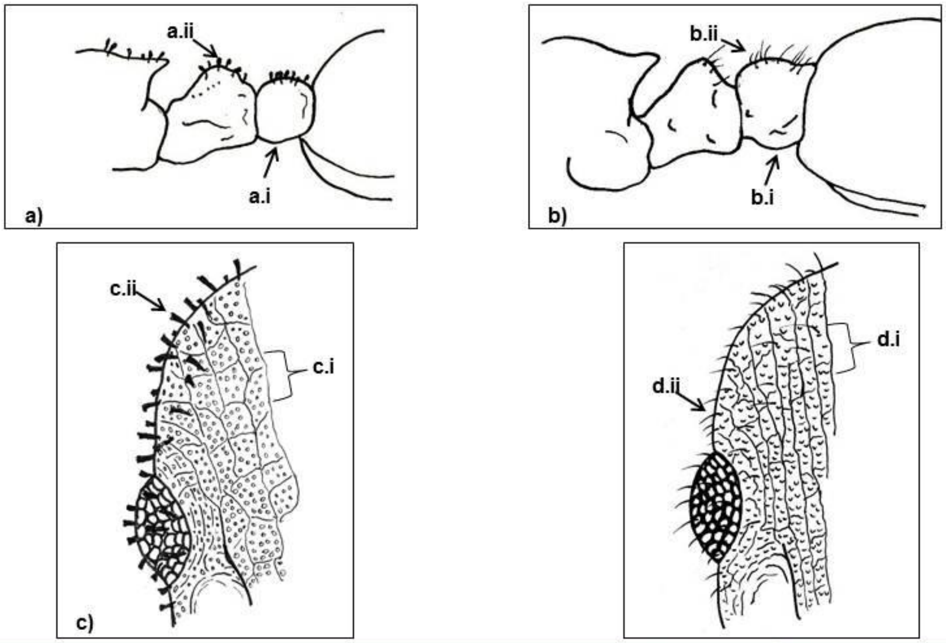
21 (20)	Basal bend of antennal scape with lamina forming a small dorsal ridge (Right antenna at basal bend: a.i posterior view; a.ii anterior view; a.iii dorsal view).	*Myrmica fracticornis*
21’	Basal bend of antennal scape with lamina forming a prominant flange (Right antenna at basal bend: b.i posterior view; b.ii anterior view; b.iii dorsal view).	*Myrmica detritinodus*

Figure 2.24: Couplet 21 of the key to the ants of Alberta.



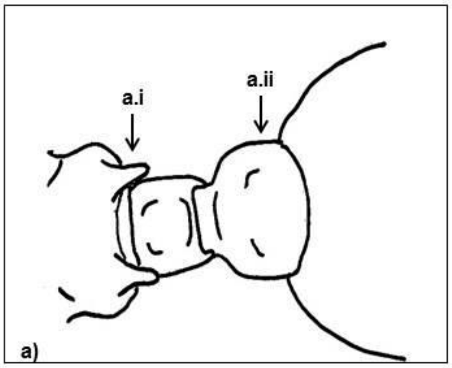
22 (10)	Eyes with erect setae (a). (Genus *Formicoxenus*).	23
22'	Eyes without setae (b).	25

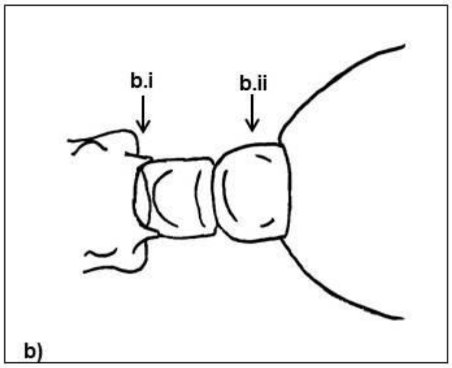
Figure 2.25: Couplet 22 of the key to the ants of Alberta.



23 (22)	Postpetiole obviously smaller than petiole and about one third the height of gaster (a.i). Head and thorax densely punctate, with very fine carinae (c.i). Setae on dorsal part of head (c.ii), thorax, and postpetiole (a.ii) claviform. Inquilines associated with *Formica* rufa species group.	*Formicoxenus hirticornis*
23’	Postpetiole slightly smaller than petiole and about one half height of gaster (b.i). Head and thorax sparsely punctate with prominent, parallel carinae (d.i). Setae on dorsal part of head (d.ii), thorax, and petiole thin (b.ii). Inquilines associated with *Myrmica* species.	24

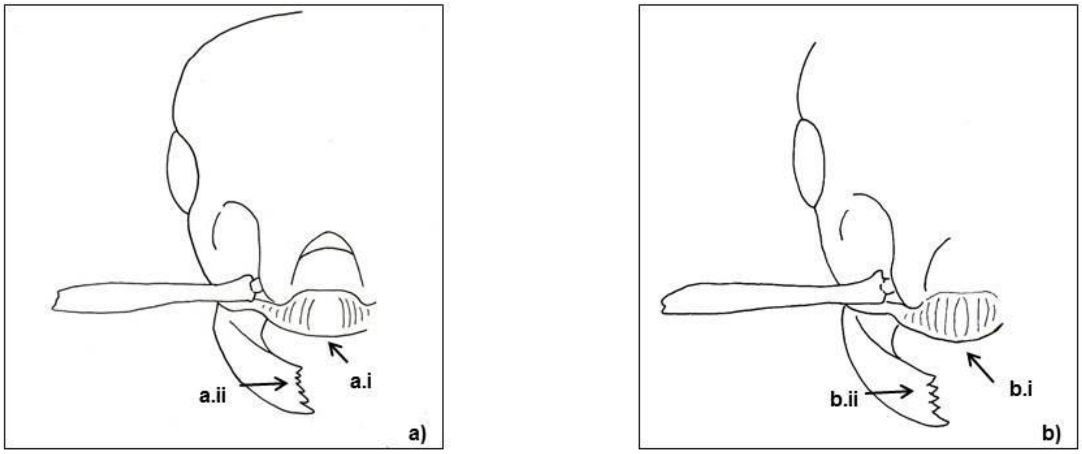
Figure 2.26: Couplet 23 of the key to the ants of Alberta.





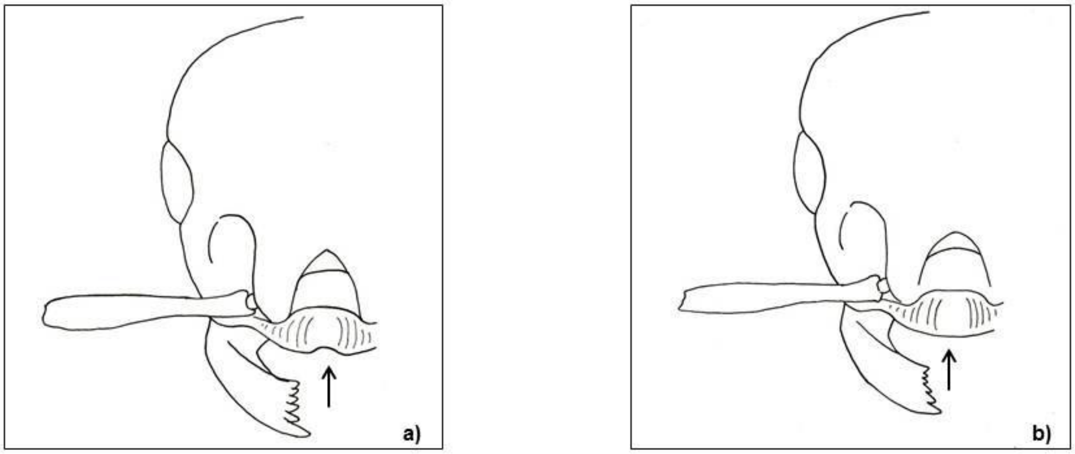
24 (23)	Propedeal spines longer (a.i) and postpetiole wider then long (a.ii). Inquilines associated with *Myrmica incompleta*.	*Formicoxenus provancheri*
24’	Propedeal spines shorter (b.i) and postpetiole as wide as long or slightly longer (b.ii). Inquilines associated with *Myrmica alaskensis*.	*Formicoxenus quebecensis*

Figure 2.27: Couplet 24 of the key to the ants of Alberta.



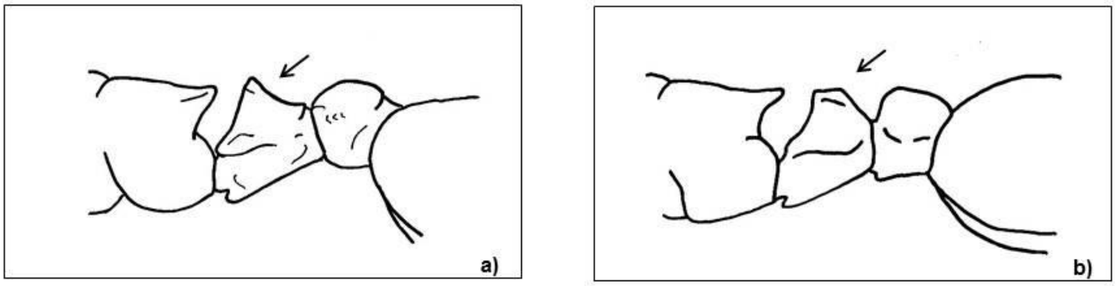
25 (22)	Clypeus medially smooth and laterally carinate (a.i); mandible with six teeth (a.ii). (Genus *Leptothorax*).	26
25’	Clypeus wholly carinate (b.i); mandible with five teeth (b.ii). (Genus *Temnothorax*).	31

Figure 2.28: Couplet 25 of the key to the ants of Alberta.



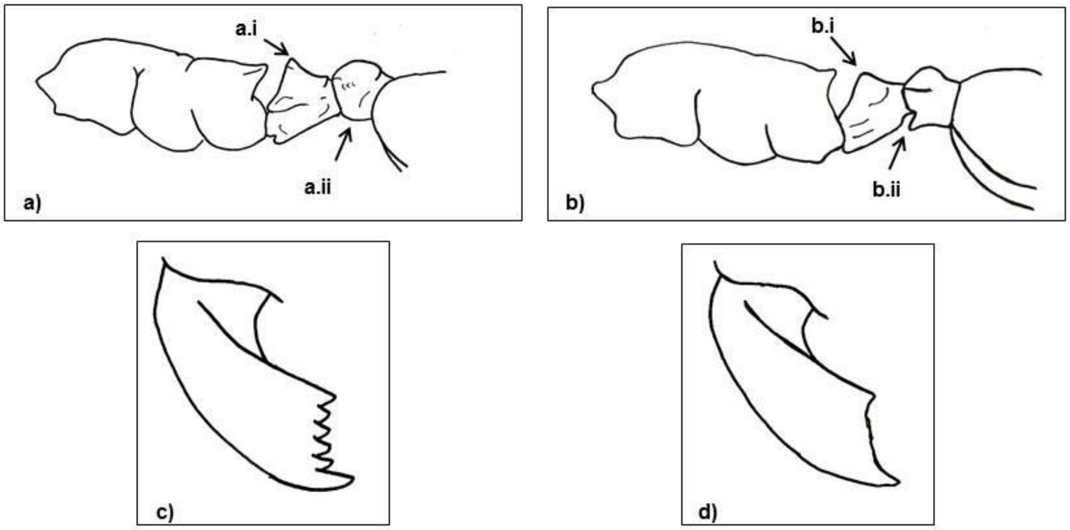
26 (25)	In frontal view, medial margin of the clypeus with a distinct notch (a).	*Leptothorax retractus*
26’	In frontal view, medial margin of clypeus without a distinct notch (b).	27

Figure 2.29: Couplet 26 of the key to the ants of Alberta.



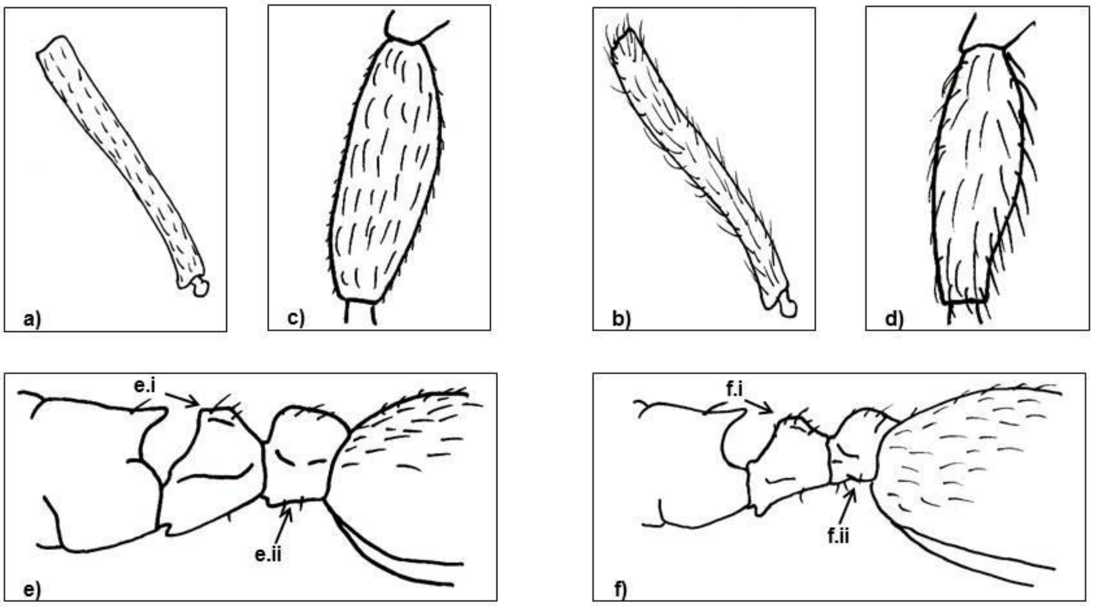
27(26)	In profile, petiole distinctly triangular, with anterior and posterior faces about the same length, and dorsal surface pointed (a).	28
27’	In profile, petiole with anterior face longer than posterior face, and dorsal surface with either flattened, or rounded apex (b).	29

Figure 2.30: Couplet 27 of the key to the ants of Alberta.



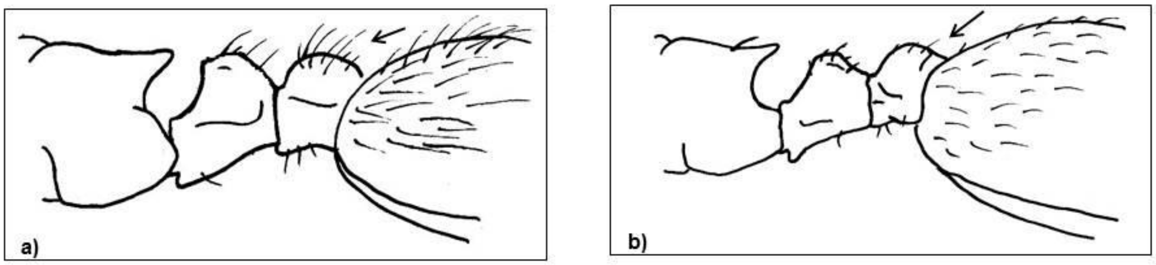
28 (27)	In profile, apex of petiole distinctly sharp (a.i); postpetiole rounded lacking any distinct ventral anterior projection (a.ii). Teeth on mandible prominent (c). Non-inquilines with worker caste and queen. Diagnostic traits based on worker caste but also characterize queens.	*Leptothorax athabasca*
28'	In profile, apex of petiole rounded (b.i); postpetiole trapezoidal, but rounded dorsally, and with a distinct ventral anterior projection (b.ii). Mandible lacking teeth (d). Inquilines associated with *Leptothorax muscorum.* Worker caste is absent; diagnostic traits based on queens.	*Leptothorax wilsoni*

Figure 2.31: Couplet 28 of the key to the ants of Alberta.



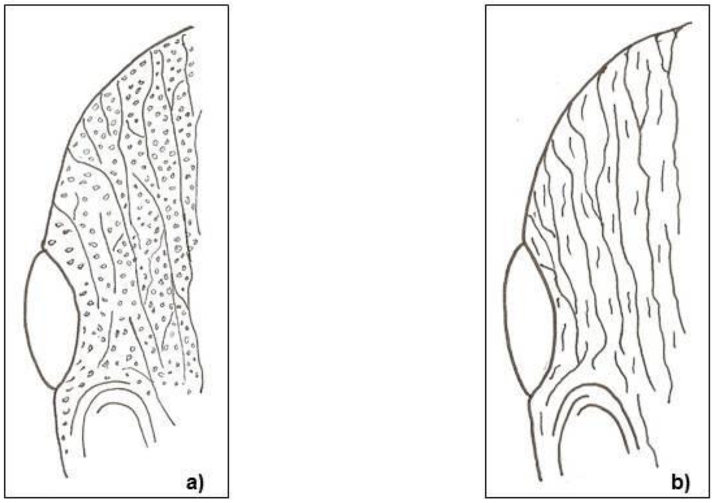
29 (27)	Erect setae absent on scape (a) and tibia (c). In profile, dorsal surface of petiole distinctly flat (e.i); postpetiole rectangular and distinctly taller than long (e.ii). Inquilines associated with *Leptothorax muscorum.*	*Leptothorax faberi*
29’	Erect setae present on scape (b) and tibia (d). In profile dorsal surface of petiole slightly rounded (f); postpetiole rounded and about as tall as long. Non-inquilline.	30

Figure 2.32: Couplet 29 of the key to the ants of Alberta.



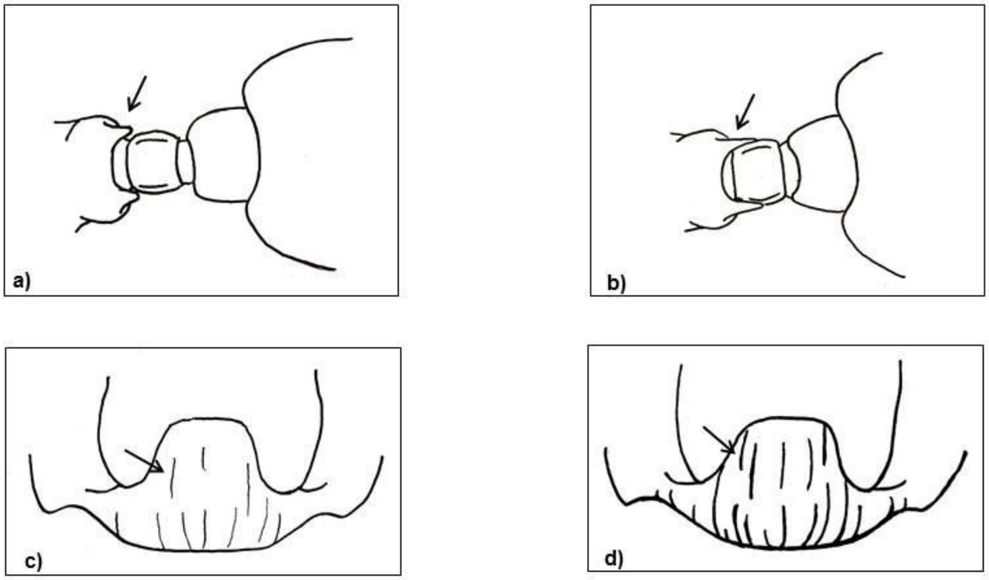
30 (29)	Setae on petiole, postpetiole and gaster distinctly long (0.06-0.1mm) (a).	*Leptothorax pocahontas*
30’	Setae on petiole, postpetiole and gaster short (0.04-0.06mm) (b).	*Leptothorax muscorum*

Figure 2.33: Couplet 30 of the key to the ants of Alberta.



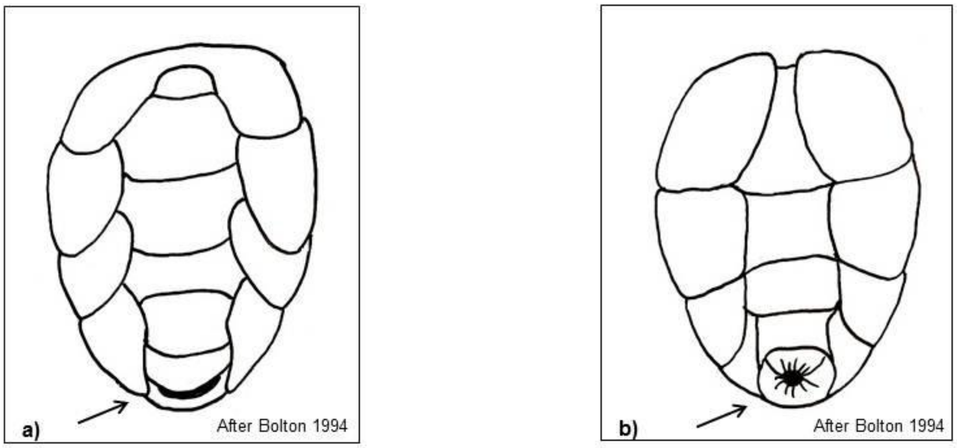
31 (25)	Head with delicate longitudinal striae, and punctate (a).	*Temnothorax ambiguus*
31’	Head with coarse longitudinal rugae, and weakly or not punctate (b).	32

Figure 2.34: Couplet 31 of the key to the ants of Alberta.



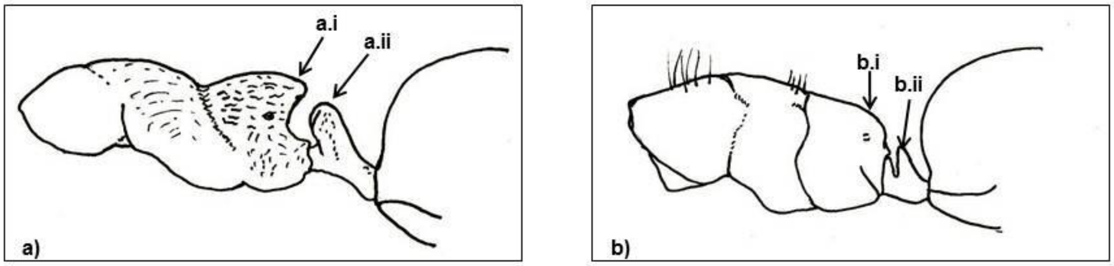
32 (<u>31</u>)	Propedeal spines thick, with blunt apexes (a). Clypeus covered with fine rugae (c).	*Temnothorax fragosus*
32’	Propedeal spines slender with sharp apexes (b). Clypeus covered with coarse rugae (d).	*Temnothorax rugatulus*

Figure 2.35: Couplet 32 of the key to the ants of Alberta.



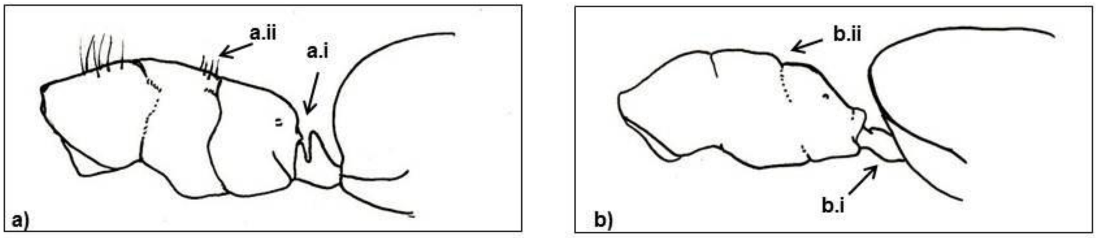
33 (1)	Apical opening of gaster transverse, and not surrounded by a fringe of setae (a). (Subfamily: Dolichoderinae).	34
33’	Apical opening of gaster circular and typically surrounded by a fringe of setae (b). If fringe of setae not present, antennal insertions set well away from the clypeus (see genus *Camponotus*: 37). (Subfamily Formicinae).	36

Figure 2.36: Couplet 33 of the key to the ants of Alberta.



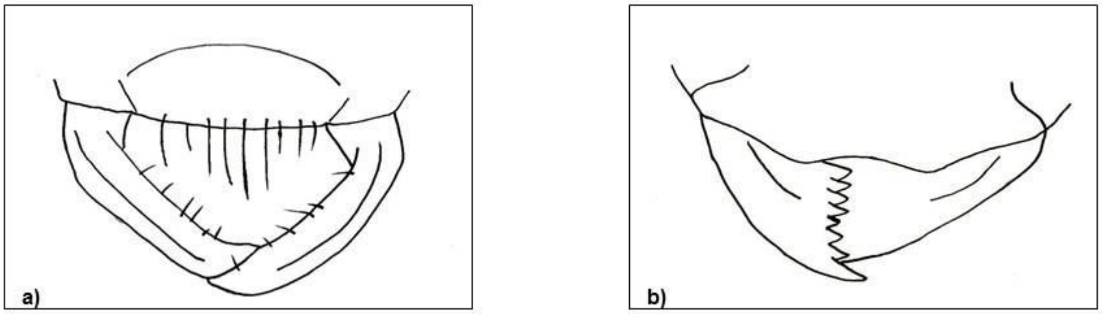
34 (33)	Declivitous face of propodeum strongly concave in profile, overhanging petiole (a.i). Petiolar scale obvious, sub-erect and fitting into shelf (a.ii). Propodeum well sculptured (a). Colour uniform brownish-black to piceous black, very shiny.	*Dolichoderus taschenbergi*
34’	Declivitous face of propodeum not overhanging petiole (b.i). Petiolar scale small (b.ii). Propodeum lacking sculpture (b). Colour variable, dull.	35

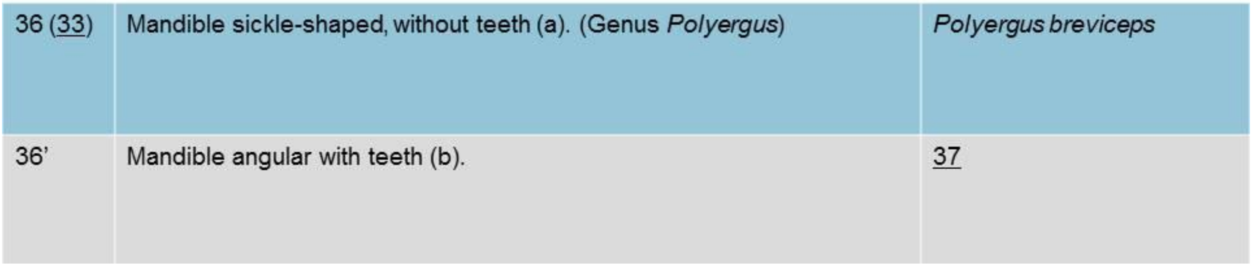
Figure 2.37: Couplet 34 of the key to the ants of Alberta.



35 (<u>34</u>)	Petiole scale protruding upwards (a.i). Erect setae on dorsum of thorax (a.ii).	Genus *Liometopum* (not yet known from Alberta, but expected in south western areas)
35’	Petiole flattened, not protruding upwards (b.i); often concealed by gaster. No erect setae on dorsum of thorax (b.ii).	*Tapinoma sessile*

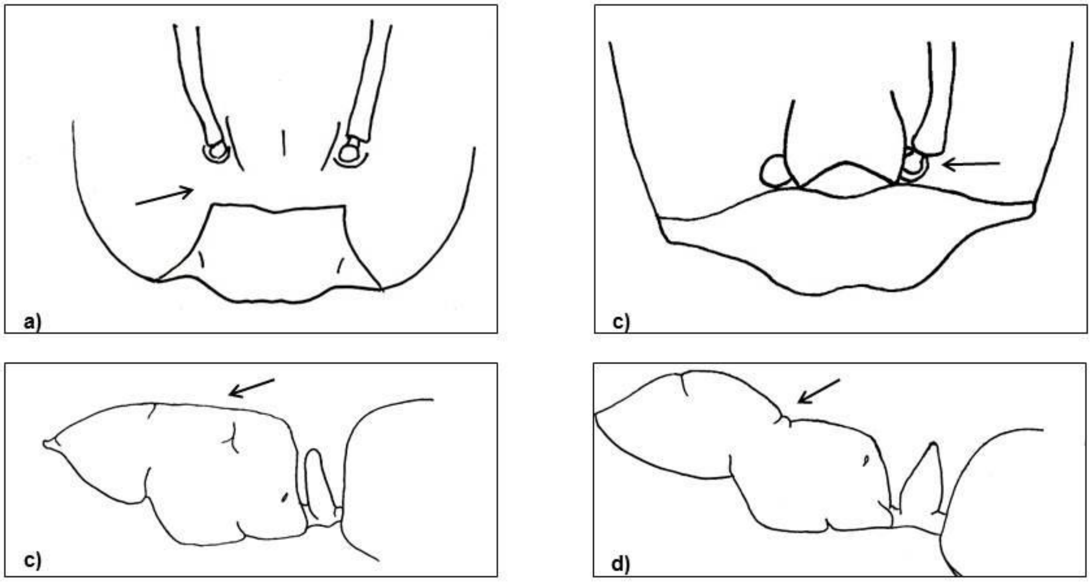
Figure 2.38: Couplet 35 of the key to the ants of Alberta.





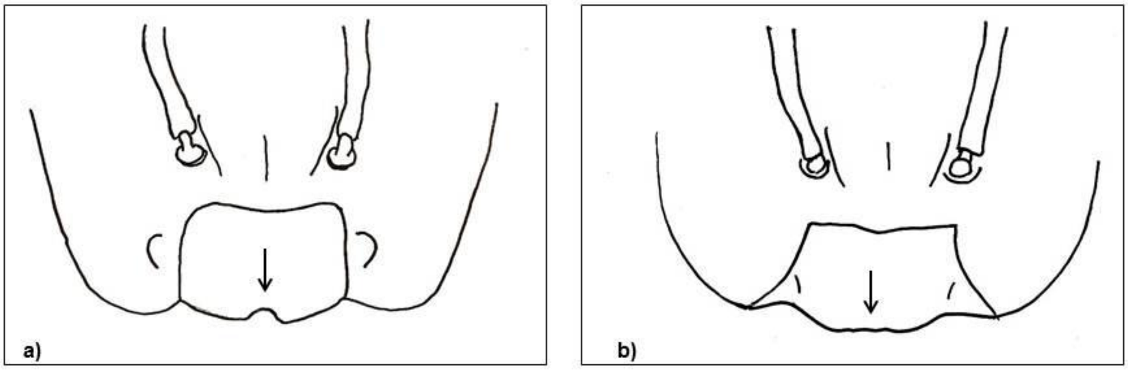
36 (33)	Mandible sickle-shaped, without teeth (a). (Genus *Polyergus*)	*Polyergus breviceps*
36’	Mandible angular with teeth (b).	37

Figure 2.39: Couplet 36 of the key to the ants of Alberta.



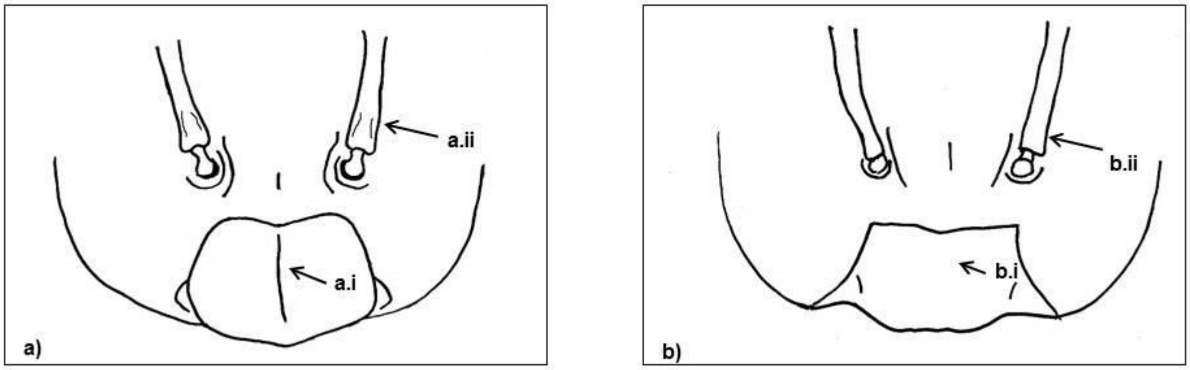
37 (36)	Antennal sockets situated well behind posterior margin of clypeus (a). Mesosomal profile evenly convex (c). (Genus *Camponotus*. Note: majors are identifiable with this key; minor workers may or may not be, so it is valuable to collect series from colonies for a comparison).	38
37’	Antennal sockets even with posterior margin of the clypeus (b). Mesosomal profile interrupted at metanotal groove, with the propodeum below the level of mesonotum (d).	43

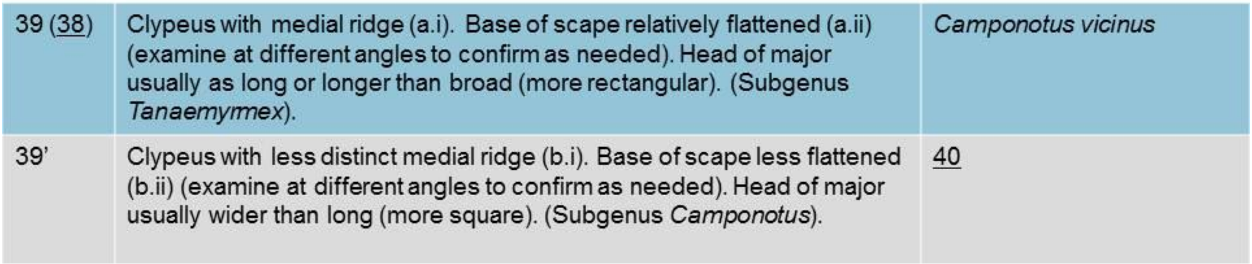
Figure 2.40: Couplet 37 of the key to the ants of Alberta.



38 (37)	Anterior border of clypeus notched (a). (Subgenus *Myrmetoma*).	*Camponotus nearcticus*
38’	Anterior border of clypeus not notched (b).	39

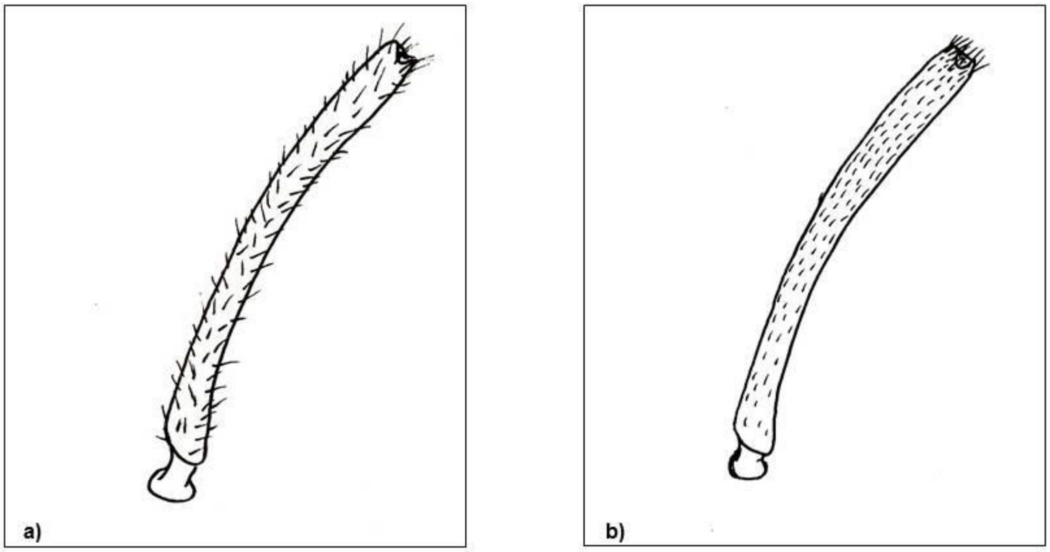
Figure 2.41: Couplet 38 of the key to the ants of Alberta.





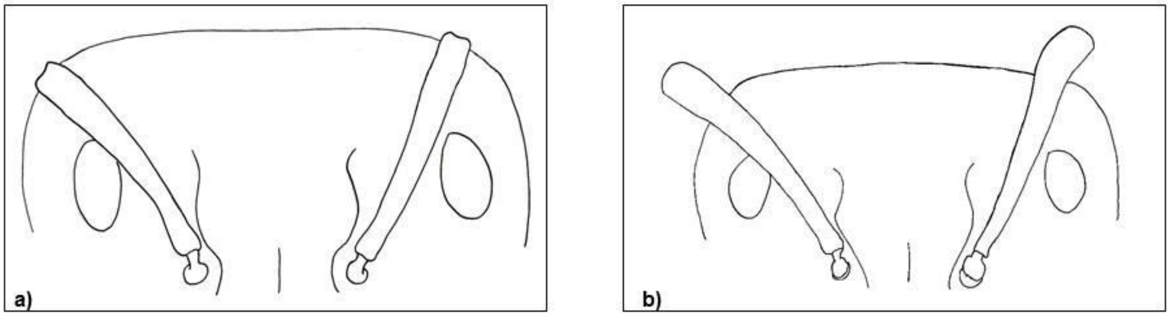
39 (38)	Clypeus with medial ridge (a.i). Base of scape relatively flattened (a.ii) (examine at different angles to confirm as needed). Head of major usually as long or longer than broad (more rectangular). (Subgenus *Tanaemyrmex*).	*Camponotus vicinus*
39'	Clypeus with less distinct medial ridge (b.i). Base of scape less flattened (b.ii) (examine at different angles to confirm as needed). Head of major usually wider than long (more square). (Subgenus *Camponotus*).	40

Figure 2.42: Couplet 39 of the key to the ants of Alberta.



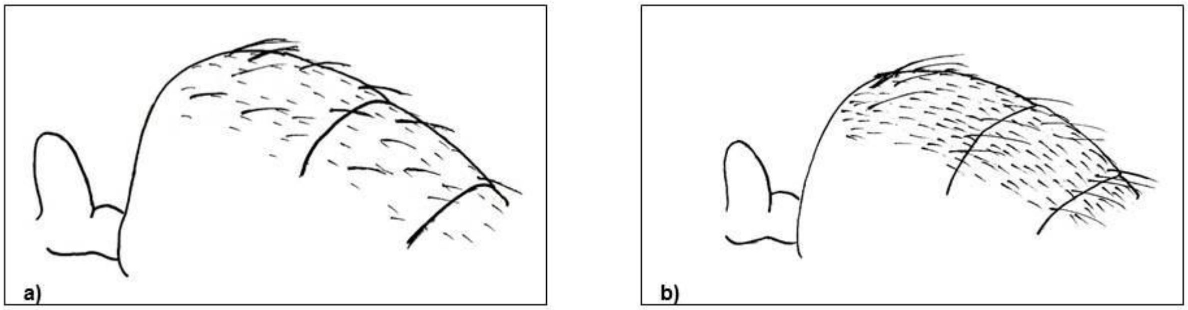
40 (39)	Scape with short erect setae (a). Entirely concolourous jet black and shiny.	*Camponotus laevigatus*
40’	Scape with appressed or no setae; erect setae maybe present on extreme tip of scape (b). Bicoloured.	41

Figure 2.43: Couplet 40 of the key to the ants of Alberta.



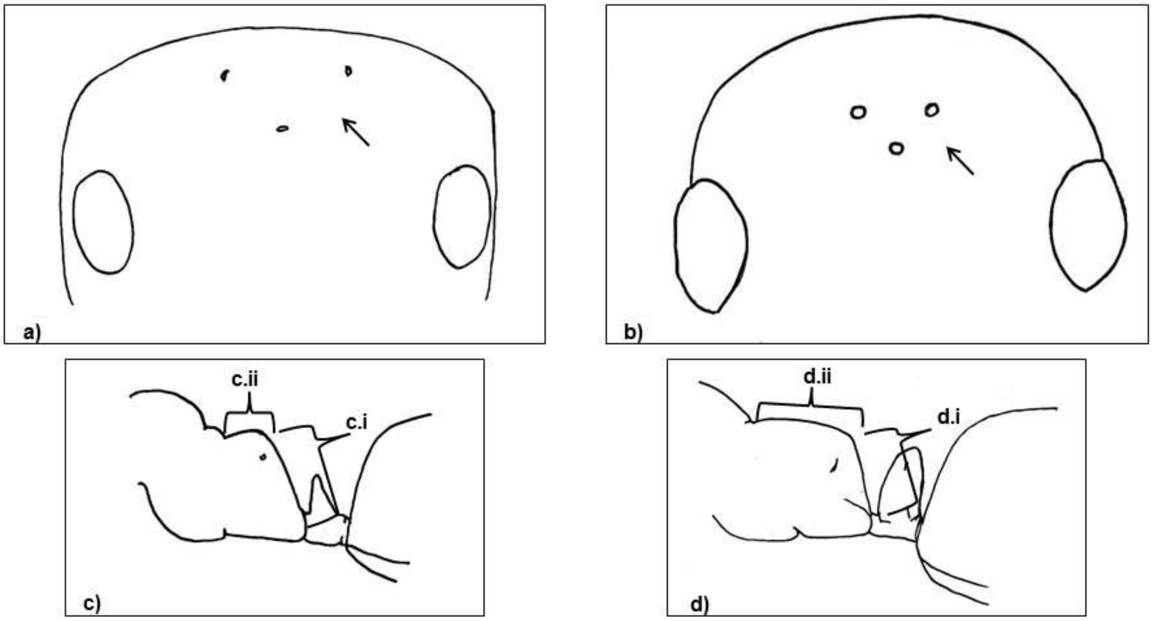
41 (40)	Scape of majors barely reaches posterior corner of head in frontal view, (sometimes not surpassing the posterior margin) (a).	*Camponotus herculeanus*
41’	Scape of majors prominently surpasses posterior margin of head in frontal view (b).	42

Figure 2.44: Couplet 41 of the key to the ants of Alberta.



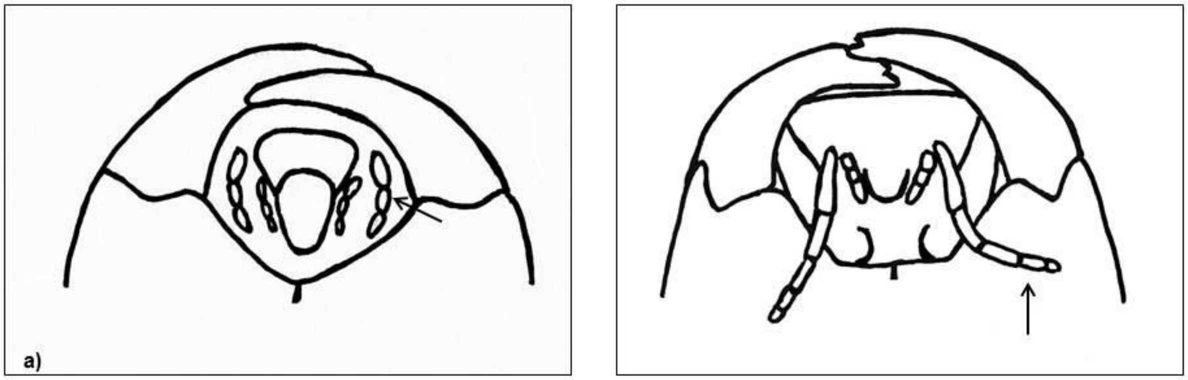
42 (41)	Pubescence on gaster fine and sparse (a). Thorax and petiole evenly red; head and gaster dark red-black.	*Camponotus novaeboracensis*
42'	Pubescence on gaster more coarse and dense (b). Thorax darker dorsally; petiole red; head and gaster dark red-black.	*Camponotus modoc*

Figure 2.45: Couplet 42 of the key to the ants of Alberta.



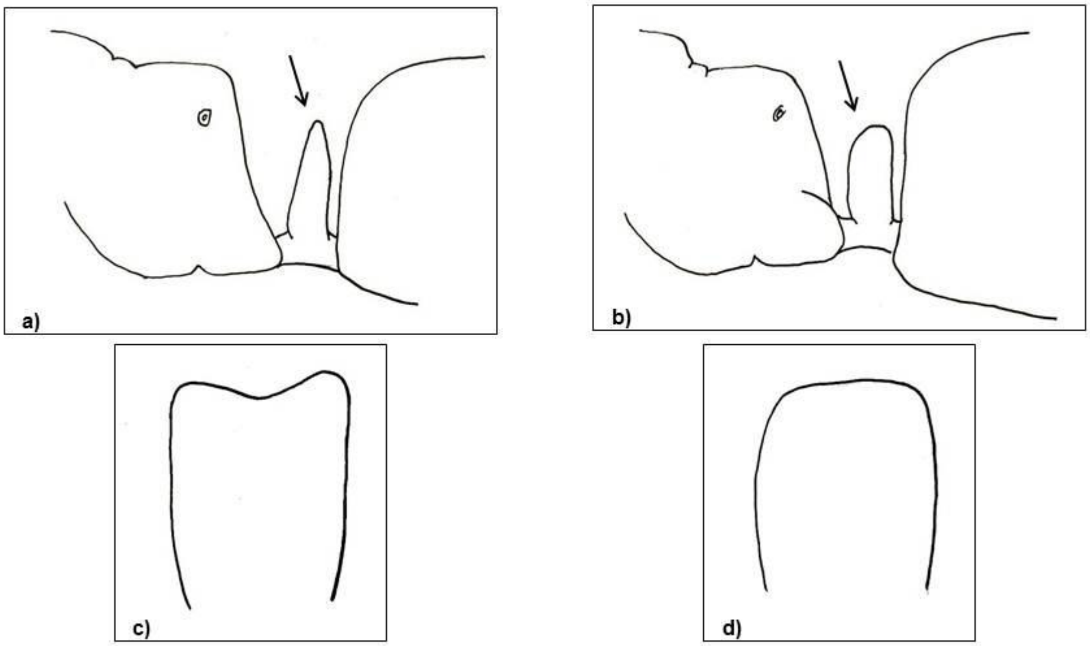
43 (37)	Ocelli very small(a). Posterior surface (c.i) of propodeum obviously longer than dorsal surface (c.ii). (Genus *Lasius*).	44
43’	Ocelli larger, obvious (b). Posterior surface of the propodeum (d.i) shorter or equal length to dorsal surface (d.ii). (Genus *Formica*).	55

Figure 2.46: Couplet 43 of the key to the ants of Alberta.



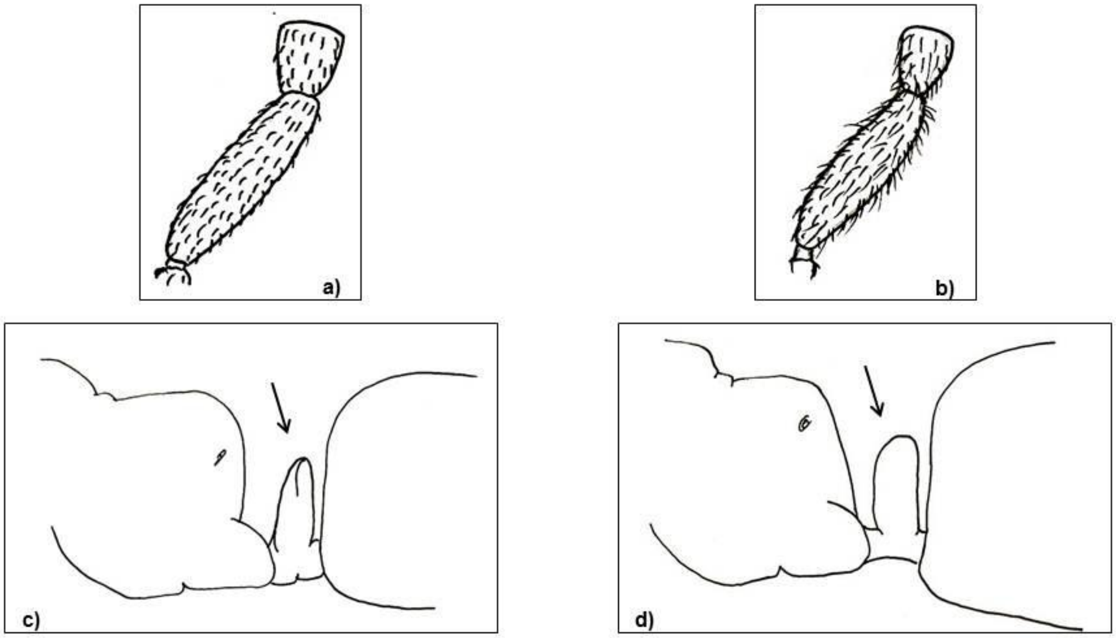
44 (43)	Maxillary palp with 3 segments although palps may be small and sometimes difficult to see (a).(Subgenus *Acanthomyops*).	45
44’	Maxillary palpal with 5 segments, and usually apparent (b).	47

Figure 2.47: Couplet 44 of the key to the ants of Alberta.



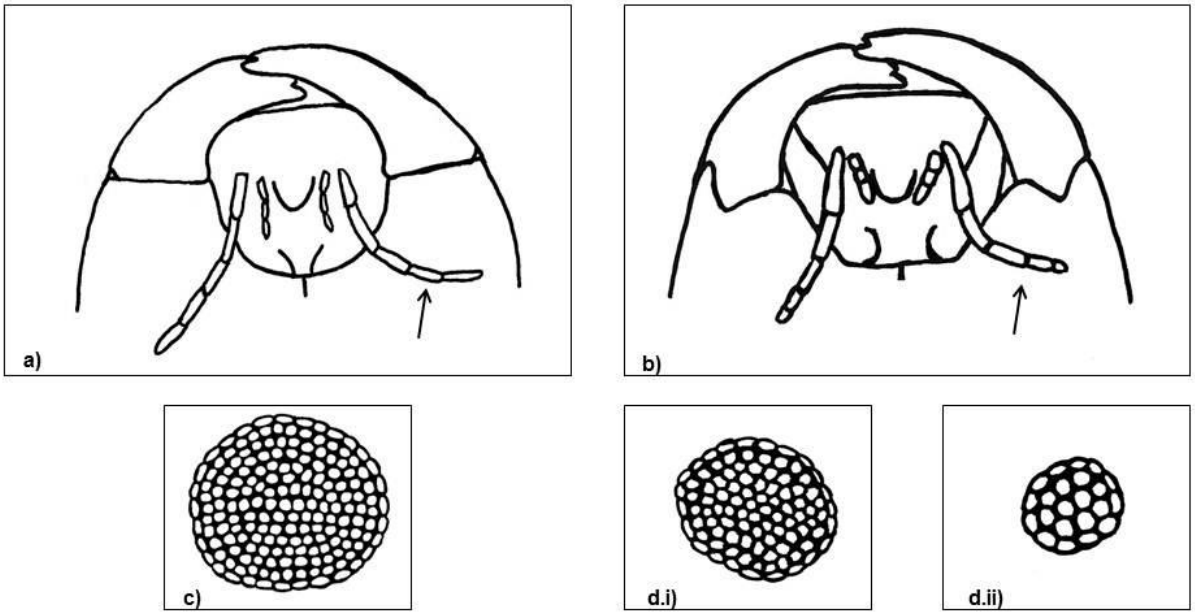
45 (44)	Petiolar crest sharp in profile view (a); in posterior view with a distinct notch in center (c).	*Lasius coloradensis*
45'	Petiolar crest blunt to moderately blunt in profile view (b); in posterior view without distinct notch, (sometimes with minor concavity) in center (d).	46

Figure 2.48: Couplet 45 of the key to the ants of Alberta.



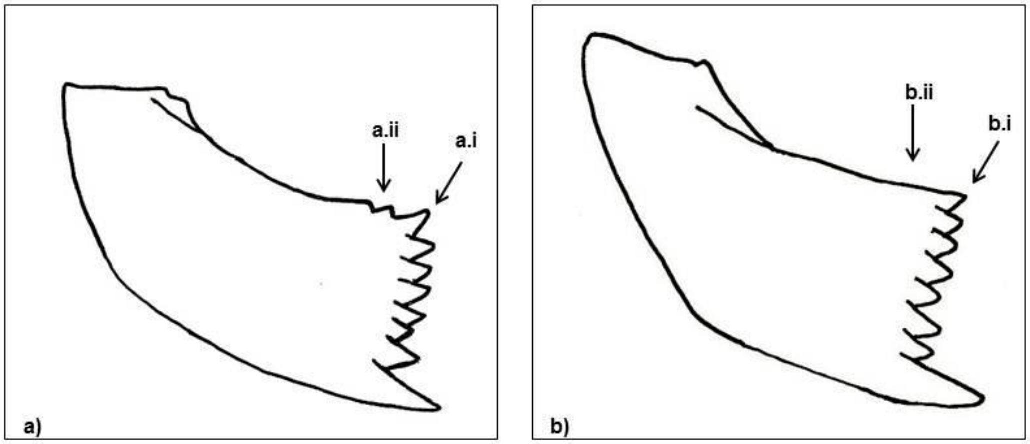
46 (45)	Profemora with erect setae confined to the flexor surface (a). Petiolar scale moderately blunt (c).	*Lasius subglaber*
46’	Profemora with erect setae on lateral surface as well as flexor surface (b). Petiolar scale distinctly blunt (d).	*Lasius latipes*

Figure 2.49: Couplet 46 of the key to the ants of Alberta.



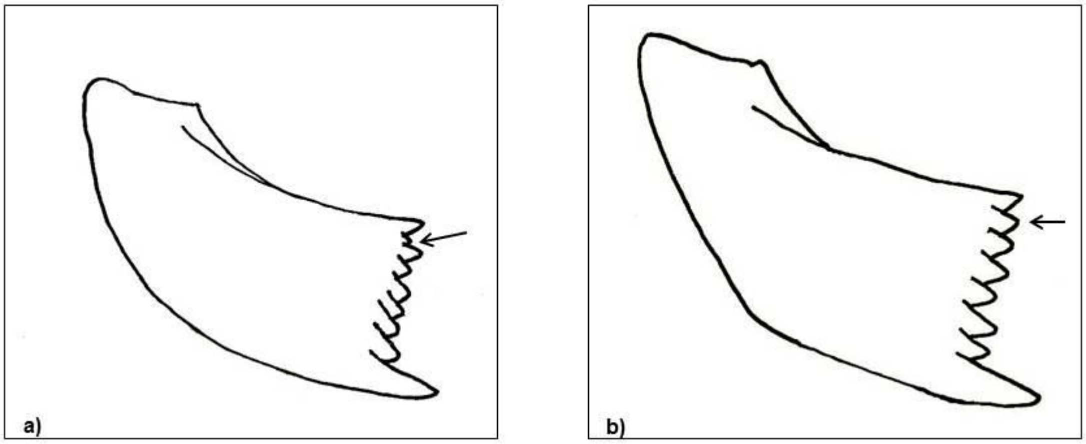
47 (44)	Maxillary palp long, last three segments equal to sub-equal in length (a). Eyes large, with more than 12 ommatidia at maximum diameter (c). (Subgenus *Lasius*).	48
47’	Maxillary palp short, with last three segments each decreasing in length (b). Eyes small, with 12 of fewer, ommatidia at maximum diameter (d.i or d.ii).	52

Figure 2.50: Couplet 47 of the key to the ants of Alberta.



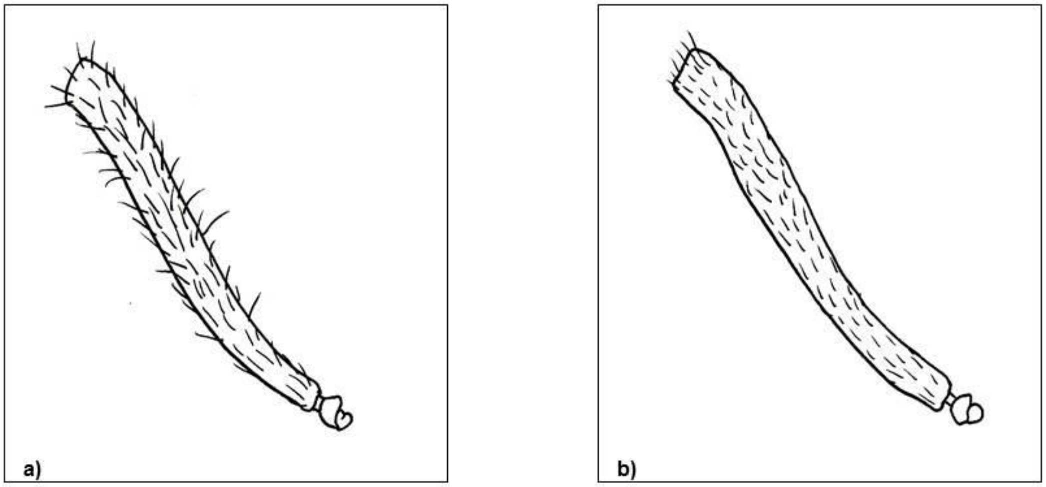
48 (47)	Basal mandibular tooth deflected posteriorly (a.i), teeth often along basal margin of mandible (a.ii).	*Lasius pallitarsis*
48’	Basal mandibular tooth not deflected posteriorly (b.i) and lacking teeth along basal margin of mandible (b.ii).	49

Figure 2.51: Couplet 48 of the key to the ants of Alberta.



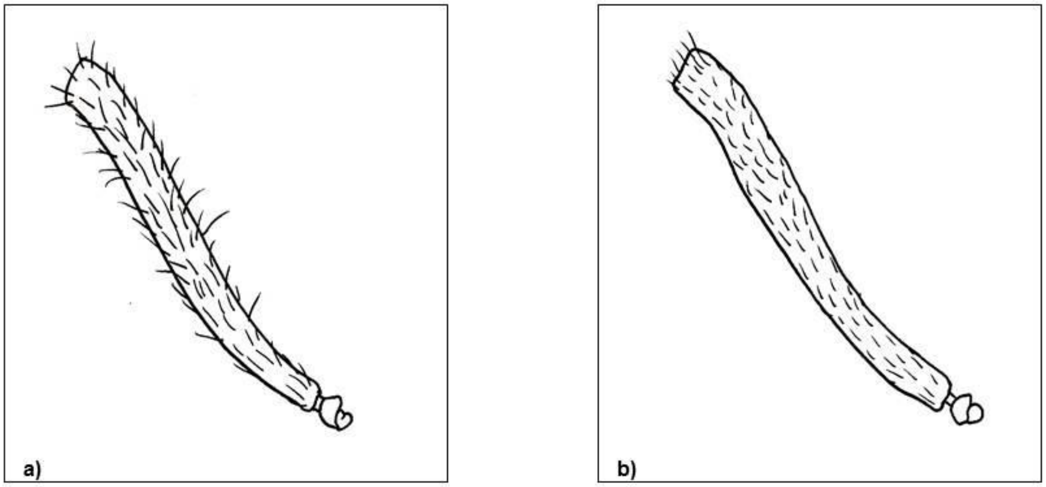
49 (48)	On at least one mandible, sub-basal tooth noticeably smaller compared to basal tooth, or a prominent diastema present between the two (a).	50
49’	On both mandibles, sub-basal and basal tooth about equal in size with no discernable diastema (b).	51

Figure 2.52: Couplet 49 of the key to the ants of Alberta.



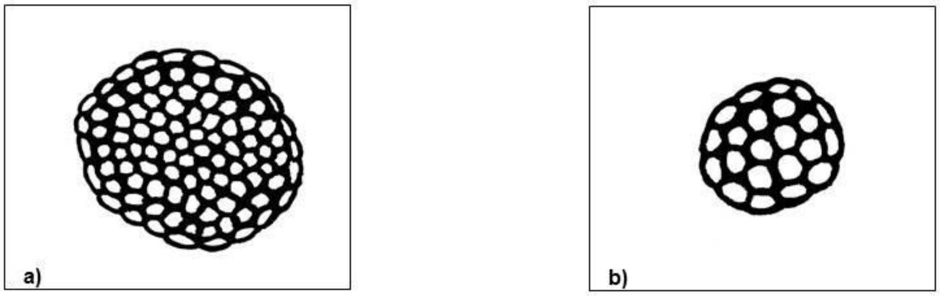
50 (49)	Scape with numerous erect and decumbent setae (a).	*Lasius neoniger*
50’	Scape without erect setae or decumbent (except on extreme tip) , though numerous appressed setae are present (b).	*Lasius crypticus*

Figure 2.53: Couplet 50 of the key to the ants of Alberta.



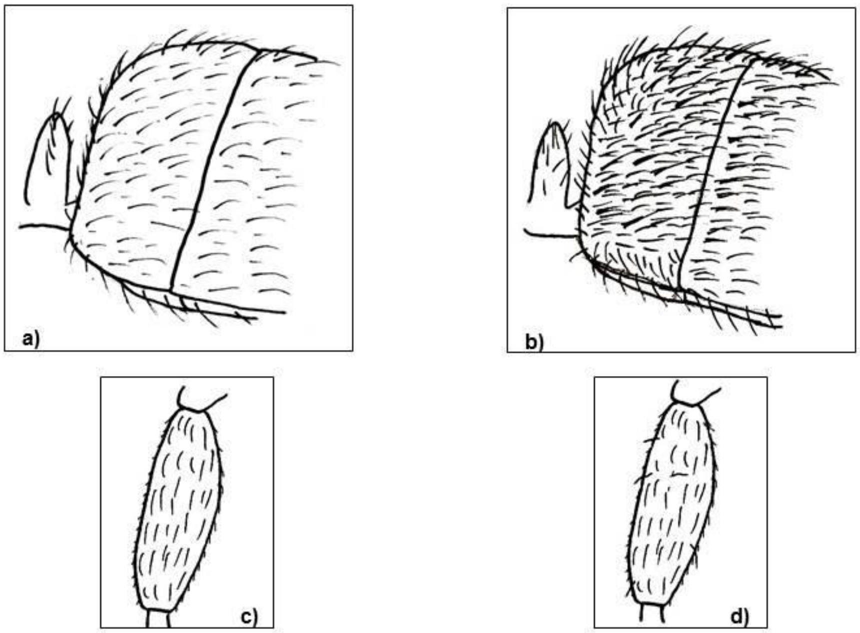
51 (49)	Scape with numerous erect and decumbent setae (a).	*Lasius niger*
51’	Scape without erect or decumbent setae (except on extreme tip), though numerous appressed setae are present (b).	*Lasius alienus*

Figure 2.54: Couplet 51 of the key to the ants of Alberta.



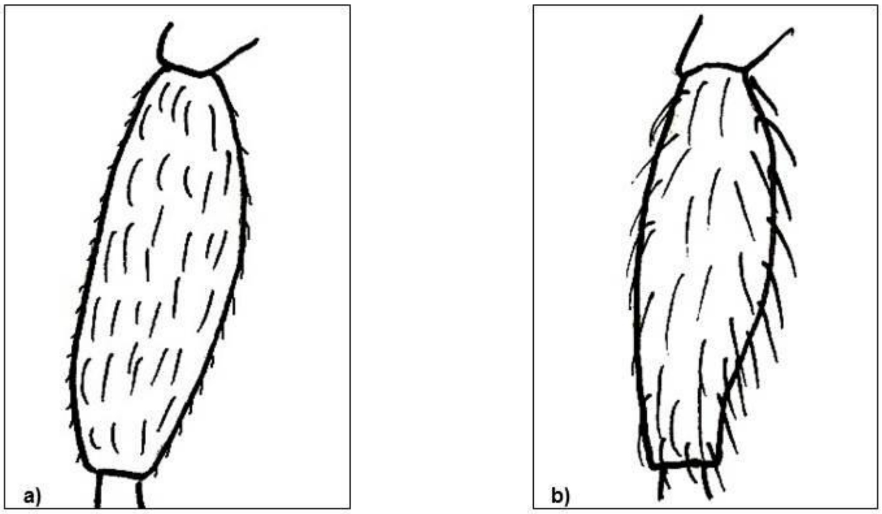
52 (47)	Eyes small, but ommatidia often easy to differentiate and with 10 to 12 ommatidia at maximum diameter (a). (Subgenus *Chthonolasius*).	53
52'	Eyes small, ommatidia relatively hard to differentiate, and with six or less ommatidia at maximum diameter (b). (Subgenus *Cautolasius*).	54

Figure 2.55: Couplet 52 of the key to the ants of Alberta.



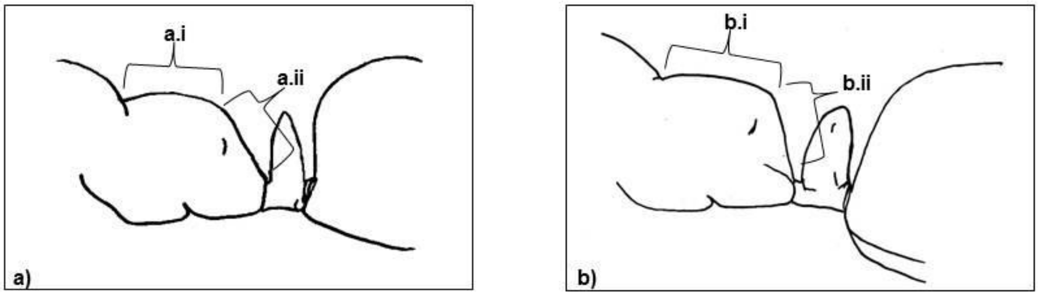
53 (52)	Dorsal surface of gaster with sparse underlying pubescence (a). Gaster feebly shiny. Outer surface of each tibia with appressed setae, but without erect setae (c).	*Lasius umbratus*
53’	Dorsal surface of gaster with dense underlying pubescence (b). Gaster moderately shiny. Outer surface of each tibia with a few decumbent and erect setae (d).	*Lasius subumbratus*

Figure 2.56: Couplet 53 of the key to the ants of Alberta.



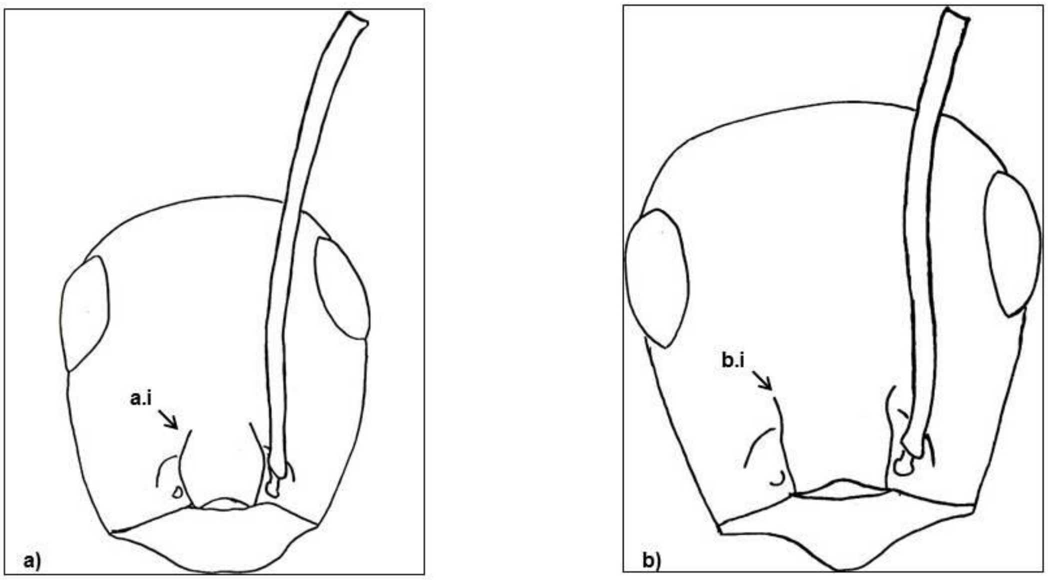
54 (47)	Outer surface of each tibia with appressed setae, but without erect setae (a).	*Lasius flavus*
54'	Outer surface of each tibia with numerous decumbent and erect setae (b).	*Lasius fallax*

Figure 2.57: Couplet 54 of the key to the ants of Alberta.



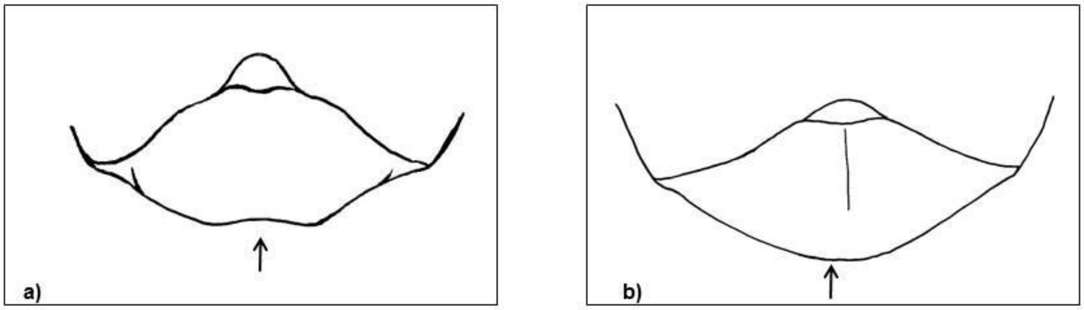
55 (43)	Typically shiny in entirety. Pubescence on body and gaster very sparse; erect setae density variable. In profile, angle between dorsal and posterior surfaces of propodeum typically forming a continuous rounded profile (a.i and a.ii). Dorsal (a.i) and posterior (a.ii) surfaces of propodeum about equal length. Habitus gracile.	56
55'	Typically dull; if shiny, gaster dull. Pubescence on body and gaster variable, but more dense then above; erect setae density variable. In profile, angle between dorsal and posterior surfaces of propodeum typically forming a more distinct angle (b.i and b.ii). Dorsal surface typically longer (b.i) then posterior surface of propodeum (b.ii). Habitus robust.	61

Figure 2.58: Couplet 55 of the key to the ants of Alberta.



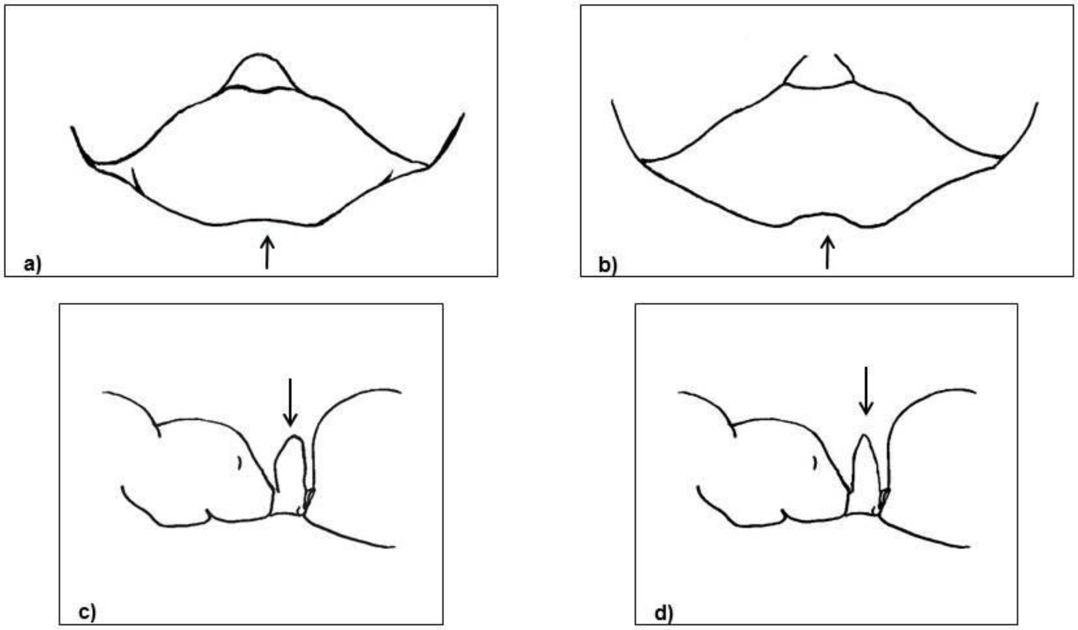
56 (55)	Scape slender and long (~1.33x length of head) (a). Frontal carinae converging posteriorly (a.i).	*Formica pallidefulva group* (not known or expected in Alberta)
56'	Scape more robust and shorter (~1.25x length of head) (b). Frontal carinae subparallel, diverging posteriorly (b.i). (*Formica neogagates* species group).	57

Figure 2.59: Couplet 56 of the key to the ants of Alberta.



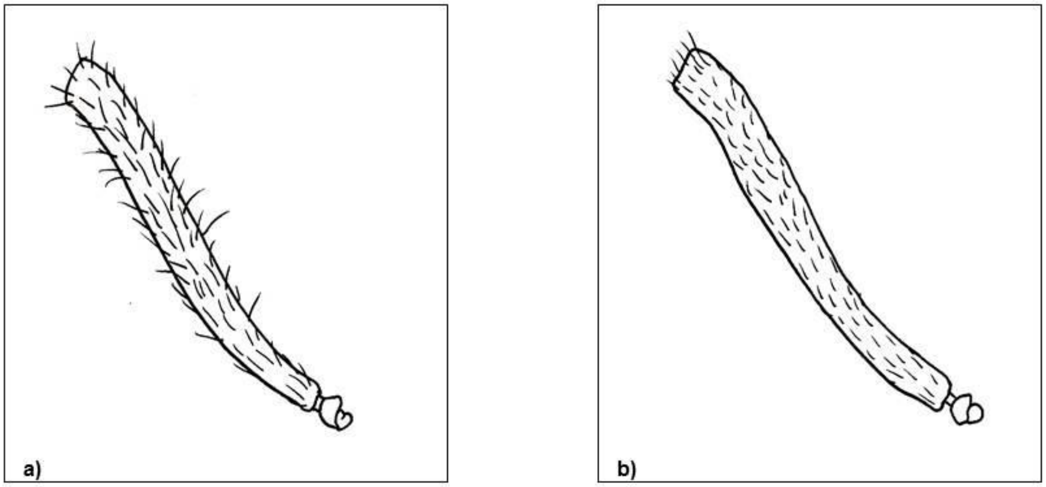
57 (56)	Anterior margin of clypeus concave or notched (a).	58
57’	Anterior margin of clypeus convex (b).	59

Figure 2.60: Couplet 57 of the key to the ants of Alberta.



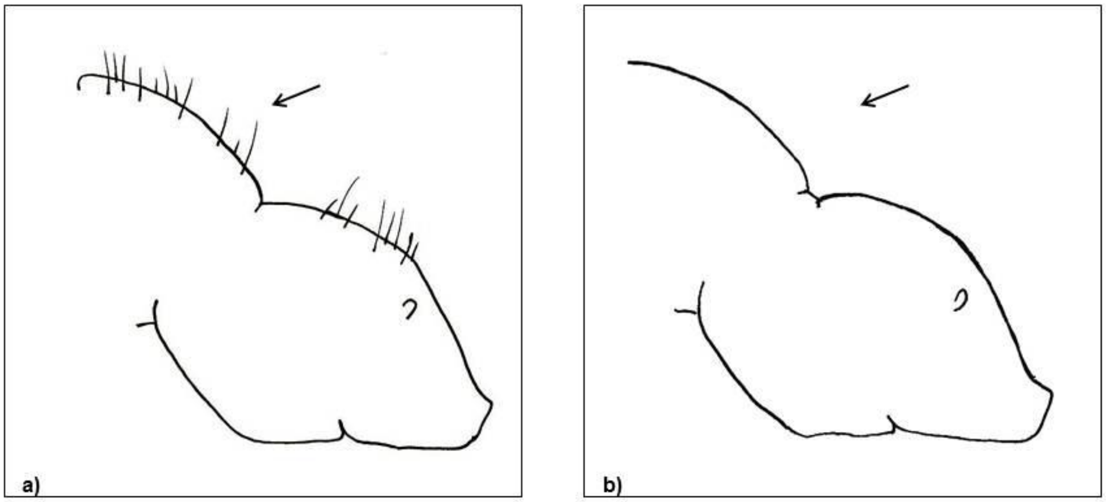
58 (57)	Anterior margin of clypeus concave (a). Petiole thick in profile (c). Gaster no darker than head and thorax. Reddish-yellow in colour	*Formica bradleyi*
58’	Anterior margin of clypeus notched (b). Petiole thin in profile (d). Gaster darker than head and thorax.	*Formica perpilosa*

Figure 2.61: Couplet 58 of the key to the ants of Alberta.



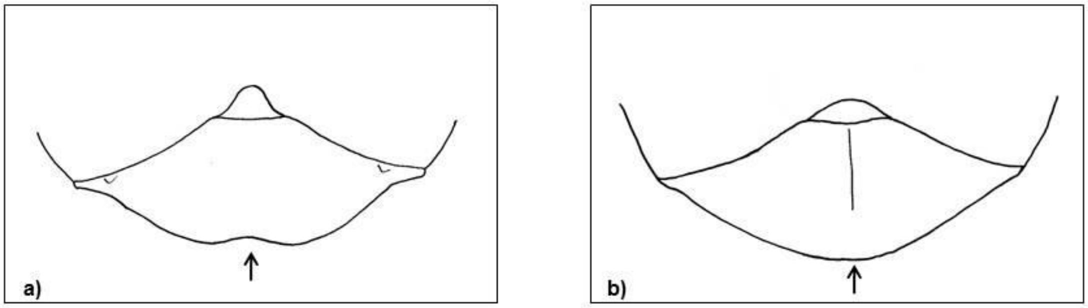
59 (57)	Scape with several erect setae (a).	*Formica lasioides*
59’	Scape without erect setae; except for a small cluster at extreme tip (b).	60

Figure 2.62: Couplet 59 of the key to the ants of Alberta.



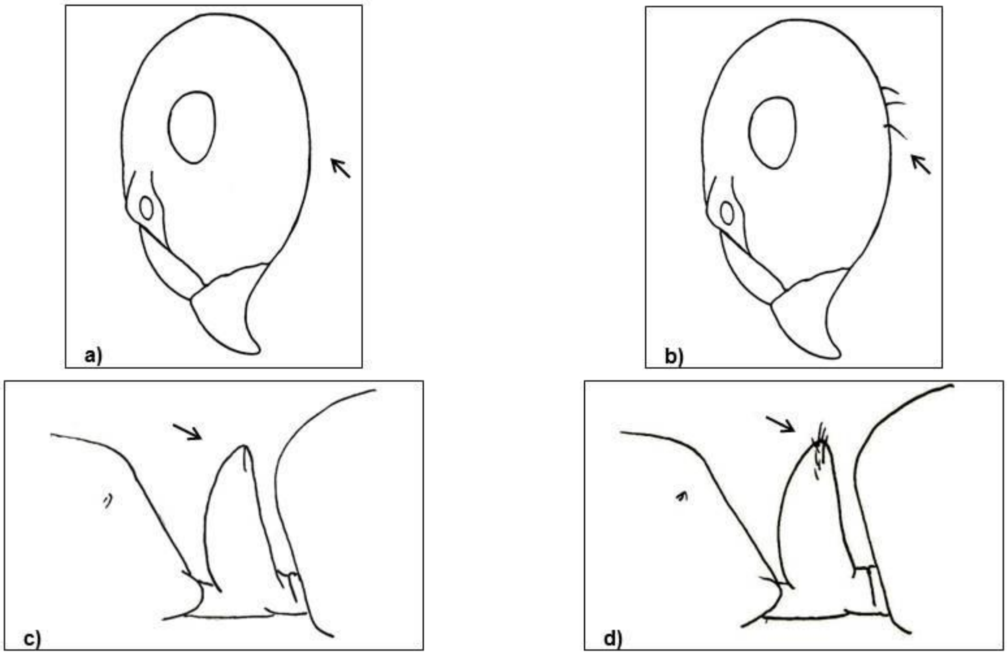
60 (59)	Mesosoma with numerous erect setae (a). Moderately shiny.	*Formica neogagates*
60’	Mesosoma without erect setae (sometimes one or two) (b). Strongly shiny.	*Formica limata*

Figure 2.63: Couplet 60 of the key to the ants of Alberta.



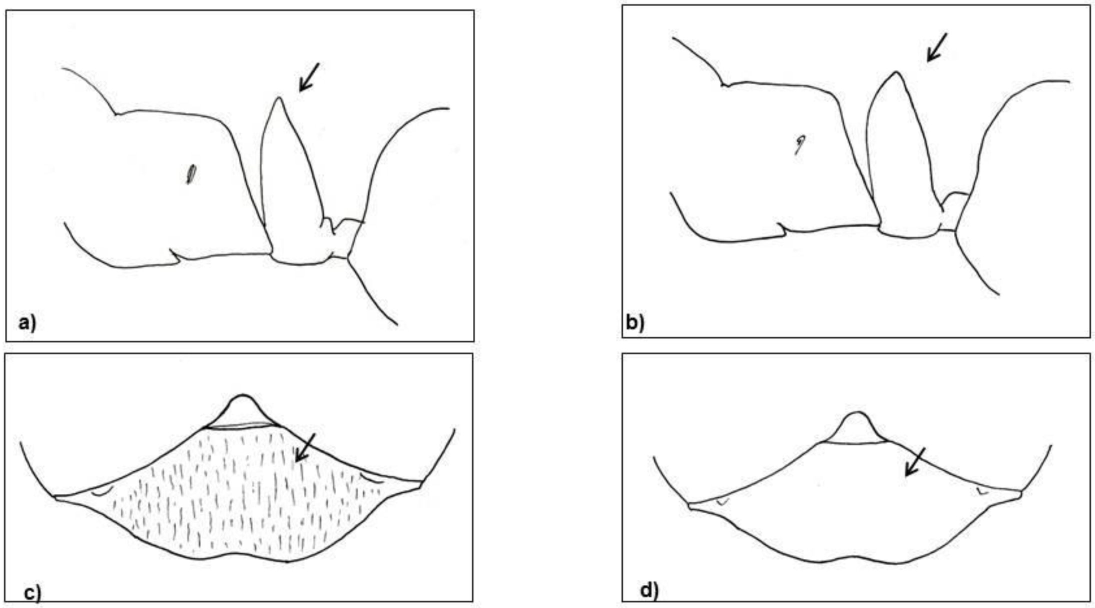
61 (55)	Clypeus with concave anteromedian margin (a). (*Formica sanguinea* species group).	62
61’	Clypeus with rounded anteromedian margin (b).	67

Figure 2.64: Couplet 61 of the key to the ants of Alberta.



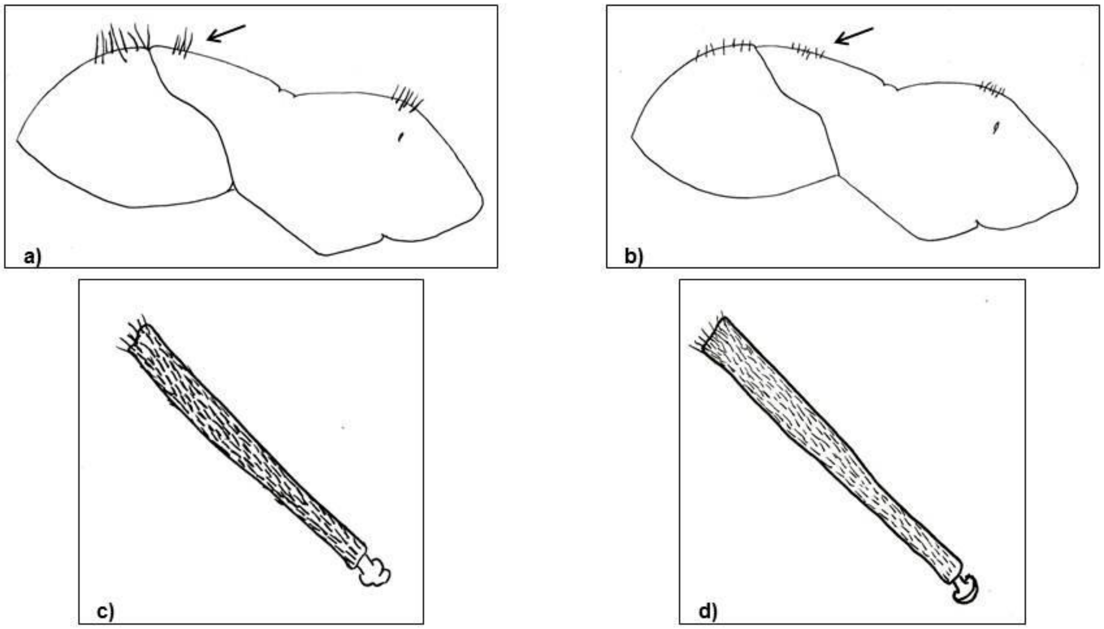
62 (61)	Underside of head (a) and crest of petiole without erect setae (c).	63
62’	Underside of head (b) and crest of petiole with erect setae (d).	64

Figure 2.65: Couplet 62 of the key to the ants of Alberta.



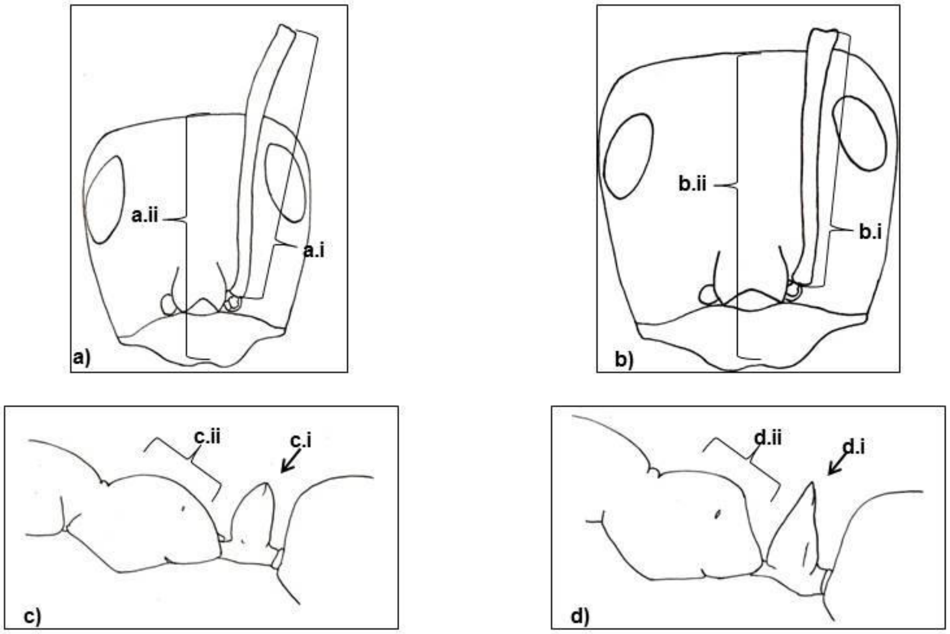
63 (62)	In profile, apex of petiole sharp (a). Clypeus with fine striae (c).	*Formica aserva*
63’	In profile, apex of petiole slightly blunt (b). Clypeus without striae (d).	*Formica emeryi*

Figure 2.66: Couplet 63 of the key to the ants of Alberta.



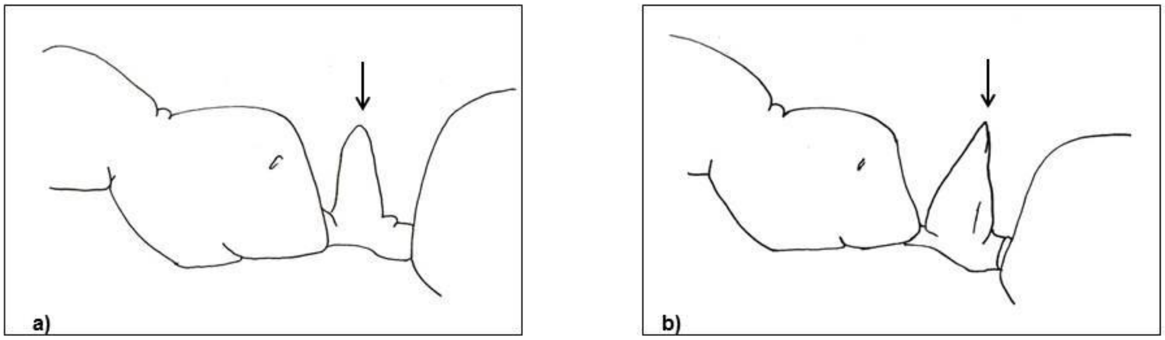
64 (62)	Erect setae of thorax long (0.10-0.25mm) and evenly tapering to the apex (a). Pubescence on scape coarse (c).	*Formica puberula*
64'	Erect setae of thorax short (0.06-0.14mm) and blunt or abruptly tapering at apex (b). Pubescence on scape fine (d).	65

Figure 2.67: Couplet 64 of the key to the ants of Alberta.



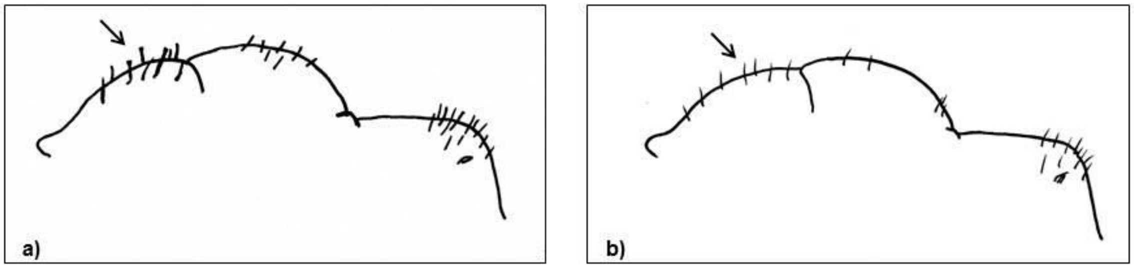
65 (64)	Scape (a.i) longer than head length (a.ii). In profile, apex of petiole blunt (c.i), and propodeum broadly rounded (c.ii).	*Formica obtusopilosa*
65'	Scape (b.i) shorter than head length (b.i). In profile apex of petiole sharp or blunt (d.i), and propodeum more angulate (d.ii).	66

Figure 2.68: Couplet 65 of the key to the ants of Alberta.



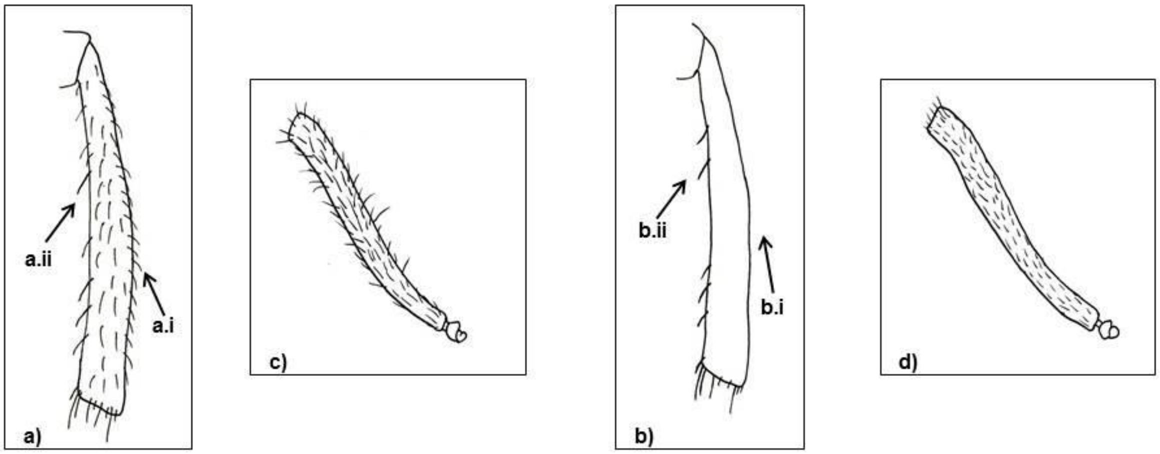
66 (65)	In profile, apex of petiole moderately blunt (a).	*Formica subintegra*
66’	In profile, apex of petiole sharp (b).	*Formica rubicunda*

Figure 2.69: Couplet 66 of the key to the ants of Alberta.



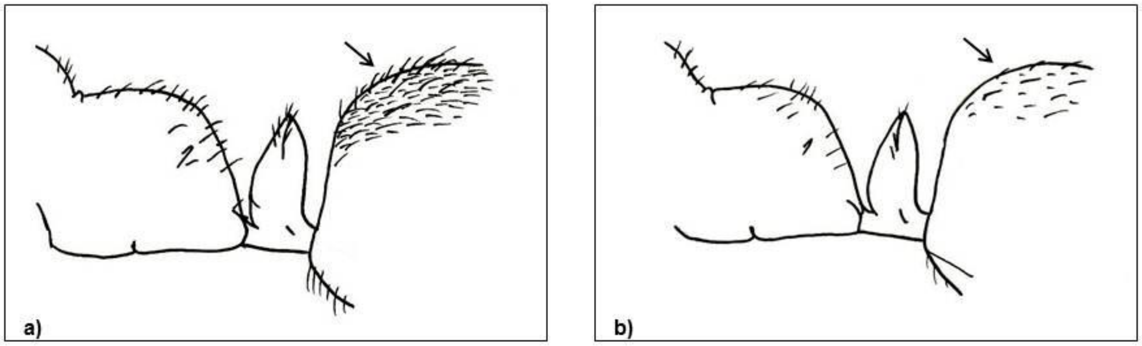
67 (61)	Erect setae on pronotum thick, sometimes clavate or truncate at apex (a); density variable. Queens smaller than the largest worker. (*Formica microgyna* species group).	68
67’	Erect setae on pronotum fine, not clavate at apex (b); density variable. Queens same size or larger than largest workers.	71

Figure 2.70: Couplet 67 of the key to the ants of Alberta.



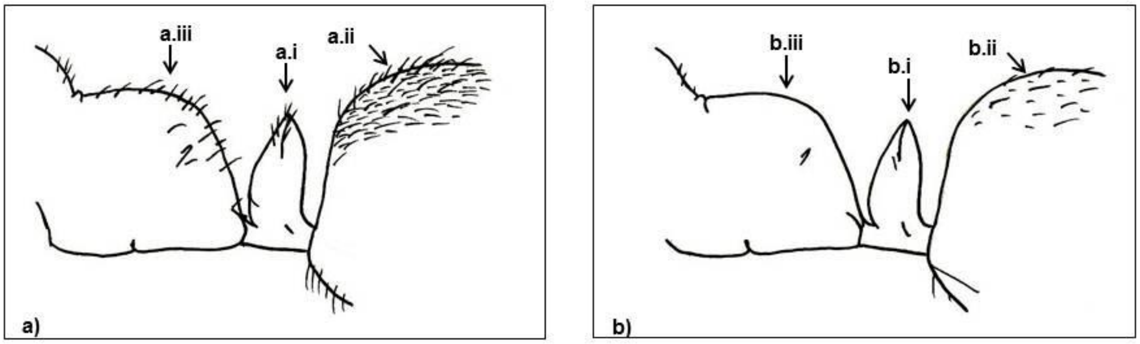
68 (67)	Tibia with erect setae (a.i) in addition to double row on flexors surface (a.ii). Scape usually with erect setae (c).	69
68’	Tibia without erect setae (b.i) except for double row on flexor surface (b.ii). Scape always without erect setae except for extreme tip (d).	70

Figure 2.71: Couplet 68 of the key to the ants of Alberta.



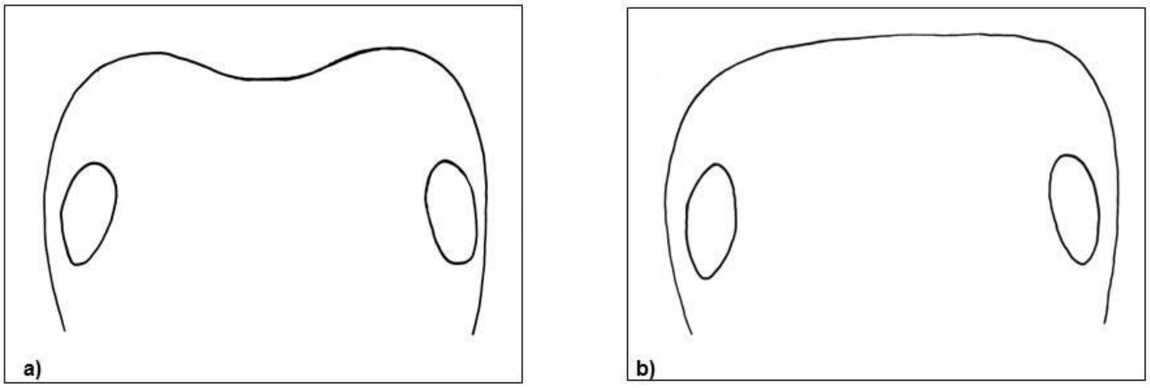
69 (68)	Erect setae on gaster dense (a).	*Formica impexa*
69’	Erect setae on gaster typically sparse (b).	*Formica microgyna*

Figure 2.72: Couplet 69 of the key to the ants of Alberta.



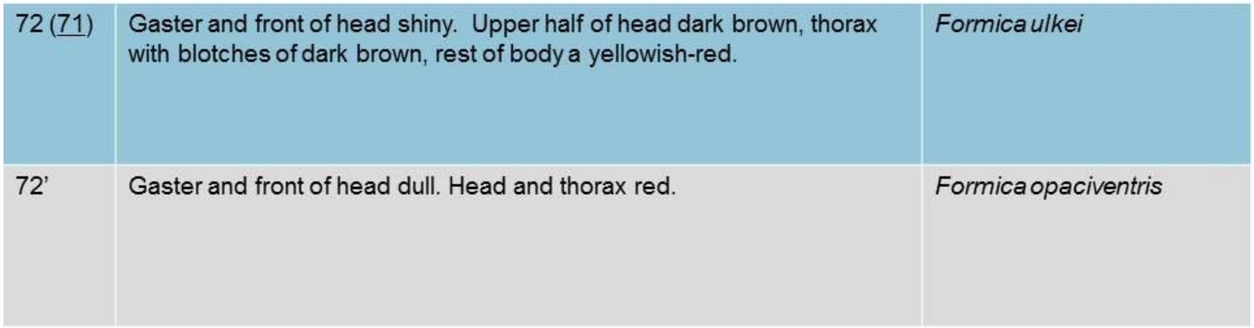
70 (68)	Erect setae on apex of petiole (a.i). Pubescence on gaster dense (a.ii). Erect setae on dorsum of mesosoma numerous (a.iii).	*Formica densiventris*
70’	Erect setae absent from apex of petiole (b.i). Pubescence on gaster sparse (b.ii). Erect setae on dorsum of mesosoma sparse (b.iii).	*Formica adamsi*

Figure 2.73: Couplet 70 of the key to the ants of Alberta.



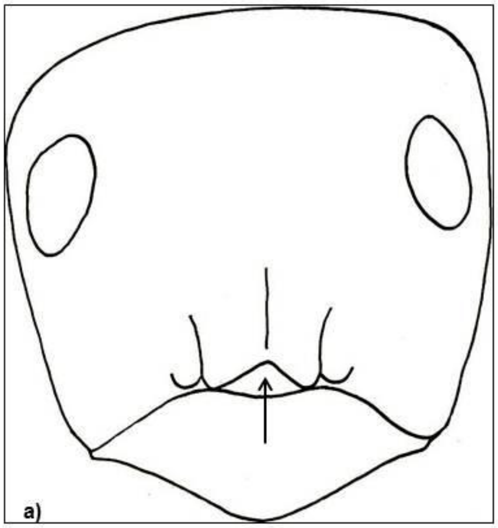
71 (67)	In frontal view posterior margin of head distinctly concave (a). (*Formica exsecta* species group).	72
71’	In frontal view posterior margin of head with slight concavity, flat, or convex (b).	73

Figure 2.74: Couplet 71 of the key to the ants of Alberta.



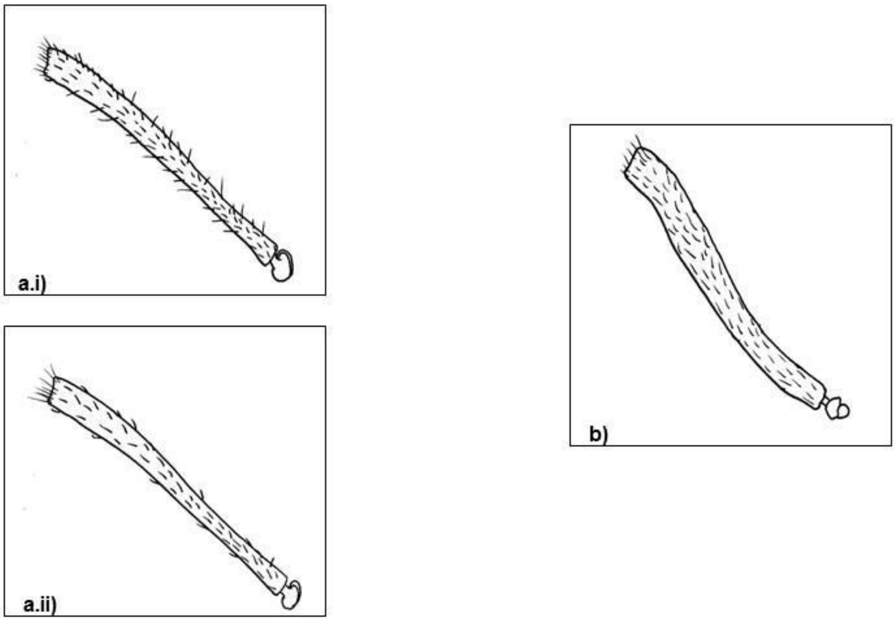
72 (71)	Gaster and front of head shiny. Upper half of head dark brown, thorax with blotches of dark brown, rest of body a yellowish-red.	*Formica ulkei*
72’	Gaster and front of head dull. Head and thorax red.	*Formica opaciventris*

Figure 2.75: Couplet 72 of the key to the ants of Alberta.



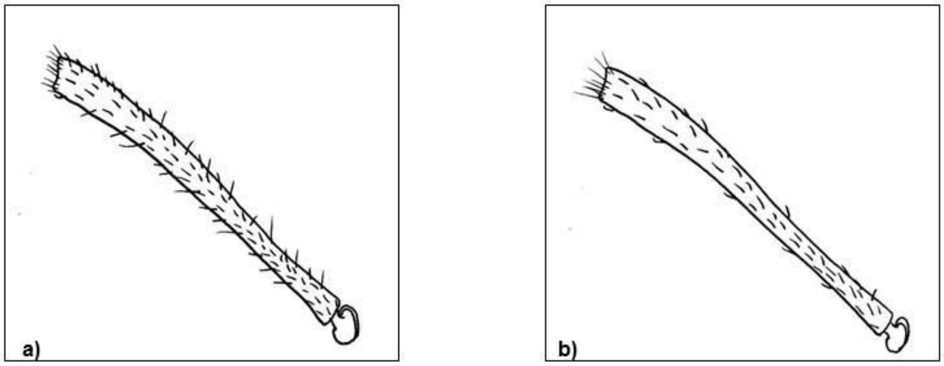
73 (71)	Bicoloured: head and mesosoma reddish or yellowish-red, or infuscated, but not entirely masking underlying colour; gaster brown or black. Frontal triangle (a) shiny. Workers strongly polymorphic (*Formica rufa* species group).	74
73'	Concolourous or bicoloured. If bicoloured: mesosoma lighter than dark head and gaster. Frontal triangle (a) dull. Workers weakly polymorphic (*Formica fusca* species group).	83

Figure 2.76: Couplet 73 of the key to the ants of Alberta.



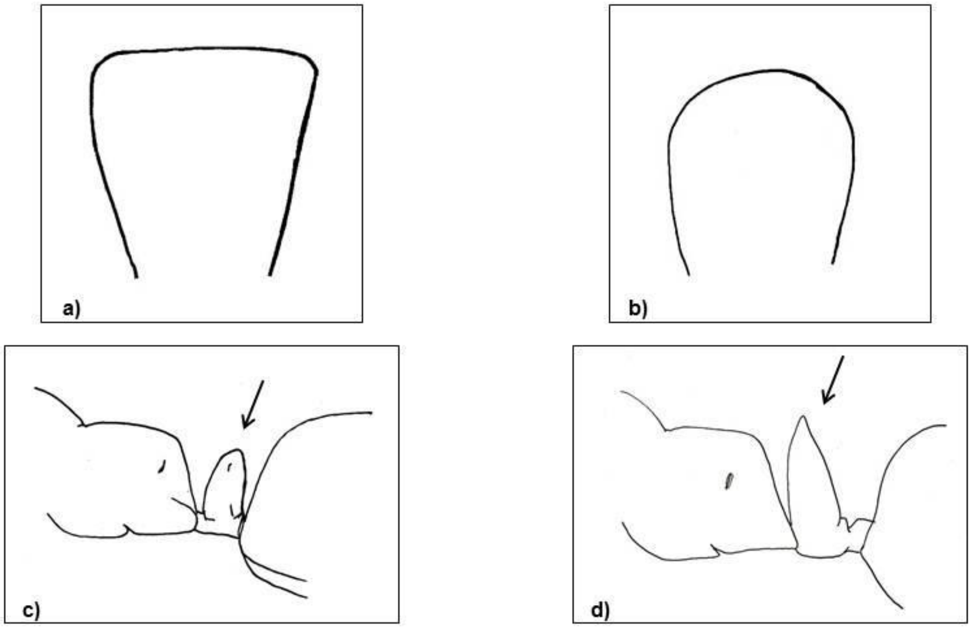
74 (73)	Scape with erect (a.i) and/or decumbent setae (a.ii). (*Formica oreas*)	75
74’	Scape without erect or decumbent setae (except for extreme tip), and typically covered in appressed setae (b).	76

Figure 2.77: Couplet 74 of the key to the ants of Alberta.



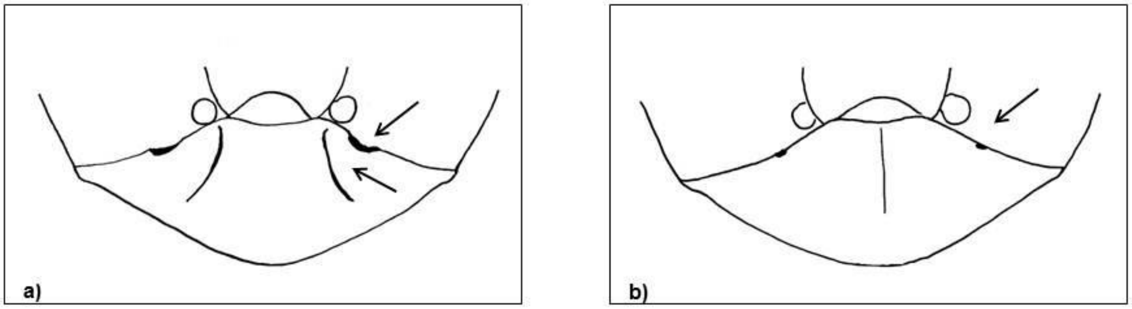
75 (74)	Scape with erect setae (a). Head and thorax not obviously infuscated.	*Formica oreas oreas*
75’	Scape with decumbent and some erect setae (b). Heavily infuscated on head and thorax.	*Formica oreas comptula*

Figure 2.78: Couplet 75 of the key to the ants of Alberta.



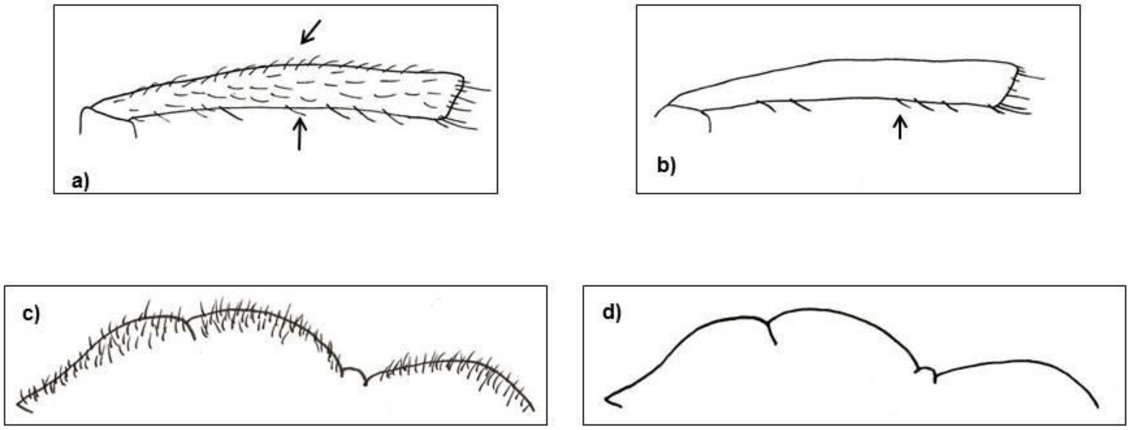
76 (74)	From behind, petiole flat, sometimes slightly concave (a). In profile, apex of petiole distinctly blunt (c).	*Formica dakotensis*
76’	From behind, petiole convex or angling upwards (b). In profile, apex of petiole sharp or blunt (d).	77

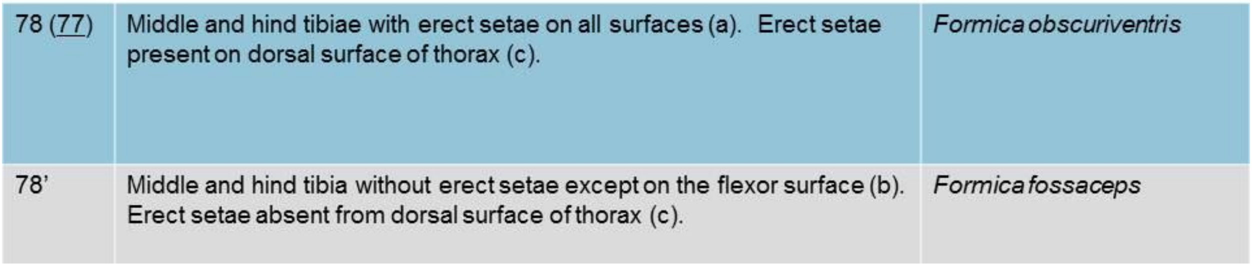
Figure 2.79: Couplet 76 of the key to the ants of Alberta.



77(76)	In frontal view, medial part of clypeus box-like, with wings of the clypeus abruptly descending to form a deep pit-like clypeal fossa below each antennal socket (a).	78
77’	In frontal view, medial part of clypeus not box-like, with wings of clypeus gradually descending to form a shallow clypeal fossa below each antennal socket (b).	79

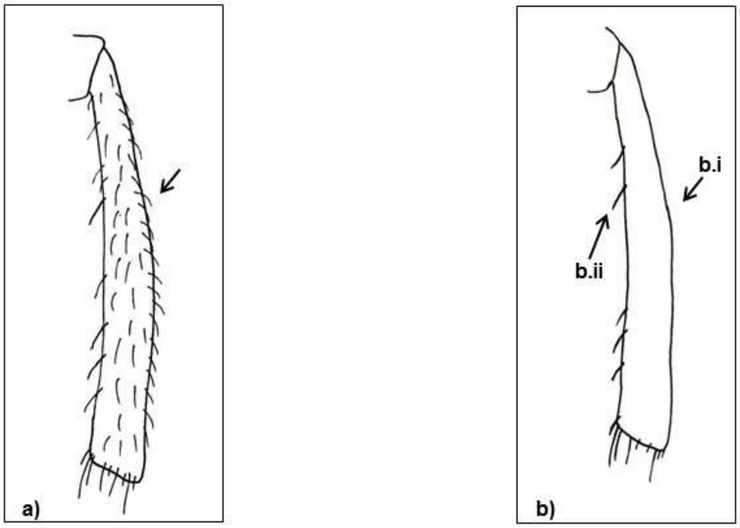
Figure 2.80: Couplet 77 of the key to the ants of Alberta.





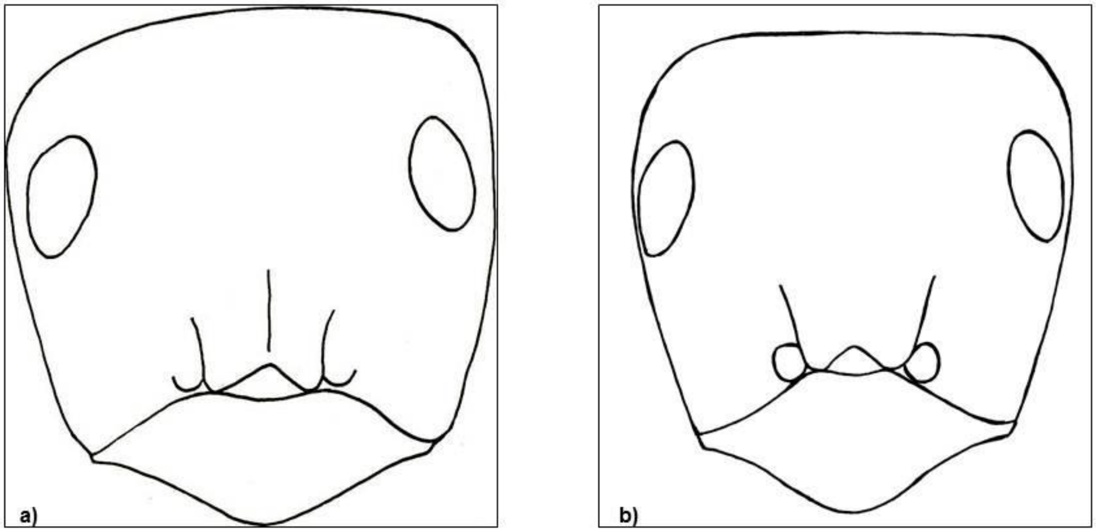
78 (77)	Middle and hind tibiae with erect setae on all surfaces (a). Erect setae present on dorsal surface of thorax (c).	*Formica obscuriventris*
78’	Middle and hind tibia without erect setae except on the flexor surface (b). Erect setae absent from dorsal surface of thorax (c).	*Formica fossaceps*

Figure 2.81: Couplet 78 of the key to the ants of Alberta.



79 (77)	Erect setae on middle and hind tibiae (a).	80
79’	Erect setae lacking on middle and hind tibiae (b.i), except along flexor surface (b.ii).	81

Figure 2.82: Couplet 79 of the key to the ants of Alberta.

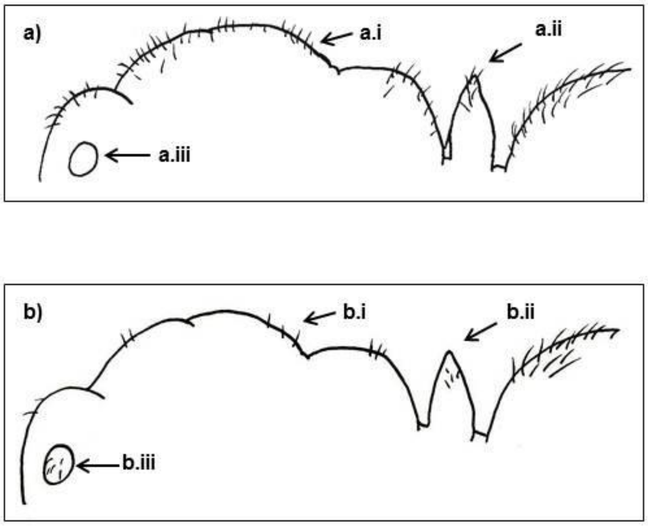


80 (79)	Head of majors broader (at widest place) than long or as broad as long (a) (not as obvious in minor workers but heads still broad). Not greatly infuscated on head or thorax.	*Formica obscuripes*
80’	Head of majors not as broad as along (b). Heavily infuscated on head and thorax.	*Formica planipilis*

Figure 2.83: Couplet 80 of the key to the ants of Alberta.

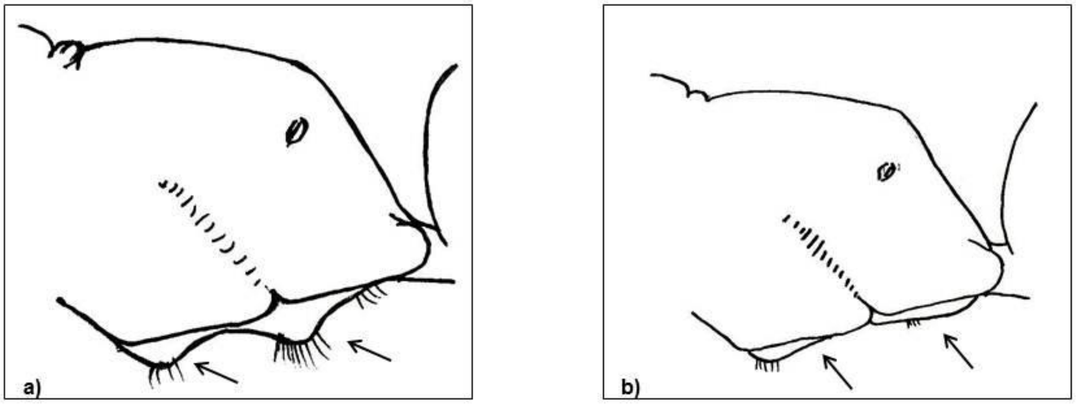
81 (79)	Clypeus and gena strongly shiny.	*Formica subnitens*
81’	Clypeus and gena dull.	82

Figure 2.84: Couplet 81 of the key to the ants of Alberta.



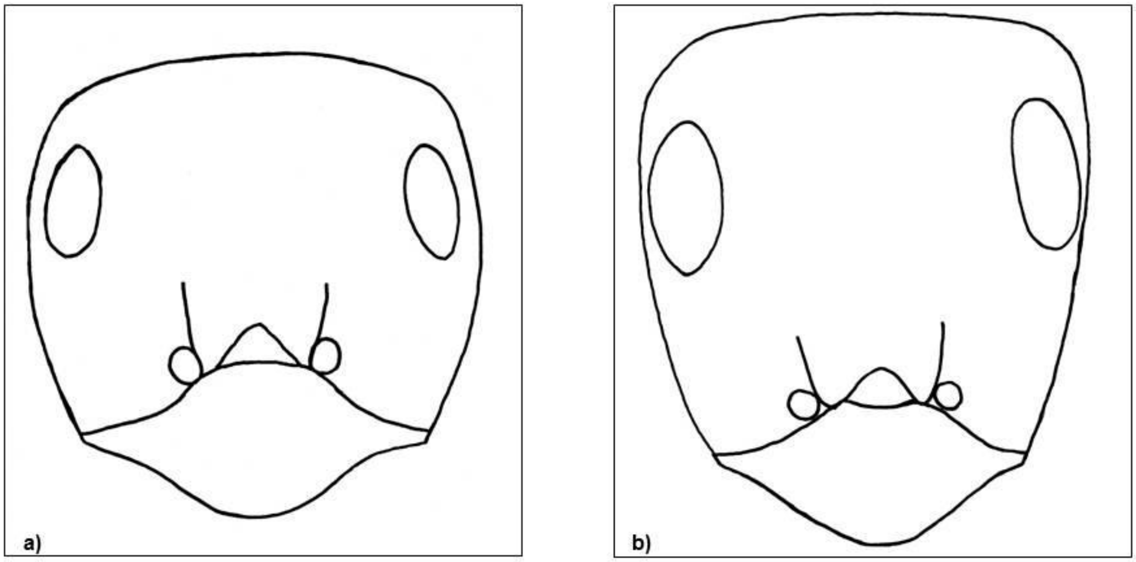
82 (81)	Erect setae on thorax (a.i) and crest of petiole numerous (a.ii). No erect setae on eyes (a.iii).	*Formica integroides*
82’	Erect setae on thorax sparse (b.i), none on crest of petiole (b.ii). Often erect setae on eyes (b.iii).	*Formica ravida*

Figure 2.85: Couplet 82 of the key to the ants of Alberta.



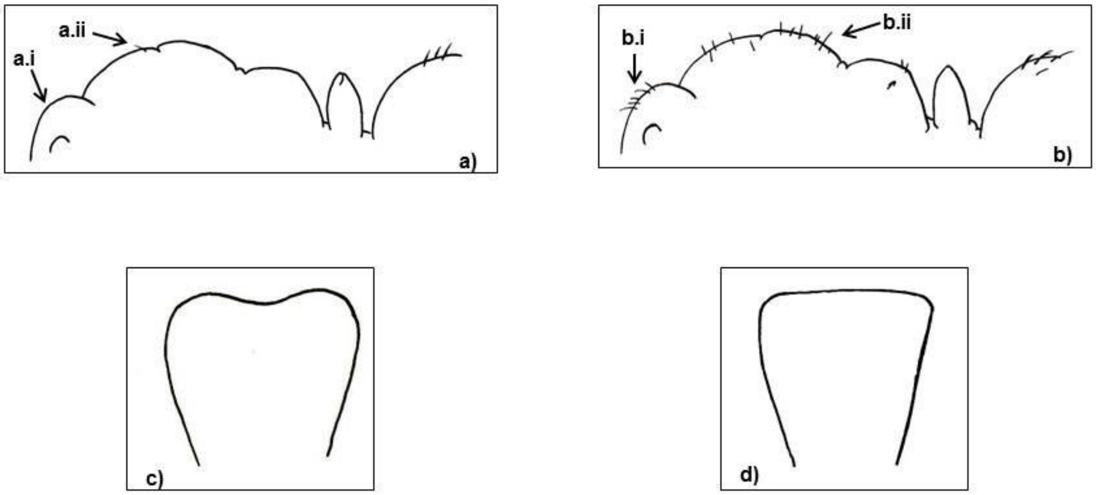
83 (73)	In lateral view, with legs removed, metasternum with two prominent distinct lobes (a).	84
83’	In lateral view, with legs removed metasternum without prominent lobes (b).	88

Figure 2.86: Couplet 83 of the key to the ants of Alberta.



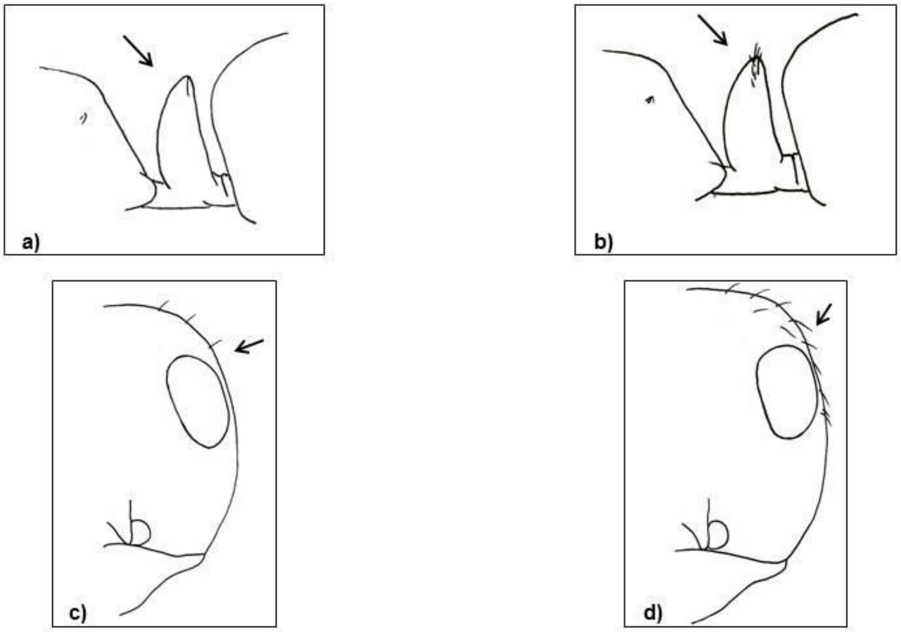
84 (83)	Eyes small (a), head broader than long (a). Gaster shiny.	*Formica subpolita*
84’	Eyes large (b), head longer than broad (b). Gaster feebly shiny or dull.	85

Figure 2.87: Couplet 84 of the key to the ants of Alberta.



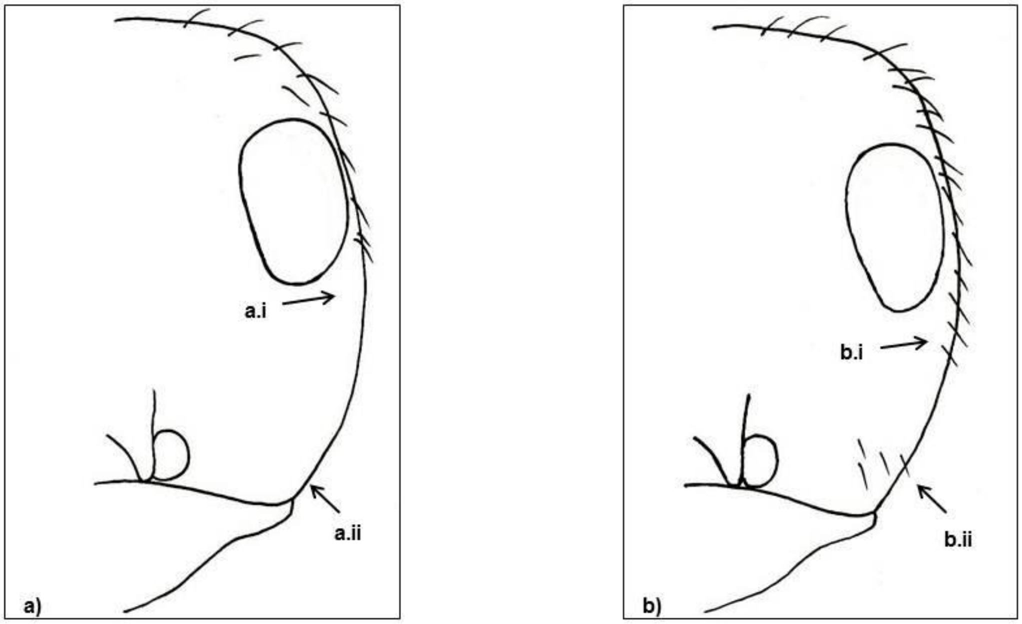
85 (84)	Erect setae absent on head (a.i). Pronotum may have 1 to 3 small erect setae (a.ii). Petiole, in posterior view with a median concavity (c).	*Formica neoclara*
85’	Erect setae present on head (b.i) and pronotum (b.ii). Petiole, in posterior view without a concavity (d).	86

Figure 2.88: Couplet 85 of the key to the ants of Alberta.



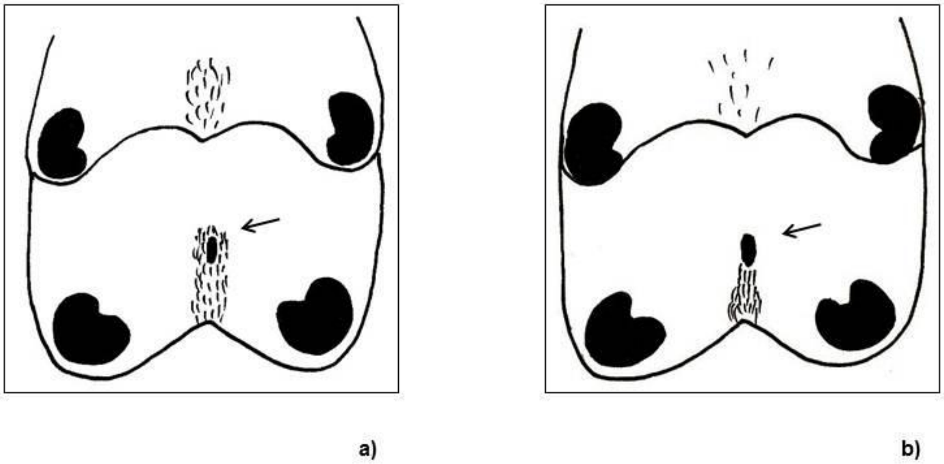
86 (85)	Crest of petiole without erect setae (a). Erect setae sparse on occipital margin and not extending to ventral border of eye (c).	*Formica altipetens*
86'	Crest of petiole with erect setae (b). Erect setae dense on occipital margin and extending to, or past ventral border of eye (d).	87

Figure 2.89: Couplet 86 of the key to the ants of Alberta.



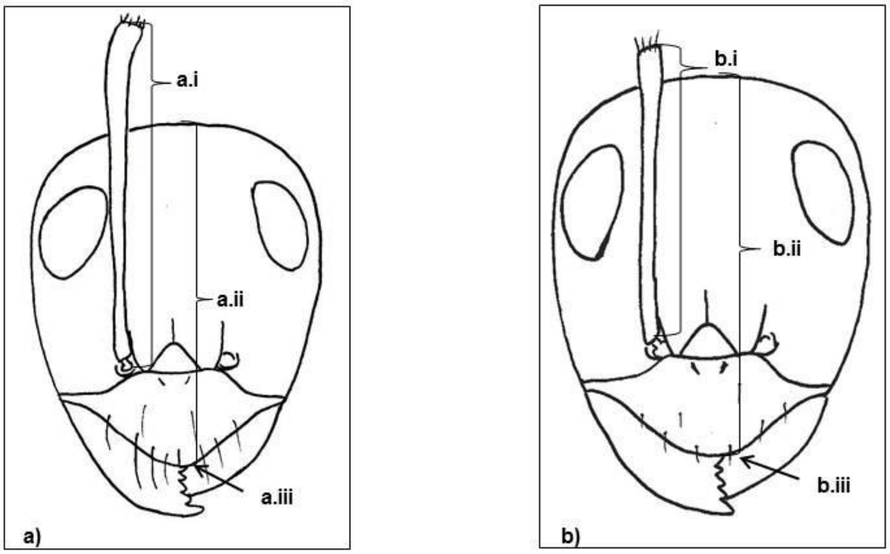
87 (86)	Erect setae extend to ventral border of eye (a.i). Erect setae on side of head sparse (a). Gena without erect setae (a.ii).	*Formica montana*
87’	Erect setae extend past ventral border of eye (b.i). Erect setae on side of head normal to dense (b). Gena with erect setae (b.ii).	*Formica canadensis*

Figure 2.90: Couplet 87 of the key to the ants of Alberta.



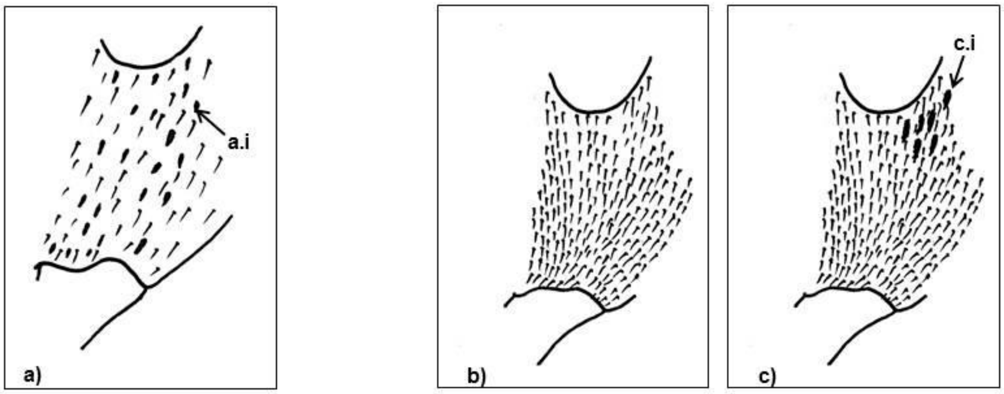
88(<u>83</u>)	Setae surrounding spinasternal cavity (area between metathoracic coxae which requires removal of legs to see) (a). First gastric tergite with low number of erect setae (maximum of 10; excluding posterior row).	<u>89</u>
88’	Setae lacking or restricted to posterad, of spinasternal cavity (b). First gastric tergite often with abundant erect setae (usually more than 10; excluding posterior row; and unless setae have been abraded, which is common).	<u>90</u>

Figure 2.91: Couplet 88 of the key to the ants of Alberta.



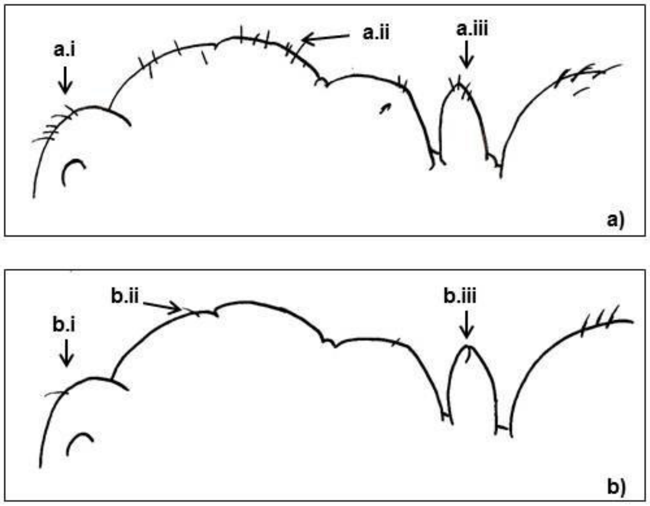
89(88)	Scape (a.i) as long or longer than head (a.ii). Margin of clypeus relatively angulate (a.iii).	*Formica accreta*
89'	Scape (b.i) shorter than head (b.ii). Margin of clypeus broadly convex (b.iii).	*Formica fusca*

Figure 2.92: Couplet 89 of the key to the ants of Alberta.



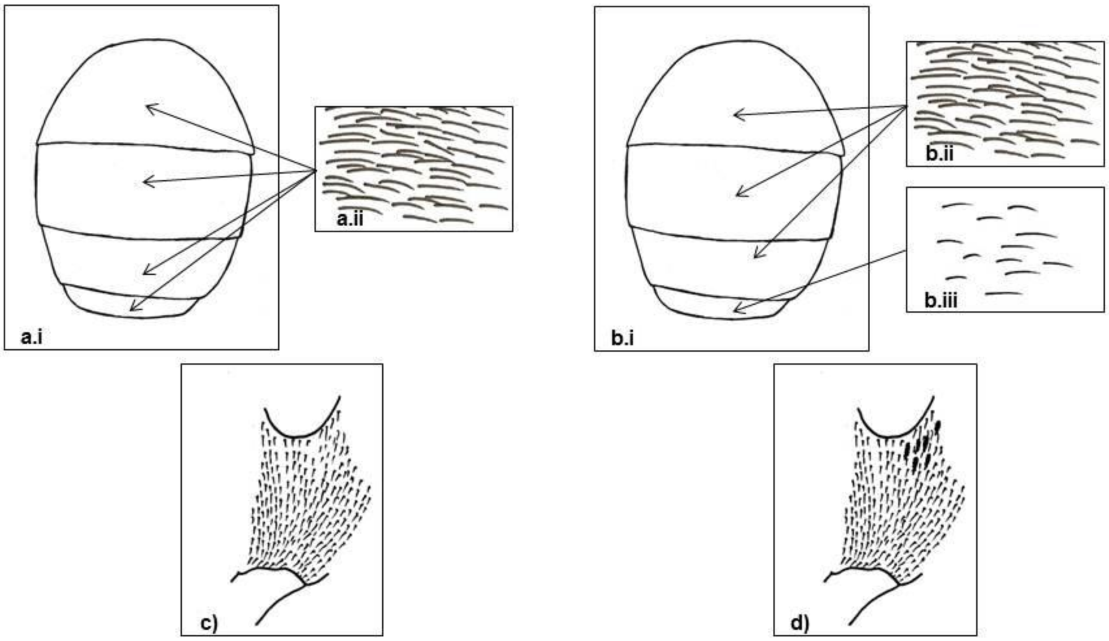
90(88)	Gena with sparse pubescence (a) and microreticulation often easily seen. Gena with minute, shallow, elongate depressions, more widely spaced on gena (a.i). (Visibility depends on angle and lighting).	91
90’	Gena with regular to dense pubescence (b and c), often masking microreticulation. Gena without minute, shallow, elongate depressions (b), or if present, they are concentrated on upper half of gena and closely spaced (c.i). (Visibility depends on angle and lighting).	92

Figure 2.93: Couplet 90 of the key to the ants of Alberta.



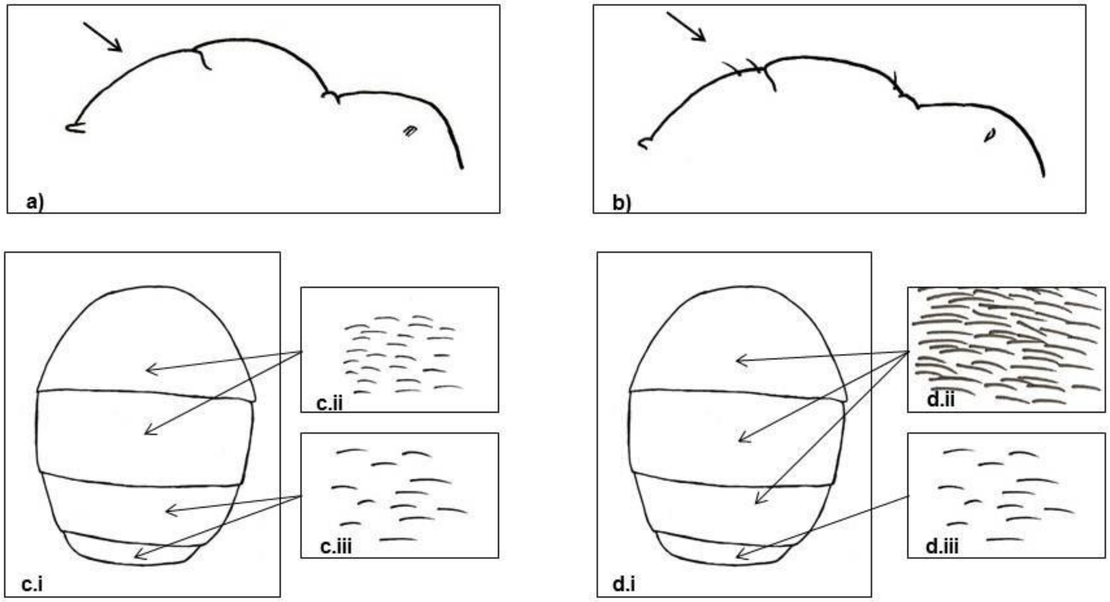
91(90)	Concolourous brownish-black. Numerous erect setae on dorsal surface of head (a.i), dorsal surface of mesosoma (a.ii), and dorsal margin of petiole (a.iii).	*Formica hewitti*
91’	Bicoloured, with thorax yellowish red, head and gaster reddish-black. One, two, or no erect setae on dorsal surface of head (b.i), dorsal surface of mesosoma (b.ii), and dorsal margin of petiole (b.iii).	*Formica neorufibarbis*

Figure 2.94: Couplet 91 of the key to the ants of Alberta.



92(90)	In dorsal view, gaster (a.i) with pubescence dense on all four gastric tergites (a.ii). Minute shallow elongate punctures absent from gena (c) (Visibility depends on angle and lighting).	*Formica argentea*
92’	In dorsal view, gaster (b.i) with pubescence on first three tergites variable in density (b.ii), sparse on fourth gastric tergite (b.iii). Faint elongate punctures present on upper half of gena (d) (Difficult to see at some angles and lighting).	93

Figure 2.95: Couplet 92 of the key to the ants of Alberta.



93(92)	Promesonotum without erect setae (a). In dorsal view, gaster (c.i) with first two dorsal gastric tergites with normal density of pubescence (c.ii), sparse on the rest (c.iii).	*Formica glacialis*
93’	Promesonotum with erect setae (a). In dorsal view, gaster (c.i) with gastric pubescence moderately dense (d.ii) on first three dorsal gastric tergites sparse on fourth (d.iii).	*Formica podzolica*

Figure 2.96: Couplet 93 of the key to the ants of Alberta.

Chapter 3: Central Alberta sand hills as biodiversity hotspots of northern Nearctic ants (Hymenoptera: Formicidae)

Introduction

Ants (Hymenoptera: Formicidae) are an important faunal component in northern temperate ecosystems of the northern Nearctic (Hölldobler and Wilson 1990). They are both predators and prey, affect soil turnover, nutrient cycling, the breakdown of wood, and dispersal of seeds (Hasen and Klotz 2005; Folgrait 1998; Briese 1982; Handel et al. 1981). They are the most numerous ground dwelling invertebrates in many systems and are therefore useful for measuring differences in biodiversity among areas (Folgrait 1998). Despite their ecological importance, little research has considered the diversity of ants in the northern temperate areas of North America, especially the prairie provinces of Canada.

In Alberta, Canada, sand dunes first formed at the end of the Wisconsin glaciation (Wolfe et al. 2004). Since formation, periods of active blowing sand have been correlated with extreme drought conditions, with the southern parts of Alberta having their last major active period during the 1930s (Wolfe et al. 2001). In contrast, the majority of northern and central dune fields in Alberta, excluding the Lake Athabasca sand dunes (Wolfe et al. 2001; Acorn 2011), have been stabilized for several centuries (Wolfe et al. 2001). The sand hills of central Alberta are often covered by jack pine (*Pinus banksiana*) barrens, a heterogeneous environment with variable canopy cover types ranging from small grassland openings to jack pine or mixed jack pine/aspen (*Populus tremuloides*) forests (Lewis and Dowding 1928). These distinct environments are surrounded by a matrix of aspen parkland vegetation and thus represent ecological "islands" of habitat when viewed at regional scales. Compared with sand hills, the surrounding aspen parkland is characterized by having a substrate of glacial till and clay and represented by grassland and dense aspen or mixed aspen/black spruce (*Picea mariana*) forests (Lewis and Dowding 1928). Also unlike the sand hills, much of the surrounding aspen parkland vegetation, particularly the grasslands, which are now rare, have been converted to agriculture (cropland and pastures).

Sand hills are important areas of invertebrate diversity because sand is a substrate that permits easy burrowing, offers thermal benefits, and is often topographically heterogeneous with high dune crests and low inter-dune valleys (Howe et al. 2010; Acorn 2011). Being dominated by jack pine and limited in soil moisture, these areas also have a higher fire frequency than surrounding aspen parkland vegetation, which further increases the variety in vegetation structure (Larsen 1997) and thus ant species diversity (Galle et al. 1998). Ant diversity is higher in sandier soils compared to soils with higher clay content (Boulton et al. 2005). Additionally ants have been found to be more diverse in areas of open canopy structure compared to denser canopy forests (Palladini et al. 2007).

My objectives in this chapter were three-fold: (1) test the prediction that ant diversity should be higher in the sand hills compared to the surrounding aspen parkland; (2) test the prediction that ant diversity should be inversely related to canopy cover within the sand hills ecosystem and thus dependent on period disturbances to restrict or slow forest succession; and (3) compare ant faunas and diversity in the central Alberta sand hills with similar faunas in the northern North America.

Study Areas

Research was conducted at six sites in central Alberta, Canada. Four of the sites were located in the Redwater sand hills, one within the Stony Plain sand hills, and the final site was in aspen parkland near Elk Island National Park (Cooking Lake – Blackfoot Grazing, Wildlife and Provincial Recreation Area) (Table 3.1). The majority of the Redwater sand hills were covered by heterogeneous jack pine woodlands, with intermixed aspen-jack pine forest (Table 2.1). The Stony Plain sand hills (Woodbend Forest) was forested with a mix of aspen, jack pine, and black spruce (*Picea mariana*) (Table 3.1). At Cooking Lake – Blackfoot Grazing, Wildlife and Provincial Recreation Area, sampling was done within the Waskahegan day use site. Vegetation there is comprised of a mix of open grassland or mixed aspen and black spruce forest grazed by livestock. Only one aspen parkland area was sampled because of time restraints, therefore an area that was typified by glacial moraines and hummocks (a similar rolling topography to the sand hills) was chosen to try and differentiate substrate instead of topography. Waskahegan has with high clay soils that are mesic compared to the xeric sand hill areas (Table 3.1).

Research Plots and Vegetation Physiognomies

Each natural area was sampled with 10 plots, with the exception of Woodbend Forest which only had 7 plots, for a total of 57 plots. Plots were defined as a 0.1 ha rectangular (20 m by 50 m) areas consisting of 10 pitfall traps (sub-samples) per plot placed in pairs 10 m apart from a centre line at intervals of 5 m, 15 m, 25 m, 35 m and 45 m from one end. Plots were selected and orientated to maintain the most homogeneous conditions (canopy cover) possible.

To allocate sampling effort and compare the effects of canopy on diversity, I divided the sand hills into the following four types of vegetation: grassland, savannah, woodland and forest. Each plot was designated a vegetation type based on site canopy cover (determined as average of densitometer readings (Lemon, 1956) values for each pitfall trap) (Table 3.2). In total, 11 grassland plots, 13 savannah plots, 10 woodland plots, and 13 forest plots were sampled. This generalized classification scheme for vegetation physiognomy was used as a simple way to compare ant diversity among different vegetation physiognomies using canopy cover measured along the 50 m centre line using line intercept methods.

Specimen Sampling and Identification

Ants were sampled twice in 2010 using pitfall traps per plot at all sites, with the exception of Woodbend forest which was sampled twice during the summer of 2009. Sample dates depended on weather and available time. The first sampling session occurred between late May through June, while second sampling session occurred between Late July and August. Pitfall traps were polypropylene sample containers, 64mm in diameter, 76mm deep, and filled with 30mL of propylene glycol, a solution that is non-toxic to vertebrates (Weeks and McIntyre 1997; Agosti et al. 2000). Traps were placed flush with the ground, retrieved after 24hrs (Agosti et al. 2000), and specimens were transferred into 75% ethanol for storage (Agosti et al. 2000). At no point was there rain during any of the sampling sessions.

Ants were identified using a number of published keys (Creighton 1950; Wheeler and Wheeler 1963; Francoeur 1973; MacKay and MacKay 2002; Hansen and Klotz 2005; Fisher and Cover 2007), by comparisons to specimens in the E. H. Strickland Entomological Museum, and through my own Ants of Alberta key (Chapter 2). Voucher specimens were deposited in the E. H. Strickland Entomological Museum, Department of Biological Sciences, University of Alberta, Edmonton, Alberta.

Statistical Analysis

Sample-based rarefaction curves were used to assess whether samples were large enough to be reliable measures of ant species richness at a site and thus facilitating comparison of species richness between ecosystems (sand hills vs. parkland) and between sand hill vegetation physiognomies (forests vs. woodland vs. savannah vs. grassland). Sample based rarefaction, using Mao Tau curves, was estimated for each ecosystem or physiognomies using EstimateS Version 8.0 (Colwell 2009). EstimateS was also used to calculate common diversity indices including, Michaelis-Menton estimator (MMMeans), Fischer's Alpha (Alpha), the Shannon Index (H'), and the Simpson Index (D). Species Rank-Abundance curves were also estimated to qualitatively compare evenness of ant faunas among sampled areas.

Results

Sample comparison

A total of 28,025 ants were captured and identified, representing 35 species from 10 genera. Overall, 34 species and all ten genera were found in the sand hills, while 18 species in six genera were sampled within the aspen parkland (Table 3.3). Only one species, *Myrmica incompleta*, was found exclusively within the aspen parkland while 17 species were found exclusively in the sand hills (Table 3.3). Based on the results of MMMeans analyses divided actual species richness, sampling overall on the sand hills was nearly equal to the predicted species richness with a 99.7% sampling efficiency (Table 3.4). Lower sampling efficiencies were found in forests and woodlands; these were, respectively, 85.8% and 85.5%. Sampling efficiency in savannah was 92.3% and in grasslands was 87.4%. Parkland had an 85.7% collecting efficiency of ants in parklands. Ants made up 81% of arthropods caught in pitfall traps in sand hills, while only contributing to 49% of collected arthropods in the aspen parkland (Figure 3.5). Coleoptera represented six percent of arthropods caught in pitfall traps in both the sand hills and parkland, while other insects made up 36% and 10% of the catch in parklands and sand hills respectively (Figure 3.5).

Three species of ants were found only in sand hill forests, two of which, *Harpagoxenus canadensis* and *Formicoxenus hirticornis,* are socially parasitic.. The third species was *Lasius alienus* (see Table 2.3), a species common in southern Alberta (personal observation). Sand hill savannahs had one unique species, *Camponotus nearcticus*; an arboreal species that is not easily sampled with pitfall traps (Hansen and Klotz 2005; Agosti et al. 2000). I would expect it to be present in all areas where *Populus* species are present, including aspen parkland. The only species unique species to the sand hill grassland vegetation was *Formica subintegra*, a slave-making species, while the only unique aspen parkland species was *Myrmica incompleta*.

Diversity patterns by ecosystems and physiognomies

Sand hills had higher ant diversity than the aspen parkland regardless of the diversity index used (Table 3.4). All four sand hill vegetation physiognomies also had significantly higher indices of diversity when compared individually to the aspen parkland sites, suggesting that forest cover itself was not the cause of differences. The Shannon index illustrated that the the most diverse community in the sand hills occurred in grassland (*H* = 2.52, effective number of species = 12.3), while forests harbored the least diverse ant assemblage (*H* = 2.13, effective number of species = 8.4) (Table 3.4). Woodland (2.28, effective number of species = 9.8) and savannah (2.20, effective number of species = 9.0) communities were intermediate in diversity (Table 3.4). In contrast, ant diversity in aspen parkland was much lower (1.65, effective number of species = 5.2) than in any of the sand hill communities. Similar results were found using the Simpson index (*D*) (Table 3.4). Values of Fisher's alpha for grassland plots were the highest among vegetation types, but differed significantly from only woodland areas, which had the lowest value.

Species accumulation and species rank-abundance curves

Species accumulation curves for sand hills and aspen parkland ecosystems reached apparent asymptotes at 10 sample plots (Figure 3.1). It was apparent from comparison of the rarefactions that species richness was significantly lower in the aspen parkland (*S* = 18) ecosystem than in sand hills (*S* = 27). Aspen parkland ant diversity was also substantially lower than in any of the four sand hill vegetation physiognomies (Figure 3.2). Moreover, there was a noticeable inverse relationship between ant diversity and canopy cover (i.e., grasslands > savannah > woodland > forest) (Figure 3.2). Total species richness (*S*) of ants for each sand hill vegetation physiognomy (at equal sample sizes of 10 plots) was 22 species for Forests, 25 species for Woodland, 27 species for Savannah, and 29 species for Grasslands.

Species rank-abundance curves for all sand hill sites illustrated that total species richness (*S*) across plots was at 34 species with a gradual slope indicating relative evenness in ant diversity (Figure 3.3). In contrast, the rank-abundance curve for the aspen parkland ecosystem had a higher slope and lower total species richness involving fewer species and suggesting lower evenness (Figure 3.4). Within the sand hills, forest habitats had the lowest evenness, with woodland, savannah, and grasslands showing similar degrees of evenness (Figure 3.4).

Discussion

Sand hills compared to aspen parkland

Species accumulation curves (Figures 3.1 and 3.2) and diversity indices (Table 3.4) suggest that sampling intensity was adequate for reliable estimations of species richness in the sand hills using pitfall traps. Sand hills had significantly higher ant species richness ($S_{sandhills}$ = 34) when compared to the aspen parkland ($S_{aspen\ parkland}$ = 18). Even the sand hill vegetation physiognomies with the lowest richness were significantly higher than observed species richness in the aspen parkland. Moreover, only one species from the aspen parkland, *Myrmica incompleta*, was not detected in the sand hills, while 17 ant species were unique to the sand hills (Table 3.3). The importance of the sand hills for supporting ant diversity in Alberta and with respect to overall ant abundance (biomass) was illustrated by compostion of arthropod assemblaes captured. In the sand hills, 81% of the arthropods captured were represented by ants, while only 49% of invertebrates captured in the aspen parkland were ants (Figure 3.5).

Given similar climate and topography among sand hill and aspen parkland sites (rolling hills), the disparity in abundance and species richness among ecosystems is most likely caused by differences in substrate (soil texture, grain size. Sand hills consist of a thin organic layer of soil over sand, while aspen parkland is characterised by deeper soils having high clay and organic content (Boultan et al. 2005). Sand provides good habitat for many invertebrates that live below ground, including ants, given the ease of burrowing and the thermal properties of sand, which are important for ecosystems typified by cold climates (Acorn 2011).

A potential confounding variable not considered in this research is that grazing by cattle is known to reduce species richness of ants in other parts of North America (Boultan et al. 2005). In general, grazing selects strongly for species that are most resilient to disturbance (Read and Andersen 2000), and commonly observed reductions in ant diversity in grazed areas are thought to be caused by soil compression and disturbance of vegetation. None of the sand hill areas were recently grazed by cattle, while the aspen parkland site was grazed annually during late summer (end of August to September). More research on how cattle affect ants both in and out of sand hill ecosystems is needed.

A second factor potentially influencing the observed differences in ant species richness between the sand hills and aspen parkland is that the sand hill samples were pooled together from 47 plots from five sites, while the aspen parkland was only sampled from 10 plots from one site. However, the significant differences between the different sand hill vegetation physiognomies and the aspen parkland (Figure 3.1), and the overall difference between sand hills compared to the aspen parkland (Figure 3.2) indicate that sand hills are more diverse regardless of differences in pooled sample sizes.

Diversity on sand hills

Relationships between species richness and vegetation physiognomies in the sand hills was difficult to interpret because of the heterogeneous nature of the areas. Samples taken within one plot may have sampled different designated vegetation physiognomies because plots were often heterogeneous, with small patches of open canopy or closed canopy harboring ant species specialized for these environments. Both the Shannon and Simpson indices demonstrated that grasslands were higher in diversity with a general trend for reduced diversity with increased canopy cover. These indices indicate that although there were ant species that were moderately abundant through all vegetation physiognomies, there were also unique species that were most abundant in single vegetation physiognomies. These results support prior findings that ants were less diverse in environments with more vegetation and canopy cover (Lassau and Hochuli 2004; Palladini et al. 2007).

A more in-depth examination of factors affecting ant species richness and species-specific occupancy patterns within sand hills is needed. Coarse categorical measurements of vegetation structure, such as using average canopy cover over a 0.1 ha plot to classify vegetation into four categories, may be too broad. Other site variables, such as ground cover, shrub density, and soil moisture, would improve our understanding of local influences of habitat on ant species (Boulton et al. 2005).

Central Alberta sand hills as biodiversity hotspots of northern North American ants

Ant species on central Alberta sand hills account for approximately one third (34 species) of the ant species here recorded from Alberta (92 species) (Glasier 2009). In fact, sand hills in central Alberta have the highest species richness of any reported Canadian locality (Table 3.5). The more southerly Okanagan Grasslands of British Columbia would be expected to have a higher diversity because of their latitude and warmer climate (Heron 2005), but the results presently available suggest that S from this area is similar to the Alberta sand hills.

Other Canadian localities with well-documented ant faunas are mostly forests, which may have a lower diversity due to higher canopy cover, reduced heterogeneity in vegetation structure, and the more mesic soils. Ants are known to select forest edges where they are thought to take advantage of warmth, with the added benefit of being able to use multiple vegetation structures (open canopy areas and closed) for foraging (Palladini et al. 2007).

My results provide insight into the diversity of ants in central Alberta sand hills and their importance. More research in ant diversity and ecology, especially habitat associations will be needed to determine why sand hills are so diverse compared to other northern Nearctic areas. Given the unprecedented capture rate of ants (81%) relative to other invertebrates in the sand hills (Figure 3.5), estimates of ant biomass would be helpful to understand how important they are to the ecosystem. The high capture rates suggests that ants are a major ecological factor affecting sand hills ecosystems and therefore need further study.

Notable species records from this study

I noted several new ant species records for the province of Alberta in the sand hills. *Dolichoderus taschenbergi* was found in all five sampled sand hill areas and appeared to be tightly associated with jack pine (*Pinus banksiana*) dominated sand hills. This represents a range extension of over 1200 km to the east (MacKay 1993). *Myrmica nearctica* appears to be another sand hill specialist that has been found only in Alberta sand hills and not previously known for Alberta until this study. *M. nearctica* is known in B.C. and Montana. *Formicoxenus hirticornis* has only been found on the sand hills in *Formica oreas* nests. However, *Formicoxenus hirticornis* would be expected to be found anywhere its host species of the *Formica rufa*-group of ants are found (Francoeur and Buschinger 1985).

This study also provides the first and only record of *Harpagoxenus canadensis* in Alberta, a species listed as Vulnerable in the IUCN redlist (IUCN 2001), was found in one plot (in only one pitfall trap section) in the Redwater Natural Area. The expansion of its range is approximately 2000 km from known localities. The specimens match descriptions of specimens from eastern Canada (Stuart and Alloway 1983; ww.antweb.org), but a comparison of genetics, actual specimens and queens has not been done. As it is a slave-making species using *Leptothorax muscorum* (and allies), it is probably found across Canada's prairie-forest ecotone in dry sandy deposits (like its host). However, the slave-making adaptation leaves it vulnerable to disturbance and fluctuations of its host species (Stuart and Alloway 1983). Assessment of *H. canadensis'*s abundance, habitat associations, as well as its use of hosts needs to be done before determining any conservation strategy.

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Table 3.1: Descriptions of study areas sampled for ants in central Alberta, Canada.

Study Area	**Latitude/ Longitude**	**Ecosystem**	**Size (Hectares)**	**Vegetation**	**Date of Most Recent Fire**	**Disturbance(s)**
Cooking Lake – Blackfoot Grazing, Wildlife and Provincial Recreation Area (Waskahegan Day site)	53°30'21.96"N 112°56'8.81"W	Aspen Parkland	250	-Aspen Parkland (Mixed Aspen and Black Spruce)	Unknown (no recent evidence)	-Livestock grazing
North Bruderheim Natural Area	53°52'8.54"N 112°56'40.10"W	Sand Hills	178	-Jack Pine Forest -Mixed aspen/jack pine forest	May 2009	-All terrain vehicles -Petroleum industry
Northwest Bruderheim Natural Area	53°52'8.54"N 112°56'40.10"W	Sand Hills	259	-Jack Pine Forest -Mixed aspen/jack pine forest	May 2009	-All terrain vehicles -Petroleum industry
Opal Natural Area	53°59'13.59"N 113°18'34.96"W	Sand Hills	372	-Jack Pine Forest -Mixed aspen/jack pine/black spruce forest	May 2010	-All terrain vehicles
Redwater Natural Area	53°56'27.66"N 112°57'17.19"W	Sand Hills	1810	-Jack Pine Forest - Mixed aspen/jack pine forest	Unknown (no recent evidence)	-All terrain vehicles -Petroleum industry
Woodbend Forest	53°23'31.66"N 113°45'15.38"W	Sand Hills	64	-Mixed aspen/jack pine/black spruce forest	Unknown (no recent evidence)	- Petroleum industry

Table 3.2: Classification scheme of vegetation physiognomies, modified from the United States National Vegetation Classification Standard (Federal Geographic Data Committee 1997), in this study to describe patterns of ant diversity in the sand hill ecosystem of Central Alberta. A plot was designated a vegetation type by having an average canopy cover that fit into one of the classifications.

Vegetation Type	Canopy Cover	Description
Grassland	0-5%	Areas of open canopy often located on the tops or southern exposures of dunes. Open sand patches are common. Lichen, sedges, and small shrubs, such as roses or pin cherry, represent the dominant ground cover.
Savannah	>5-25%	Openings with a few jack pine and aspen. Often dominated by lichen, but with bryophytes under forest canopy. Sedges and grasses are common, with scattered shrubs such as saskatoons, pin cherry and roses.
Woodland	>25-60%	Jack pine and aspen overstory with a mix of lichen and bryophyte ground cover. Roses and saskatoons are common. Grasses and sedges are uncommon
Forest	>60-100%	Jack pine forest, interspersed with rare patches of aspen. Ground cover dominated by bryophytes, although sometimes a thick layer of shrubs is present.

Table 3.3: Species occurrence matrix summarized by vegetation physiognomies in central Alberta, Canada. Aspen parkland represents forests on mesic soils, while the remaining physiognomies are in sand hills.

Species	**Aspen Parkland**	**Forest**	**Woodland**	**Savannah**	**Grassland**
Dolichoderus taschenbergi		x	x	x	x
Tapinoma sessile		x	x	x	x
Camponotus herculeanus	x	x	x	x	x
Camponotus nearctica				x	
Camponotus novaeboracensis	x	x	x	x	x
Formica accreta	x	x	x	x	x
Formica adamsi			x	x	x
Formica aserva	x	x	x	x	x
Formica dakotensis	x		x	x	x
Formica densiventris		x	x	x	x
Formica hewitti	x	x		x	x
Formica impexa			x		x
Formica lasioides	x	x	x	x	x
Formica neorufibarbis	x	x	x	x	x
Formica obscuriventris		x	x	x	x
Formica oreas		x	x	x	x
Formica podzolica	x	x	x	x	x
Formica subintegra					x
Formica ulkei	x		x	x	x
Formicoxenus hirticornis		x			
Lasius alienus		x			
Lasius neoniger		x	x	x	x
Lasius niger				x	x
Lasius pallitarsis	x	x	x	x	x
Lasius subumbratus				x	x
Polyergus breviceps	x			x	x
Harpagoxenus canadensis		x			
Leptothorax muscorum	x	x	x	x	x
Myrmica ab01	x	x	x	x	x
Myrmica alaskensis	x	x	x	x	x
Myrmica brevispinosa		x	x	x	x
Myrmica detritinodis	x	x	x	x	x
Myrmica fracticornis	x	x	x	x	x
Myrmica incompleta	x				
Myrmica nearctica		x	x	x	x
Generic richness	6	8	7	8	8
Species richness (*S*)	18	23	23	27	28

Table 3.4: Diversity indices of ants on sand hills compared with aspen parkland in central Alberta, Canada.

Ecosystem	Species Richness (Generic Richness)	MMMeans	Alpha (StD)	Shannon Index (StD)	Simpson Diversity Index
A. Sand Hills					
Overall	34 (10)	34.1	3.86 (0.21)	2.58 (0)	9.98
Forest	25(8)	29.1	3.64 (0.27)	2.13 (0)	5.90
Woodland	25(7)	29.2	3.33 (0.23)	2.28 (0)	6.71
Savannah	29(8)	31.4	3.67 (0.23)	2.20 (0.12)	6.89
Grassland	30(8)	34.3	4.07 (0.26)	2.52 (0)	9.32
B. Aspen Parkland	18(6)	21.0	2.72 (0.24)	1.65 (0.05)	3.39

Table 3.5: Comparison of ant diversity (species and generic richness) for northern Nearctic localities, including central Alberta.

Locality	**Ecosystem**	**Ant Species (Generic) Richness**	**Author**
Central Alberta Sand Hills, Alberta, Canada	Pine Barrens	34 (10)	Glasier, this paper
Southern Okanagan Grassland, British Columbia, Canada	Brush Shrub Steppe	31(13)	Heron 2005
Rangeland Institute University of Alberta, Duchess, Alberta, Canada	Grassland	29(7)	Glasier, unpublished
Molson Reserve, Quebec, Canada	Maple-Beech Forest	24 (12)	Lessard and Buddle 2005
Prince George, British Columbia, Canada	Boreal Forest	19(7)	Lindgren and MacIsaac 2002
Cooking Lake Blackfoot Grazing Reserve, Alberta, Canada	Aspen Parkland	18 (6)	Glasier, this paper
EMEND, Peace River, Alberta, Canada	Boreal Forest	15 (5)	Bergeron and Glasier, unpublished

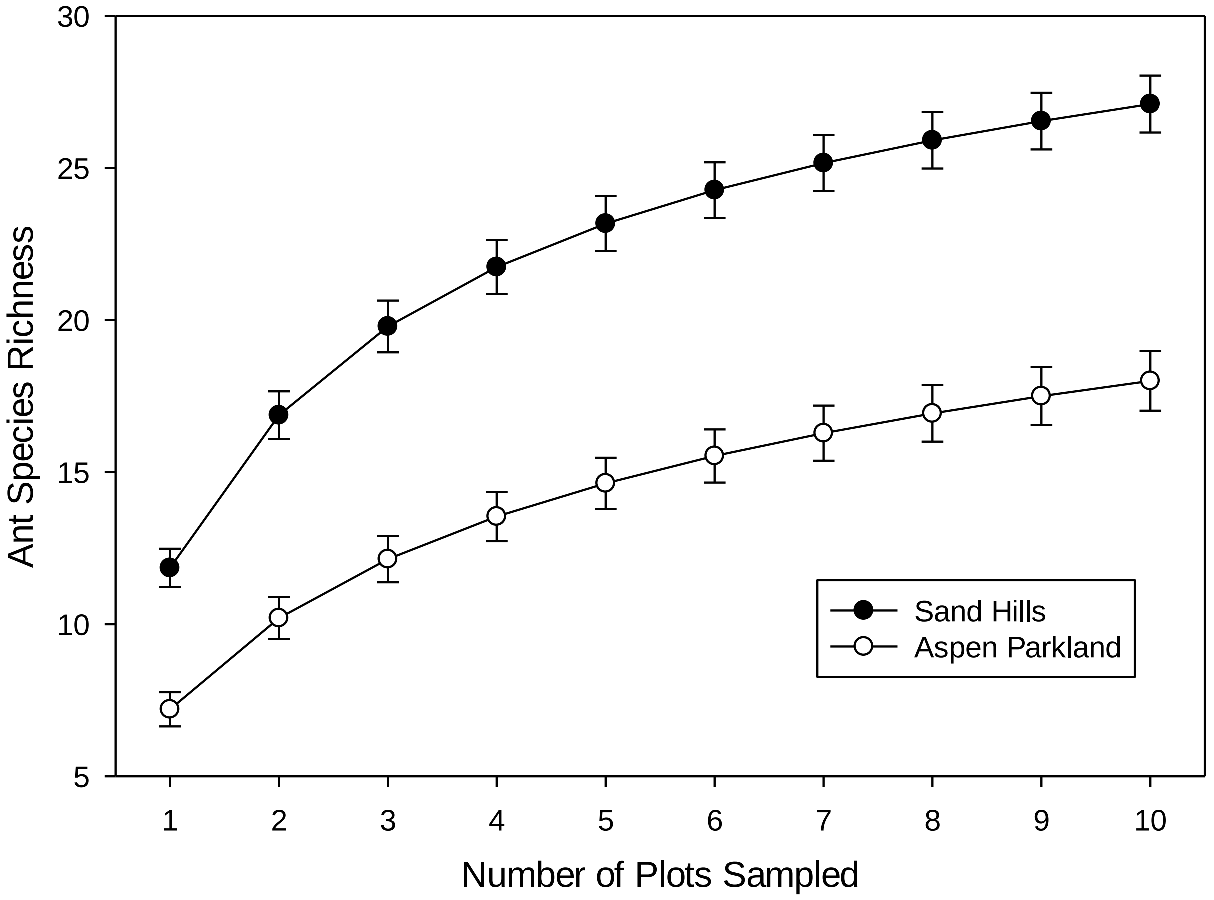

Figure 3.1: Rarefaction curves illustrating ant species richness between sand hill and aspen parkland ecosystems using 1000 randomizations of plot-based rarefaction. Error bars represent standard errors of 1000 randomizations.

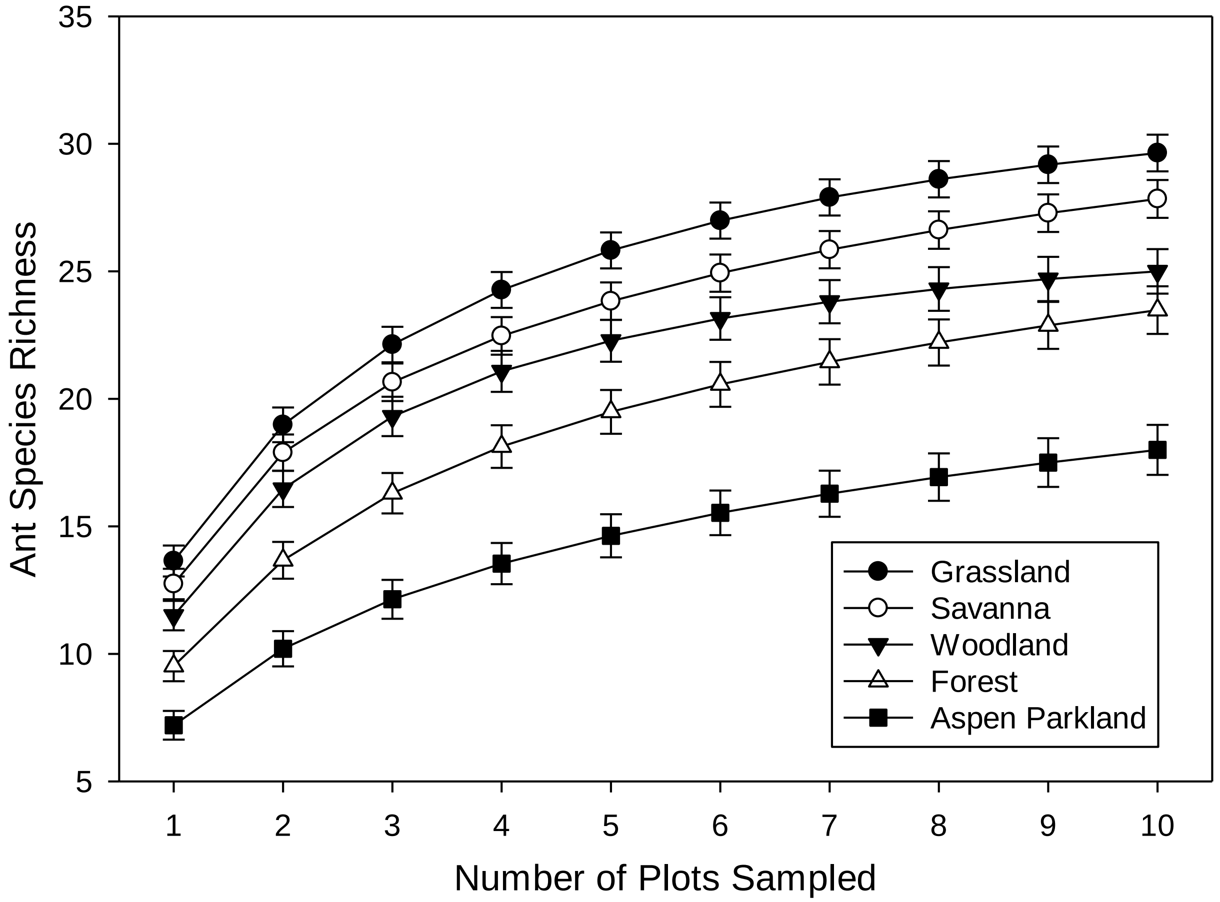

Figure 3.2: Species rarefaction curves for vegetation physiognomies within the sand hill and the topographically similar aspen parkland ecosystems using 1000 randomizations of species data. Error bars represent standard errors of 1000 randomizations.

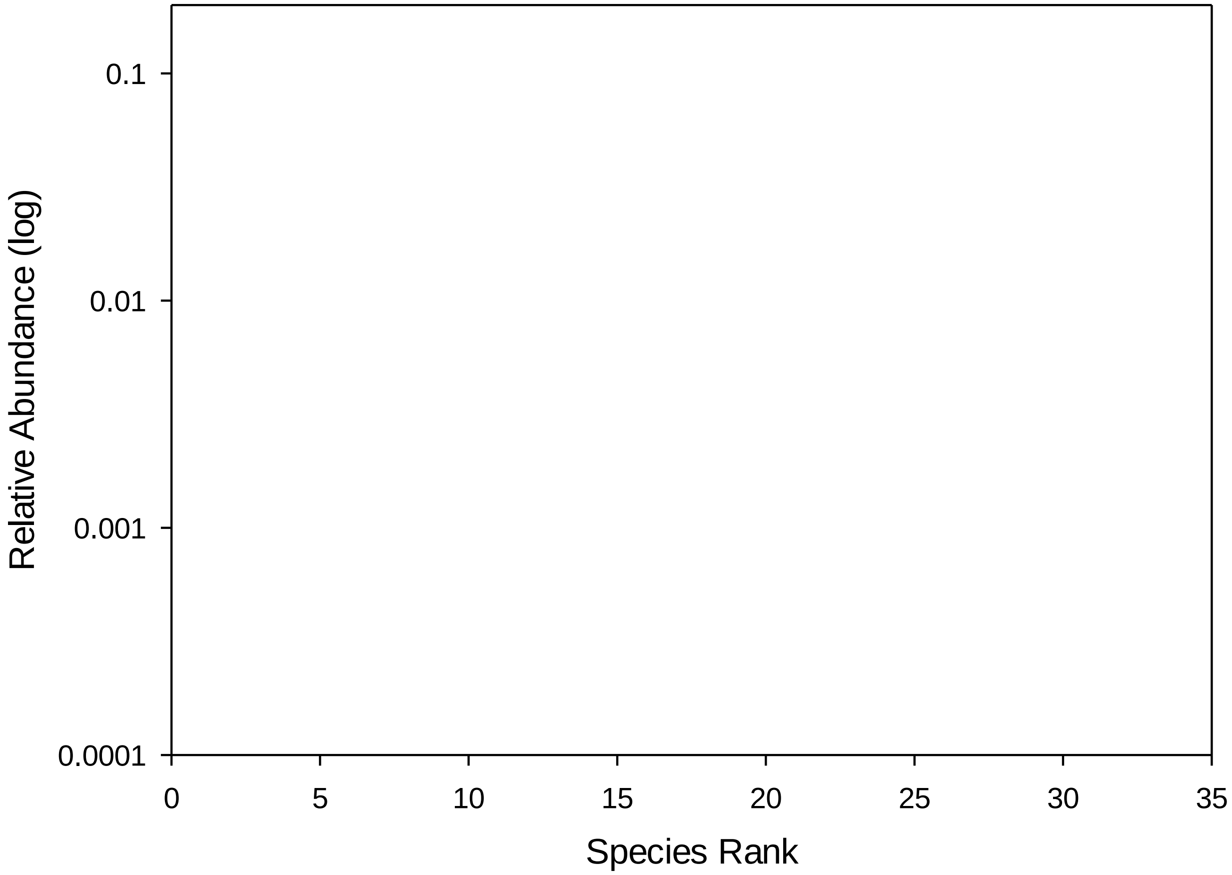

Figure 3.3: Species rank-abundance (log scale) curve for sand hill ant species in central Alberta, Canada. The broken stick shape indicates high ant species evenness and no single dominant species.

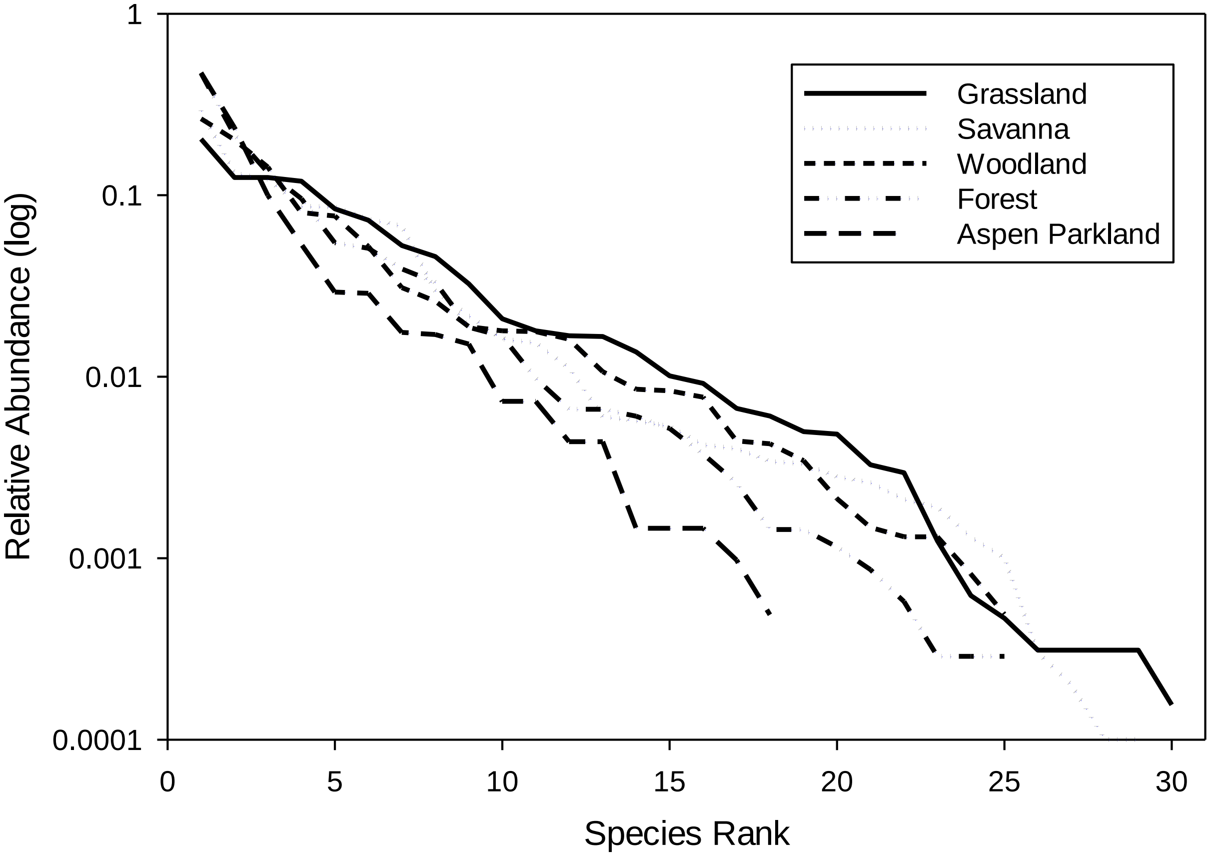

Figure 3.4: Species rank-abundance (log scale) curves comparing ant species abundance by vegetation physiognomies within sand hills and forested aspen parkland. Aspen parkland had the highest slope, indicating the lowest evenness among ant fauna. The sand hill vegetation physiognomies do not differ greatly.

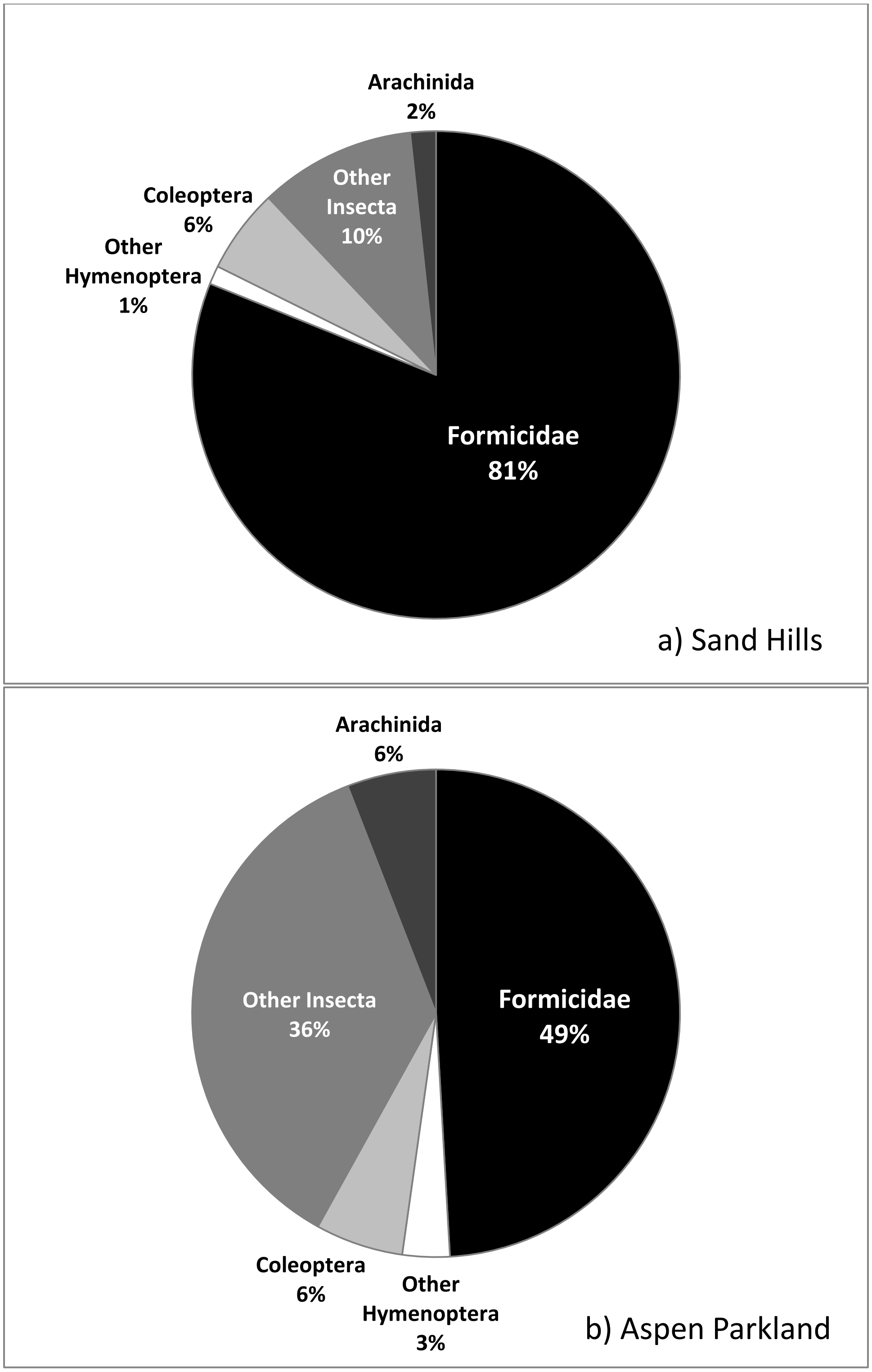

Figure 3.5: Arthropod composition in pitfall traps in sand hills (a) and aspen parkland (b) ecosystems in central Alberta, Canada.

Chapter 4: Ant (Hymenoptera: Formicidae) body size influences post-fire changes in abundance

Introduction

Fire is an important ecological disturbance in the parkland and boreal forests of Canada (McCullough et al 1998; Boulanger and Sirois 2007; Cobb et al. 2007). Wildfires vary in intensity and local frequency, and thus they increase local landscape heterogeneity and associated biodiversity of flora and fauna (Cobb et al. 2007). Conversely, fire causes direct mortality of organisms (Andersen et al. 2007; Parr and Andersen 2008; Matsuda et al. 2011) and can simplify habitat structure and affect resource availability through combustion of plant biomass (Bond and van Wilgen 1996). Organisms with traits that increase survivorship during and after a fire would be expected to benefit most in a post-fire environment and therefore increase in abundance (Lafleur et al. 2006; Andersen et al. 2007; Parr and Andersen 2008).

Unlike the majority of ground invertebrates (McCullough et al. 1998), ants have traits that increase survivorship during and after a fire (Parr and Andersen 2008; Houdeshell et al. 2011). Many ground nesting ant species, for example, are able to survive the initial disturbance of fire because they nest deep underground or within tree bases where fire may not affect them. After many fires, ant species richness (Houdeshell et al. 2011) and ant abundance changes little (Andersen et al. 2007; Parr and Andersen 2008) or is actually increased due to changes in habitat structure resulting in an increased capture rate of foragers (Andersen and Yen 1985). The main influence of fires on ants appears to be in changes associated with assemblage composition, with particular species increasing or decreasing in abundance (Lafleur et al. 2006; Farji-Brener et al.

2002; Andersen et al. 2007; Parr and Andersen 2008). Factors that are often invoked to explain changes in ant assemblages and composition are interspecific competition (Andersen and Yen 1985; Lafleur et al. 2006), changes in leaf litter (Christiansen and Lavigne 2010), and changes in vegetation and canopy structure (Andersen et al. 2007; Parr and Andersen 2008). What is often overlooked is how life history and biological traits affect post-fire responses in different ant species.

Ant faunas of the boreal forest and parkland of North America are generally less diverse than in more southern regions (Gregg 1972; Lafleur et al. 2006), and therefore few ecological studies have focused on them (Lafleur et al. 2006). Few biological traits, such as average colony size, colony life span, diet (trophic level), and below ground nest structure, are known for North American ant species from the boreal and aspen parkland. Most studies have focused on nesting characteristics, such as reliance on coarse woody debris, ground nesting, and/or mound building (Lindgren and. MacIsaac 2002; Lafleur et al. 2006). Moreover, the effects of fire on boreal and parkland ant species has only been examined in detail in one published study from northern Quebec, Canada (Lafleur et al. 2006), which showed that ant species composition was related to the regeneration age of woodlands (Lafleur et al. 2006).

The objective of this study is to determine the effects of fire on ant assemblages on sand hills in the parkland-boreal transition zone of Alberta, Canada. Specifically, I examined three different questions: 1) what is the impact of fire on ant abundance and species richness? 2) Which ant species were most affected by fire? and 3) What life history and biological traits, if any, were related to post-fire changes in abundance of ants? Following other research (Lafleur et al 2006; Farji-Brener et al. 2002; Andersen et al. 2007; Parr and Andersen 2008), I predicted 1) that ant abundance and species richness would remain similar when compared among different fires, and 2), that fire would select for traits that allowed for better survivorship during a fire and/or were advantageous for surviving in a post-fire environment. From field observations, I predicted that ants that nested in combustible materials (wood or thatched nests) would have higher rates of mortality compared to ants that did not because the areas where they store their brood (Hölldobler and Wilson, 1990) and spend much of their time during the summer would burn while those that nest totally within the soil would be sheltered. Furthermore, as resources may be limited in post-fire due to reductions in vegetation structure (Bond and van Wilgen 1996; McCullough et al 1998), I predicted that smaller sized ants with smaller colony sizes would be most able to cope with limitations in food resources, and thus potentially benefit from decreases in larger and more dominant species of ants (Lafleur et al. 2006). Finally, I expected ants with polygynous colonies to do better as they would have higher queen survivorship following disturbance (and therefore colony survivorship), thus enabling them to more readily replace lost workers (Hölldobler and Wilson, 1990).

Study Areas

Research was conducted during 2009 and 2010 at four sites in the Redwater sand hills of central Alberta, Canada (Table 4.1). Vegetation cover is predominantly jack pine woodlands intermixed with patches of aspen (*Populus tremuloides*) and small patches of black spruce (*Picea mariana*) in the lower swales (Table 4.1). The Redwater Natural Area has no recent evidence of fire and is thus considered a control for comparisons with the other three sites (Table 4.1).

Research Plots

Research plots were 0.1 ha (20m by 50m) in size with 10 pitfall traps placed in pairs five meters from the center line at 10 meter distances (i.e., 5, 15, 25, 35, and 45 m). Ten plots were established and orientated qualitatively to site all traps under the most homogeneous canopy cover possible.

Each plot was classified as a ‘One Year Post-fire’ (OYPF), ‘Year of Fire’ (YF), or ‘Control’ (CON). For OYPF, fire occurred in May 2009 with sampling conducted just after the fire (that summer) and one year post-fire, in 2010. For YF, fire occurred May 2010, with sampling conducted in 2009 pre-fire and 2010 post-fire. For Control (CON) plots, it was determined fire had not recently occurred in the area based on Alberta Parks and Recreation information. Control plots were sampled in summers of 2009 and 2010.

Specimen Sampling and Identification

Ants were sampled twice each summer, during 2009 and 2010, using pitfall traps. Each pitfall trap was a polypropylene container, 64mm in diameter, 76mm deep, filled with 30mL of propylene glycol, a solution non-toxic to vertebrates (Weeks and McIntyre 1997; Bestelmeyer et al. 2000). Traps were placed flush with the ground, and were retrieved after 24hrs of being set. Specimens were transferred to 75% ethanol for storage. Exact sampling dates depended on weather, but the first sampling sessions were done in late May to June while the second sampling sessions occurred in late July to August during both sample years. No rain occurred during any of the sampling sessions.

Ants were identified using a number of published keys including Fisher and Cover (2007), Creighton (1950), Wheeler and Wheeler (1963), Wheeler and Wheeler (1986), MacKay and MacKay (2002), Hansen and Klotz (2005), Francoeur (1973), by comparisons to specimens in the E. H. Strickland Entomological Museum, and using my own key (Chapter 2). Life history traits were assigned (Table 4.2) using personal knowledge and information provided in the previously mentioned keys. Voucher specimens where deposited in E. H. Strickland Entomological Museum.

Statistical Analysis

Response ratios (RR), mean, and standard error were calculated for total ant abundance, ant species richness, and forager abundance of individual ant species. Response ratios are the ratio of mean treatment effects (i.e., change from fire) to mean effect in control plots that were not disturbed (Hedges et al. 1999).

More specifically, the following equation was used to quantify response ratios:

$$\mathrm{RR} = \ln(\frac{\bar{X}_e}{\bar{X}_c})$$

Where: RR = response ratio; $\bar{X}_e$ = mean abundance in a treatment from 2010, divided by the mean abundance from 2009; $\bar{X}_c$ = mean abundance in the control plots from 2010, divided by the mean abundance from 2009.

Response ratios are helpful in describing treatment effects across time (pre vs. post-treatment) relative to natural variation (Hedges et al. 1999). For analyses of individual abundance of species, a constant of “1” was added to each sample to alleviate problems related to division by zero (i.e., when a species was not present for one of the sample years, but present for the other year). A change was considered significant if the mean RR was at least one standard error value away from zero.

I used linear regression modeling (Hosmer and Lemeshow 2000) with response ratio results for both the OYAF and YF treatments, in Stata 9 (2005), to determine which life history and biological traits (Table 4.2) most affected changes in ant species abundance. Models were generated for both the YF and OYAF treatments (Tables 4.3 and 4.4) and combined into a final composite model by assessing predicted combinations and ranking them using Akaikes’s Information Criterion (AIC) (Tables 4.3 and 4.4). Model uncertainty was incorporated into the analysis using weighted averages for coefficients, standard errors, and confidence intervals (Burnham and Anderson 2011) by estimating response coefficients from all candidate models.

Results

A total of 33,714 ants from 33 species were collected over the summers of 2009 and 2010 from a total of 40 plots: 15 CON; 15 OYAF; 10 YF. Total abundance and species richness of did not significantly change in YF or OYAF (Figure 4.2).

Of the 33 species sampled, activity of 21 species was assessed with response ratios (Table 4.5) with 19 species assessed in YF (Figure 4.5) and 20 species for OYAF plots (Figure 4.4). For YF, three species increased in abundance, ten species showed no significant change in abundance, while six species decreased in abundance (Figure 4.5). For OYAF, the abundance of three species significantly increased, eight species showed no change, and nine species significantly decreased (Figure 4.5).

Only one of the species, *Formica podzolica*, increased under both YF and OYAF, while five species decreased for both treatments (Table 4.3). Species that decreased were *Camponotus herculeanus*, *Formica lasiodes*, *Formica obscuriventris*, *Leptothorax muscorum*, and *Myrmica fracticornis* (Table 4.3). Only four ant species showed no significant change in abundance with fire: *Formica neorufibarbis*, *Lasius neoniger*, *Myrmica ab01*, and *Myrmica detritinodus*.

For the YF data no models tested were more supported than a null (constant) model (Table 4.4), but for the OYAF data, all but the nest type models were supported more than the null model (Table 4.5). The most supported model for OYAF was body size (w_i = 0.324), with models using(body size + small colony size (w_i = 0.169)) and (body size + large colony size (w_i = 0.119)) being most influential. The remaining models all had Akaike weights of < 0.1 (Table 4.5). Average coefficients were estimated for all variables across all models (Table 4.6). Body size was inversely related to changes in abundance following fire (Table 4.6). Colony size also explained changes in abundance following fire. Ants typified by having small colonies were positively affected by fire, while ants characterized by having large colonies were negatively affected by fire (Table 4.6).

Discussion

Fire effects on total ant abundance and species richness

Previous studies in other ecosystems suggest that ant forager abundance and species richness does not change significantly post-fire (Andersen et al. 2007; Parr and Andersen 2008;

Matsuda et al. 2011). This is consistent with responses observed in sand hills of central Alberta; there were no significant changes following fire for either total ant abundance or species richness.

Lack of significant responses for total ant abundance may be related to several factors. First, ants are known to distribute worker roles depending on the need of the colony (Hölldobler and Wilson 1990; Tschinkel 1999). Directly following a fire, when mortality is high but food is scarce, ants search more for food, resulting in more foragers being sampled and thus maintaining a consistent measurement of aboveground abundance. Additionally, species of ants that forage in trees are forced to forage on the ground after fires (Parr and Andersen 2008), therefore increasing their representation in pitfall trap samples. Alternatively, ant mortality may have been simply low resulting in similar abundances pre and post-fire. Thus, species richness would have been maintained since most ants are able to survive fire underground or increase forager abundance (Parr and Andersen 2008; Houdeshell et al. 2011). The lack of significant change in total ant abundance and diversity, and the mechanism for coping with mortalities related to fire implies that ant faunas of the central Alberta sand hills are generally resilient to periodic fires. Nonetheless, particular species may show some impact..

Species-specific responses to fire and relationships to life history traits

No life history traits included in my models explained the effect of fire on ant species abundance in the Year of Fire (YF), even when there were obvious changes in particular species abundances (Figure 4.3). This finding contradicts my predictions on how traits of individual species would influence their sensitivity to fire. Most surprising was that nest type had no effect despite reasoning that ant species with nests constructed of combustible materials (thatching and wood) would have a higher mortality rate and therefore, lower measured abundance. A possible explanation for this disparity is that ants are able to detect fire and escape it by going deeper than surface thatching (Sharplin 1966) before fire reaches the colony, and therefore are able to survive fire. Similarly, ants nesting in wood often have additional galleries underground (Hansen and Klotz 2005) where they would be able escape fire. Furthermore, it has been noted that ants are more often found in moist dead wood as it is easier to excavate (Lindgren and MacIssac 2002). Moist wood would also burn less intensively than drier wood, perhaps allowing for better survivorship.

In contrast, changes in particular species abundances one year after fire (OYAF) were related to life history traits in ants. In particular, larger bodied ants declined in abundance relative to smaller-bodied species (Table 4.6), suggesting that smaller ants have an advantage after fire. As larger ants, which appear to be generally more dominant (Deslippe and Savolainen 1995), are reduced in number, smaller ants may be able to forage with less competition.

Additionally, smaller ants require less energy (Lafleur et al. 2006). As fire simplifies the environment (Bond and van Wilgen 1996) and reduces food availability, larger ants could be more sensitive to reduction in food resources. Similarly, colony size was an important factor affecting changes in ant abundance. A smaller colony size was positively related to increases in ant abundance, while species with large colonies were more likely to decrease in ant abundance (Table 4.6). This again could be related to resource dependence, and more research on diets of particular ant species, the effects of fires on those diets is needed to help determine what is driving the advantage for smaller ants and smaller colonies.

Notable changes in particular ant species post-fire

Only one species of ant, *Formica podzolica,* increased over both treatments. This species is ubiquitous over most of Canada (Francoeur 1973; Lafleur et al. 2006) beingfound across the majority of terrestrial ecosystems, and can be considered a generalist species preying on insects and farming aphids for honey-dew (Deslippe and Savolainen 1994). This generalist lifestyle of *F. podzolica* would be advantageous for sites following recent disturbance. Alternatively, *F. podzolica* forager numbers may have increased due to reduced population sizes of competitors. Other studies have found that the more dominant *Formica rufa* group (such as *Formica aserva, Formica obscuriventris,* and *Formica oreas*) is often in direct competition with *Formica podzolica* (Deslippe and Savolainen 1995). In fact, the *Formica rufa* group did indeed show a decrease following fire (Table 4.3).

Other species that decreased in activity under both treatments include three forest species that nest almost exclusively in dead wood: *Camponotus herculeanus*, *Leptothorax muscorum*, and *Myrmica fracticornis* (Lindgren and MacIssac 2002). Although nest type was not the most supported model to explain variations in ant species abundance, nesting in dead wood is the only trait used in this study that is shared by these three species. It maybe that the nests of these three species have few underground nesting chambers, and thus they did not escape and the impact of fire and were reduced in abundance. Additionally, size of each ant was variable, with *L. muscorum* being the smallest ant sampled, *M. fracticornis* being a small ant, and *C. herculeanus* being largest ant species sampled (Table 4.2). This variation in size indicates that *L. muscorum* and *M. fracticornis* do not follow the general trend in the one year after fire treatment, where smaller ants were found to increase in abundance. More research into other biological life history traits, such as diet, and a potential look into more detailed nest structure is needed before explanation of these three decreasing in both fire treatments can be done.

Decreases in forager abundance of *Formica lasioides* and *Formica obscuriventris* is more difficult to explain. These species do not share a common feeding style, nest type, or life cycle (Creighton 1950; Wheeler and Wheeler 1963). More research into these two species' specific biology and ecology is needed.

Four ant species were found to be fire resilient (no change in abundance post fire for both treatments) (Table 4.3). *Myrmica ab01*, *Myrmica detritinodus,* and *Lasius neoniger* are common in the central Alberta sand hills while *Formica neorufibarbis* is less common, but widespread in North America, especially on sandy soils (MacKay and MacKay 2002).

Other factors not measured in this study but may affect ant abundance and diversity includes distribution of food sources, such as insect availability (Cobb et al. 2007), including aphids for honeydew farming (MacKay and MacKay 2002), and the trophic level of each ant species. Additionally, average colony size, instead of categorical measurements, for the sampled species may be beneficial in determining if colony size is more influential in determining ant abundance in post-fire environments.

Conclusions

Fire does not have a direct effect on total ant abundance or ant species richness both directly after fire (YF) or during the first post-fire year (OYAF), however, abundance of 15 of the 21 ant species assessed, did change significantly following fire suggesting compositional changes among species, but similar total composition (Table 4.3). Body size was predicted change in ant abundance, with larger ants showing an overall decrease in abundance compared with smaller ant species. As fire is often critical in sand hill jack pine forests (Cayford, and McRae 1983), it is important to determine how it affects insect populations, especially ants, which are an important part of northern ecosystems. More research on particular species, both with respect to fire and overall biology is needed. Long-term monitoring of the ant community is needed in order to better understand successional dynamics in both the forest and ant community. Timing of burns should also be examined, since fires in different seasons may have different effects on ants. As species richness did not change with most species remaining within the sampled plot at least one-year post-fire, it can be concluded that the ant fauna of the sand hills of central Alberta is fire resilient and adapted for life in areas with frequent fire.

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Tables:

Table 4.1: Descriptions of study areas sampled for ants in central Alberta, Canada. Fire occurred in three of the four study areas over the course of 2009-2010.

Study Area	Latitude/ Longitude	Area Type	Size (Hectares)	Date of Recent Fires
North Bruderheim Natural Area	53°52'8.54"N 112°56'40.10"W	Sand Hills	178	May 2009
Northwest Bruderheim Natural Area	53°52'8.54"N 112°56'40.10"W	Sand Hills	259	May 2009
Opal Natural Area	53°59'13.59"N 113°18'34.96"W	Sand Hills	372	May 2010
Redwater Natural Area	53°56'27.66"N 112°57'17.19"W	Sand Hills	1810	No recent (>50 years) fires

Table 4.2: Traits of ant species examined for fire effects on the sand hills of central Alberta. Nest Type: indicates which type of nest the ant species builds (mound: nest is built primarily out of mineral soil; thatched: a nest with deep layer of pine needles and/ or grass cuttings as the primary part of the mound; wood: nest is built within wood be it alive or dead). Colony size indicates the relative size of an average colony by ant species (small < 1000, medium 1000-5000, large > 5000). Body size is the length of an ant, excluding the mandibles. Polygynous indicates if colonies have multiple queens (yes) or not (no).

Ant Species	Nest Type	Colony Size	Body Size (mm)	Polygynous
Dolichoderus taschenbergi	thatched	large	4	yes
Tapinoma sessile	wood	medium	3	yes
Camponotus herculeanus	wood	large	11	no
Camponotus novaeboracensis	wood	large	11	no
Formica accreta	wood	medium	5	no
Formica adamsi	thatched	medium	7	no
Formica aserva	thatched	large	8	no
Formica dakotensis	thatched	large	6	no
Formica hewitti	wood	medium	6	no
Formica lasioides	mound	medium	5	no
Formica neorufibarbis	wood	medium	6	yes
Formica obscuriventris	thatched	large	7	yes
Formica oreas	thatched	large	8	no
Formica podzolica	mound	large	6	yes
Lasius neoniger	mound	medium	3	yes
Leptothorax muscorum	wood	small	2	yes
Myrmica ab01	mound	small	5	yes
Myrmica alaskensis	wood	small	5	yes
Myrmica detritinodus	mound	small	5	yes
Myrmica fracticornis	wood	small	5	yes
Myrmica nearctica	mound	small	3	yes

Table 4.3: Candidate regression models describing changes in ant abundance following fire in the year of fire (YF). Models are ranked from most supported to least supported based in Akaike weights (***w_i***).from null model for change in ant abundance for the treatment year after fire (YF). *df:* number of parameters;. AIC: Akaikes's Information Criterion; AIC$_c$: small-sample sized corrected AIC; w_i: AIC$_c$ weights, and model fit (Model R^2 and Adj. R^2).

Model No.	**Model**	***df***	**AIC**	**AIC$_c$**	w_i	**Model R^2**	**Adj. R^2**
1	Null	1	31.114	31.364	0.350	0	0
2	Size	2	32.919	33.669	0.142	0.010	-0.048
3	Polygynous	2	33.111	33.861	0.129	0	-0.059
4	Wood nest + thatched nest	3	33.753	35.253	0.094	0.069	-0.047
5	Body size + polygynous	3	34.766	36.266	0.056	0.018	-0.105
6	Body size + large colony size	3	34.822	36.322	0.055	0.015	-0.108
7	Body size + small colony size	3	34.872	36.372	0.054	0.013	-0.111
8	Body size + moderate colony size	3	34.917	36.417	0.052	0.010	-0.113
9	Moderate colony size + small colony Size	3	35.107	36.607	0.048	0	-0.125
10	Body size + moderate colony size + small colony Size	4	36.816	39.316	0.020	0.016	-0.181

Table 4.4: Candidate regression models describing changes in ant abundance following one year of fire (OYAF). Models are ranked from most supported to least supported based in Akaike weights (***w_i***).from null model for change in ant abundance for the treatment year after fire (OYAF). *df:* number of parameters;. AIC: Akaikes's Information Criterion; AIC$_c$: small-sample sized corrected AIC; w_i: AIC$_c$ weights, and model fit (Model R^2 and Adj. R^2).

Model No.	**Model**	***df***	**AIC**	**AIC$_c$**	**w_i**	**Model R^2**	**Adj. R^2**
1	Body size	2	48.721	49.427	0.324	0.301	0.262
2	Body size + small colony size	3	49.225	50.018	0.169	0.351	0.275
3	Body size + large colony size	3	49.927	51.4267	0.119	0.328	0.249
4	Body size + polygynous	3	50.313	51.813	0.098	0.315	0.234
5	Body size + moderate colony size	3	50.518	52.018	0.089	0.308	0.226
6	Polygynous	2	51.581	52.287	0.078	0.193	0.148
7	Small colony size + moderate colony size	3	51.889	53.389	0.045	0.259	0.171
8	Body size + moderate colony size + small colony size	4	51.094	53761	0.037	0.356	0.235
9	Null	1	53.875	54.097	0.031	0	0
10	Wood Nest + Thatched	3	54.889	56.389	0.010	0.137	0.035

Table 4.5: Ant species affected by fire in the sand hills of central Alberta, Canada. One year after fire (OYAF) represent sites where fire occurred in May 2009 and sampled directly after the fire (2009) and the following summer (2010). Year of fire (YF) represent sites where fire occurred in May 2010 and were sampled the summer before (2009) and then after the fire (2010). Type of change for each species is noted.

Ant Species	**Abbreviation**	**Year of fire**	**1-year post fire**
Dolichoderus taschenbergi	D.tasc	Non-significant	Increased
Tapinoma sessile	T.sess	Non-significant	Increased
Camponotus herculeanus	C.herc	Decreased	Decreased
Camponotus nearctica	C.near	N/A	N/A
Camponotus novaeboracensis	C.nova	Non-significant	Decreased
Formica accreta	F.accr	Decreased	Non-significant
Formica adamsi	F.adam	N/A	Non-significant
Formica aserva	F.aser	Non-significant	Decreased
Formica dakotensis	F.dako	Increased	Non-significant
Formica densiventris	F.dens	N/A	N/A
Formica hewitti	F.hewi	Non-significant	N/A
Formica impexa	F.impe	N/A	N/A
Formica lasioides	F.lasi	Decreased	Decreased
Formica neorufibarbis	F.neor	Non-significant	Non-significant
Formica obscuriventris	F.obsc	Decreased	Decreased
Formica oreas	F.orea	N/A	Decreased
Formica podzolica	F.podz	Increased	Increased
Formica subintegra	F.subi	N/A	N/A
Formica ulkei	F.ulke	N/A	N/A
Lasius alienus	L.alie	N/A	N/A
Lasius neoniger	L.neog	Non-significant	Non-significant
Lasius niger	L.nige	N/A	N/A
Lasius pallitarsis	L.pall	N/A	N/A
Lasius subumbratus	L.subu	N/A	N/A
Polyergus breviceps	P.brev	N/A	N/A
Formicoxenus hirticornis	F.hirt	N/A	N/A
Harpagoxenus canadensis	H.cana	N/A	N/A
Leptothorax muscorum	L.musc	Decreased	Decreased
Myrmica ab01	M.ab01	Non-significant	Non-significant
Myrmica alaskensis	M.alas	Increased	Non-significant
Myrmica detritinodus	M.detr	Non-significant	Non-significant
Myrmica fracticornis	M.frac	Decreased	Decreased
Myrmica nearctica	M.near	Non-significant	Decreased

Table 4.6: Weighted model variable coefficients (Coef) and standard errors (Std.Err.) for change in ant abundance for one year after fire treatment (OYAF) on sand hills of central Alberta, Canada.

Model Variable	**Weighted Coef.**	**Weighted Std.Err.**
Null	0.633	0.532
Body size	-0.160	0.053
Small colony size	0.144	0.068
Moderate colony size	0.018	0.040
Large colony size	-0.046	0.021
Polygynous	0.089	0.037
Thatched	-0.008	<0.001
Wood	-0.004	<0.001
Mound	-	-

Figure 4.1: Photographs illustrating differential responses of ant nest structure according to nest type; A) thatched nest of *Formica obscuriventris* is burned into the ground following fire; B) nest mound of *Formica podzolica* is not physically burned and even has new grass growth occuring. Both photos were taken 08/05/2009, two days after the fire occured. C) wood nest of *Camponotus herculeanus* in the base of a burnt tree (taken 12/05/2009).

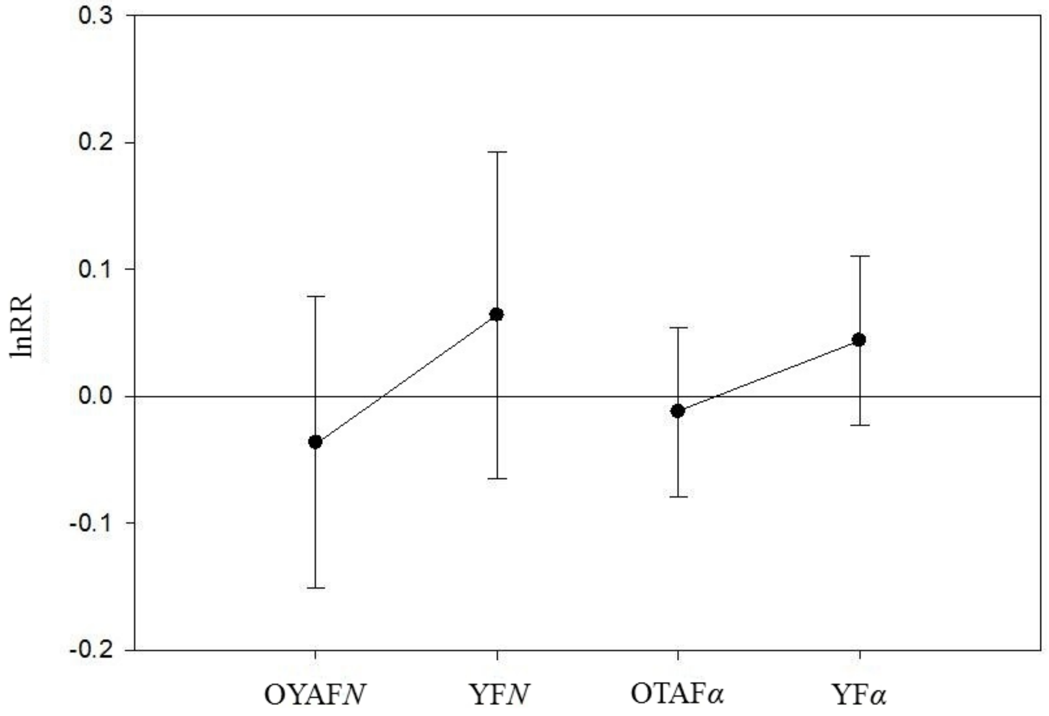

Figure 4.2: Response ratios for total ant abundance (*N*) and species richness (α). One year after fire (OYAF) plots were sampled the summer after the fire in May 2009, and the following summer of 2010. Year of fire (YF) plots were sampled pre-fire, summer of 2009, and then post-fire in May 2010, during the summer. Error bars represent standard errors.

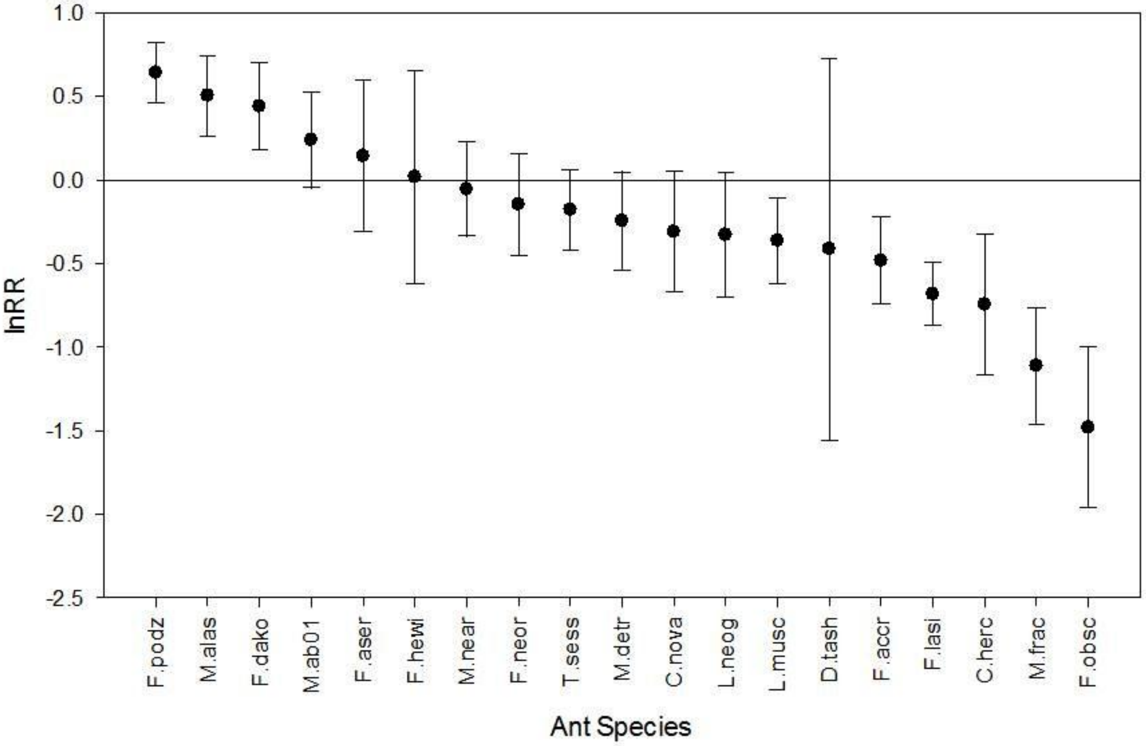

Figure 4.3: Response ratios by ant species sampled for year of fire (YF). YF plots were sampled the summer of 2009, pre-fire, and then after the fire in May 2010, during the summer. Error bars represent standard error. Abbreviations for species can be found in Table 4.3

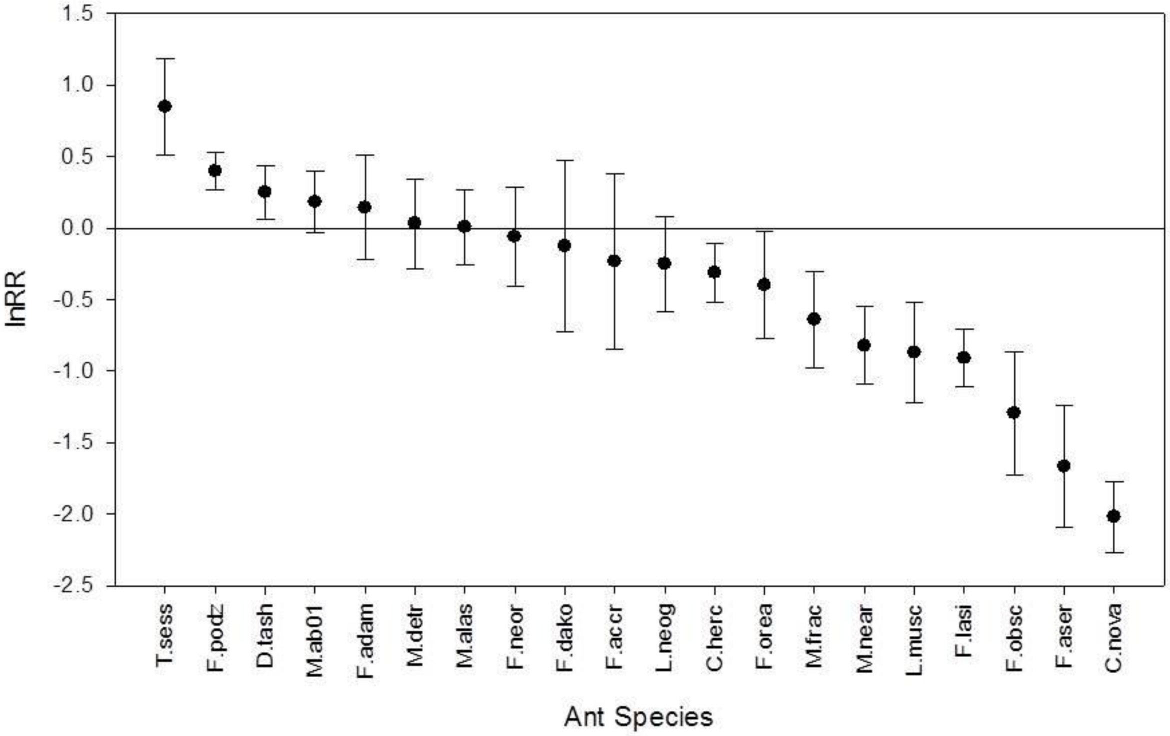

Figure 4.4: Response ratios for ant species sampled for one year after fire (OYAF). OYAF plots were sampled the summer after the fire in May 2009, and the following summer of 2010. Error bars represent standard error. Abbreviations for species can be found in Table 4.3.

Chapter 5: Overview

Main Results

My study provides important baseline data about the diversity of ants in Alberta, particularly in the central Alberta sand hills, which contained a third of the province's known ant species. My research also compares patterns of ant diversity between sand hill and aspen parkland ecosystems, and considers the effect of vegetation physiognomy on ant diversity, and the effects of wildfires on ant abundance and diversity. Below I describe the important contributions of my work specific to each of the three research chapters.

In Chapter Two, I prepared the first in-depth review of ant species known in Alberta. Through this work, I increased the number of ant species known in Alberta from 40 (Sharplin 1966) to 92 species. This result emphasizes the general lack of information and knowledge of ants in the province. In addition, I created the first illustrated key of ants from Alberta, to aid in their identification and, I hope, support and promote badly-needed ecological work.

In Chapter Three, I compared the distribution and abundance of ant species among vegetation types in the sand hills of central Alberta, and compared the sand hill fauna with what is found on the surrounding aspen parkland matrix. Ant communities were more diverse in sand hills than in the surrounding aspen parkland. Furthermore, ants made up 81% of arthropods caught in pitfalls from sand hills, compared to 49% of arthropods captured in aspen parkland. Both these results suggest that ants are important biodiversity elements in sand hill ecosystems, in agreement with other research showing that areas with sandy soils have higher ant biodiversity compared to clay-based soils (Boultan et al. 2005). Within sand hills, ant species richness was compared among vegetation physiognomies defined by canopy cover. As predicted, ant species richness followed a general trend of reduced diversity with increased canopy cover, also in agreement with prior research (Lassau and Hochuli 2004; Palladini et al. 2007). However, there was a less pronounced difference between physiognomies than expected, most likely because of the heterogeneous nature of plots being sampled.

Intriguingly, the central sand hills of Alberta had the highest ant species richness in reported in the northern Nearctic (Lindgren and MacIsaac 2002; Heron 2005; Lessard and Buddle 2005). Although this may be due, in part, to different sampling effort or techniques, it implies that central Alberta sand hills are important areas for ant biodiversity. In contrast, the aspen parkland ecosystem of Alberta had the lowest diversity of any northern Nearctic ant community. This implies that sand hills are indeed "ecological islands" of high ant diversity surrounded by a matrix of less diverse aspen parkland. The high diversity and high capture rates of ants in sand hill ecosystems suggest they represent a major ecological factor that warrants more scientific attention and perhaps conservation focus.

Chapter Four focused on the effects of spring wildfires on ant communities found in central Alberta sand hill ecosystems. Using response ratios, I examined how species richness, total ant abundance, and forager abundance of particular ant species were affected by fire. Similar to the results of other studies (Andersen et al 2007; Christiansen and Lavigne, 2010), overall species richness and total ant abundance did not change significantly following fire.

Particular ant species, however, showed significant responses to fire. For example, *Formica podzolica*, showed an increase in forager abundance after both fires. Several species (*Formica neorufibarbis*, *Lasius neoniger*, *Myrmica ab01*, and *Myrmica detritinodus*) showed no significant change after fire, indicating that they may have adaptations that allow them to be resilient to fire. Five ant species (*Camponotus herculeanus*, *Formica lasiodes*, *Formica* *obscuriventris*, *Leptothorax muscorum*, and *Myrmica fracticornis*) showed declines in forager abundance after both fire treatments. Comment more on the significance of these observations … interpret them in relation to natural history.

Using regression I assessed whether biological character traits of ants were correlated with changes in ant abundance the year of fire and one year following fire. Surprisingly, no model assessed supported patterns in changes in abundance the year of a fire. Body size, however, was a useful predictor of changes in abundance of ants one year after a fire, with larger-bodied species becoming proportionately less common after fire. Colony size had a similar influence, with ant species having larger colonies more likely to show reduced post-fire abundance. These findings imply that fire creates an environment that favours smaller ants and smaller colonies. As fire simplifies the environment (Bond and van Wilgen 1996) resources available for larger ants to exploit may be reduced, favouring smaller ants in the process (Lafleur 2006).

Implication for the Conservation of Sand Hills

Sand hills are distinct areas surrounded by more extensive aspen parkland, are unproductive for agriculture, and are often protected as natural areas (Acorn 2011). The four areas sampled in Alberta (Opal, Redwater, North Bruderheim and North-west Bruderheim) are all provincial natural areas. However, all four are impacted by human disturbance, particularly from camping, all-terrain vehicle use, and/or local petroleum exploration. All-terrain vehicles and other recreational activities are often associated with local pollution, such as garbage, spilled gas, and used bullet casings (personal observation). Furthermore, human activities can result in even more drastic disturbances such as wildfires (both fires in my study were human caused). Given the high human impact of these areas, promoting effective conservation measures is challenging.

Though it data are insufficient to state that ant biodiversity directly correlates with biodiversity of other taxa in the central Alberta sand hills, high ant diversityseems to be associated with high diversity of other taxa, such as tiger beetles (Coleoptera: Carabidae: Cicindelini), moths (Lepidoptera), sand wasps (Hymenoptera: Crabronidae: Bembicini) (Acorn 2011) and vascular plants (Nielsen, unpublished). Taken together, this information suggests that sand hills are important with respect to biodiversity. More specifically for ants, sand hills have significantly higher diversity compared to the surrounding aspen parkland, including one-third the ant fauna recorded for Alberta. Additionally, rare ant species from Alberta, such as *Harpagoxenus canadensis* and *Dolichoderus taschenbergi* have only been found in sand hill areas.

In contrast, aspen parkland, which surrounds the central Alberta sand hills have comparatively low ant species diversity, implying that sand hills are acting as “ecological islands”. The high biodiversity of ants and other organisms suggests that these “ecological islands” warrant more research and further conservation and/or enforcement in relation to human activities such as all-terrain vehicle use and energy exploration. I recommend that these areas be better managed, with more protection towards preserving the landscape, be it from sand extraction, off-road vehicles, or prescribed burns. Additionally more research on how those disturbances affect the biodiversity of these areas should be considered.

Future Research and Limitations of Dissertation

My research provides an updated and integrated look at the ant fauna of Alberta and a more focused treatment of ant biodiversity on central Alberta sand hills. This 'business' is unfinished, however, and there is always potential for increased research when dealing with the natural world. The following is a set of recommendations for further research on ants in Alberta as well as on sand hills:

1) Although Chapter Two provides an in-depth look at ant species present in Alberta, the species list and its key are not complete. For example, southern Alberta was not sampled intensively during my research, leaving a wide area where one would expect additional species to exist. Lists from Idaho (Cole 1934) and Montana (Wheeler and Wheeler 1988) have several species that may have ranges that extend north into Alberta. Furthermore, neither of these states have had extensive ant surveys, leaving the presence of additional species open. British Columbia (Naumann et al. 1999) to the west has several ant species not known from Alberta, again leaving the potential for additional species to occur in Alberta. To the east of Alberta, only a little myrmecological work has been done in Saskatchewan (Kidd and Longair 1997) and more work is needed before we can be fully confident of the lists for these two provinces. Additional work on taxonomic problems within the genera *Myrmica*, *Leptothorax*, and potentially *Temnothorax*, is also needed to make recognition of species easier.

2) The aspen parkland site sampled had relatively low ant biodiversity compared to not only local sand hills, but also other northern Nearctic sites. The aspen parkland site sampled

was, however, grazed by cattle, potentially biasing samples since cattle have negative effects on ant species richness (Read and Andersen 2000). More extensive sampling of parkland habitats, including more plots and in areas without cattle grazing, may increase species richness for the aspen parkland ecosystem and our understanding of ant distribution in the province.

3) In my dissertation, I determined that fire affects particular ant species, but does not much affect overall species richness or ant abundance. These findings are in agreement with previous studies that also found that although the species richness and ant abundance remained relatively unchanged, ant community structure did change (Andersen et al 2007; Christiansen and Lavigne, 2010). To determine the effects of fire on ant species, more biological knowledge of particular ant species is needed. With increased knowledge of factors such as, food sources or nest depth, one could better understand why disturbances, like the wildfires in 2009 and 2010, affected ant species differently. Moreover, this information could enhance our understanding of northern temperate ants and contribute to assessing the roles played by ants Alberta ecosystems.

4) Biodiversity conservation has been well publicized as one of the important topics of our time (Magurran 2004). Ants are also described as important organisms, being among the organisms driving ecological processes on our planet (Hölldobler and Wilson 1990). However, in northern North America little research has been done on ant biodiversity and its relationship to other taxa. In the sand hills of central Alberta, ants are likely significant ecological players, but it is unknown how they specifically affect or directly correlate with the diversity of other arthropods, vertebrates or plants.

Large numbers of organisms rely on ants for habitat (ant nests), food, and dispersal (Hölldobler and Wilson 1990), but most of the work to illustrate these interactions has been done in tropical ecosystems. Research on ants and potential correlation with other taxa is desperately needed in order to determine if ants can be used as indicator taxa in northern temperate ecosystems.

In this dissertation I demonstrated that ants in Alberta are more diverse than expected, and that northern Canadian ant species richness and relative abundance are affected by fire similarly to other ant communities worldwide; however one year post-fire environments favour smaller ant species. My work therefore contributes to our understanding of local ant faunas in Alberta, as well as contributing to our understanding of global patterns of ant ecology, diversity and biogeography.

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