Diversity, Habitat Use and Potential Biocontrol Services of Rove Beetles (Coleoptera: Staphylinidae) in Soybean Agroecosystems and Adjacent Hedgerows

by

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A Thesis presented to
The University of Guelph

In partial fulfilment of requirements
for the degree of
Master of Science
in
Environmental Biology

Guelph, Ontario, Canada
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ABSTRACT

DIVERSITY, HABITAT USE AND POTENTIAL BIOCONTROL SERVICES OF ROVE BEETLES (COLEOPTERA: STAPHYLINIDAE) IN SOYBEAN AGROECOSYSTEMS AND ADJACENT HEDGEROWS

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Rove beetles (Staphylinidae) in Ontario soybean-hedgerow agroecosystems were surveyed in 2009-2010 to identify common, widespread species and assess their potential biological control of Soybean Aphid and Bean Leaf Beetle. The spatiotemporal distributions, habitat use, and co-occurrence of staphylinids with soybean pests were studied to provide a framework for future agroecological studies of biocontrol services in soybean. A taxonomic review of the Staphylinina (Staphylinidae: Staphylininae) ('large rove beetles') for the geographic area of study was conducted and identification keys were created to assist in future staphylinid research. Common soybean staphylinids were generally exotic, penetrated field interiors, utilized hedgerow habitat outside the growing season and co-occurred with pest populations during vulnerable life stages. Several species exhibited nocturnal activity in soybean foliage. Biocontrol of overwintering Soybean Aphid and Bean Leaf Beetle populations in hedgerows by staphylinids may occur in buckthorn canopies and leaf litter, respectively.
Acknowledgements

I would first like to thank my advisors Drs. Rebecca Hallett and Stephen Marshall for their academic guidance and unwavering support over the course of my thesis research. I also wish to thank the people of the Insect Systematics and Hallett labs for creating such an enjoyable place to work each day. Thanks to Christie Bahlai for many fruitful discussions involving SBA biology, factors driving population dynamics and natural predator ecology, and for extensive assistance with statistical methodology. I sincerely thank Dave Cheung for his support and patience over the past three years and for many hours of technical assistance and essential training used to construct the online version of the keys found in Chapter II.

Dave Cheung and Morgan Jackson assisted me with mapping software and creation of the custom maps in Chapter II. Thanks to Justin Renkema and Don McAlpine for bringing the presence of Platydracus cinnamopterus in Nova Scotia and New Brunswick to my attention, respectively. Reggie Webster and Ales Smetana recognized the misidentification present in Klimaszewski et al. (2005) and allowed me to represent this in Chapter II. Margaret Thayer read an earlier version of Chapter II and provided many helpful comments.

Cody Anderson, Lauren DesMarteaux, Adam Jewis-Gaines and Dave Makynen provided impeccable support as field and lab assistants and were instrumental in the retrieval of accurate data over the season. I am so grateful to have had such dedicated friends working with me. Thanks to participating soybean growers and to Tracey Baute (OMAFRA) who provided the initial list of contacts for field sites. I’d like to thank the
Nature Conservancy of Canada and rare Charitable Research Reserve for access to their properties. Thanks to Alfred Newton, Margaret Thayer, Jan Klimaszewski, Alexey Solodovnikov and Christopher Majka for their generosity, hospitality and mentorship. Your enthusiasm and friendship has inspired me to become a lifelong student of Staphylinidae.

Funding for this thesis was provided by the Grain Farmers of Ontario, an NSERC PGS-M and rare research scholarship awarded to A. Brunke and an OMAFRA-University of Guelph Sustainable Production Systems research grant to R. Hallett.
Table of Contents

Acknowledgements ........................................................................................................ iii
Table of contents ........................................................................................................ v
List of tables ................................................................................................................ viii
List of maps ................................................................................................................ ix
List of figures ................................................................................................................. xii

Chapter I: Literature Review and Research Focus

1. Introduction ................................................................................................................ 1
2. Ecology and life history of two major soybean pests and notes on others .......... 2
3. Rove beetle biology and spatiotemporal distributions ........................................ 9
4. Staphylinids as predators of agricultural pests .................................................... 13
5. Staphylinid agroecology .......................................................................................... 19
6. Sampling Staphylinidae in agroecosystems .......................................................... 21
7. Research Objectives ............................................................................................... 25

Chapter II: Taxonomic Review. The Staphylinidae of Eastern Canada and Adjacent United States (ECAS). Key to subfamilies; Staphylininae: Tribes and Subtribes, and Species of Staphylinina

1. Introduction ................................................................................................................ 28
2. Materials and Methods ............................................................................................. 30
3. Results and Discussion
   3.1 Key to the subfamilies in ECAS .......................................................................... 35
   3.2 Key to the tribes and subtribes of Staphylininae in ECAS ................................. 41
   3.3 Key to the genera of Staphylinina in ECAS ..................................................... 42
   3.4 Key to the Dinothenarus species in ECAS ....................................................... 44
   3.5 Key to the Ocypus species in ECAS ............................................................... 44
   3.6 Key to the Ontholestes species in ECAS ......................................................... 44
   3.7 Key to the Platydracus species in ECAS ......................................................... 44
   3.8 Key to the Tasgius species in ECAS ................................................................. 48
   3.9 The subfamilies of Staphylinidae in ECAS ..................................................... 48
   3.10 The tribes and subtribes of Staphylinidae in ECAS ...................................... 67
   3.11 The species of Staphylinina in ECAS ............................................................. 78

Chapter III: Rove beetles (Coleoptera: Staphylinidae) in southern Ontario soybean fields and adjacent hedgerows: assemblage composition, seasonality and habitat use

1. Introduction .............................................................................................................. 152
2. Materials and Methods
   2.1 Study sites .......................................................................................................... 154
2.2 Sampling protocol ........................................................................................................... 154
2.3 Specimen identification and categorization ................................................................. 160
2.4 Statistical analyses ......................................................................................................... 161

3. Results
3.1 Assemblage abundance, richness and origin ................................................................. 162
3.2 Species excluded from study .......................................................................................... 164
3.3 Common species ............................................................................................................ 164
3.4 Seasonality and habitat use of common soybean species ............................................. 166
3.5 Influence of hedgerow habitat type on common soybean species ......................... 183

4. Discussion
4.1 Assemblage richness and composition ......................................................................... 183
4.2 Seasonal activity patterns in soybean fields ................................................................. 186
4.3 Habitat use of common soybean Staphylinidae ............................................................ 188
4.4 Potential biocontrol services and future directions ....................................................... 190
4.5 Conclusion ...................................................................................................................... 191

Chapter IV: Rove beetles (Coleoptera: Staphylinidae) associated with Soybean Aphid
(Aphis glycines Matsumura) and Bean Leaf Beetle (Ceratoma trifurcata (Forster))
populations in soybean-hedgerow landscapes

1. Introduction ....................................................................................................................... 192

2. Materials and Methods
2.1 Spatiotemporal distributions of rove beetles ............................................................... 194
2.2 Population dynamics of soybean pests ........................................................................ 195
2.3 Diel activity patterns in the soybean rove beetle assemblage .................................... 195
2.4 Statistical analyses ........................................................................................................ 196

3. Results
3.1 Seasonal occurrence of Soybean Aphid and Bean Leaf Beetle ............................... 198
3.2 Canopy activity of staphylinids in soybean fields and their adjacent hedgerows .... 200
3.3 Rove beetle and co-occurring early season Soybean Aphid populations .............. 208
3.4 Seasonality of large rove beetles ................................................................................. 208
3.5 Spatial co-occurrence of large rove beetles with adult Bean Leaf Beetles ............ 208
3.6 Common rove beetle and Bean Leaf Beetle populations in soybean ................... 213
3.7 Diel activity patterns in the soybean rove beetle assemblage ................................ 213

4. Discussion
4.1 Seasonality of soybean pests ...................................................................................... 215
4.2 Canopy activity in Staphylinidae ............................................................................... 218
4.3 Rove beetles associated with Bean Leaf Beetle populations in the soybean-
hedgerow landscape ........................................................................................................ 220
4.4 Conclusion ........................................................................................................... 222

Chapter V: Conclusions 
  5.1 Summary of results .......................................................................................... 224 
  5.2 Future research directions .............................................................................. 224 
  5.3 Synergism between faunistic surveys, identification tools and ecology .... 227

References ............................................................................................................... 229

Appendix 1. List of Staphylinidae collected in hedgerows ................................ 262
Appendix 2 List of Staphylinidae collected in soybean fields .............................. 278
Appendix 3 List of Staphylinidae collected from soybean foliage by suction sampling..... 285
List of Tables

Table 1. Summary of southern Ontario field site locations and sampling periods.

Table 2. Soil attributes of southern Ontario field sites. Organic matter content determined using the Walkley-Black method (Walkley and Black 1934) and soil textures derived from Ontario Soil Maps (AAFC 2008).

Table 3. Species richness and percent exotic species of twelve soybean fields and their adjacent hedgerows, in southern Ontario.

Table 4. Percent activity density (AD) of common species collected in pitfall and pan traps (pooled) in soybean fields and adjacent hedgerows in 2009-2010. Common species were those that comprised ≥1% of total individuals captured. Exotic species denoted by ‘+’.

Table 5. Presence of Staphylinidae in hedgerow canopy traps in 2009-2010 and mean percent (± SE) (untransformed) of total individuals captured in canopy traps (canopy activity). Means within a season followed by the same letter do not differ significantly, Tukey’s HSD, α = 0.05.

Table 6. Presence of Staphylinidae in canopy traps over the 2009 soybean growing season and mean percent of total individuals (± SE) captured in canopy traps (canopy activity). The period of early soybean aphid population growth (July 13-July 27) is delimited by the black rectangle; presence of a species is indicated by grey squares.
List of Maps

Map 1. Distribution of *Diochus schaumi* Kraatz in eastern Canada and adjacent United States. Records include data from Smetana (1982).

Map 2. Distribution of *Tympanophorus puncticollis* (Erichson) in eastern Canada and adjacent United States.

Map 3. Distribution of *Atanygnathus bicolor* (Casey) in eastern Canada and adjacent United States. Records include data from Smetana (1990).

Map 4. Distribution of *Creophilus maxillosus* (L.) in eastern Canada and adjacent United States.

Map 5. Distribution of *Dinothenarus badipes* (LeConte) in eastern Canada and adjacent United States.

Map 6. Distribution of *Dinothenarus capitatus* (Bland) in eastern Canada and adjacent United States.

Map 7. Distribution of *Ocypus brunnipes* (Fab.) in eastern Canada and adjacent United States.

Map 8. Distribution of *Ocypus nitens* (Schrank) in eastern Canada and adjacent United States.

Map 9. Distribution of *Ontholestes cingulatus* (Gravenhorst) in eastern Canada and adjacent United States.

Map 10. Distribution of *Ontholestes murinus* (L.) in eastern Canada and adjacent United States.

Map 11. Distribution of *Platydracus cinnamopterus* (Gravenhorst).

Map 12. Distribution of *Platydracus cinnamopterus* (Gravenhorst) in eastern Canada and adjacent United States.

Map 13. Distribution of *Platydracus comes* (LeConte) in eastern Canada and adjacent United States.

Map 14. Distribution of *Platydracus exulans* (Erichson) in eastern Canada and adjacent United States.
Map 15. Distribution of *Platydracus femoratus* (Fab.) in eastern Canada and adjacent United States.

Map 16. Distribution of *Platydracus fossator* (Gravenhorst) in eastern Canada and adjacent United States.

Map 17. Distribution of *Platydracus immaculatus* (Mannerheim) in eastern Canada and adjacent United States.

Map 18. Distribution of *Platydracus maculosus* (Gravenhorst) in eastern Canada and adjacent United States.

Map 19. Distribution of *Platydracus mysticus* (Erichson) in eastern Canada and adjacent United States.

Map 20. Distribution of *Platydracus praelongus* (Mannerheim) in eastern Canada and adjacent United States.

Map 21. Distribution of *Platydracus praetermissus* sp. nov.

Map 22. Distribution of *Platydracus praetermissus* sp. nov. in eastern Canada and adjacent United States.

Map 23. Distribution of *Platydracus tomentosus* (Gravenhorst) in eastern Canada and adjacent United States.

Map 24. Distribution of *Platydracus violaceus* (Gravenhorst) in eastern Canada and adjacent United States.

Map 25. Distribution of *Platydracus viridanus* (Horn) in eastern Canada and adjacent United States.

Map 26. Distribution of *Platydracus zonatus* (Gravenhorst).

Map 27. Distribution of *Platydracus zonatus* (Gravenhorst) in eastern Canada and adjacent United States.

Map 28. Distribution of *Staphylinus ornaticauda* (LeConte) in eastern Canada and adjacent United States.

Map 29. Distribution of *Tasgius ater* (Gravenhorst) in eastern Canada and adjacent United States.

Map 30. Distribution of *Tasgius melanarius* (Heer) in eastern Canada and adjacent United States.
Map 31. Distribution of *Tasgius winkleri* (Bernhauer) in eastern Canada and adjacent United States.
List of Figures

Figures 1-11 (plates in Chapter 2) are not included in this version of the thesis; a version of chapter 2 with all figures can be acquired via: http://www.biology.ualberta.ca/bsc/efjournal/bnkmm_12/otherpgs/downloads.html

Figure 12. Location of east and west field site groups in southern Ontario.

Figure 13. Basic construction of canopy trap and placement in buckthorn (*Rhamnus cathartica* L.) canopies within a hedgerow. Canopy traps in soybean were constructed identically.

Figure 14. Individuals of *Anotylus rugosus* (Fabricius) captured per trap on different sampling weeks by pitfall and canopy traps in southern Ontario soybean fields and their adjacent hedgerows at: A) 2009 east sites (SG, SC1, SC2); B) 2009 west sites (LA, LG, LB); C) 2010 east sites (E, RA1, RA2); and D) 2010 west sites (GD1, GD2, GD3).

Figure 15. Individuals of *Oxypoda brachyptera* (Stephens) captured per trap on different sampling weeks by pitfall and canopy traps in southern Ontario soybean fields and their adjacent hedgerows at: A) 2009 east sites (SG, SC1, SC2); B) 2009 west sites (LA, LG, LB); C) 2010 east sites (E, RA1, RA2); and D) 2010 west sites (GD1, GD2, GD3).

Figure 16. Individuals of *Strigota ambigua* (Erichson) captured per trap on different sampling weeks by pitfall and canopy traps in southern Ontario soybean fields and their adjacent hedgerows at: A) 2009 east sites (SG, SC1, SC2); B) 2009 west sites (LA, LG, LB); C) 2010 east sites (E, RA1, RA2); and D) 2010 west sites (GD1, GD2, GD3).

Figure 17. Individuals of *Stethusa spuriella* (Casey) captured per trap on different sampling weeks by pitfall and canopy traps in southern Ontario soybean fields and their adjacent hedgerows at: A) 2009 east sites (SG, SC1, SC2); B) 2009 west sites (LA, LG, LB); C) 2010 east sites (E, RA1, RA2); and D) 2010 west sites (GD1, GD2, GD3).

Figure 18. Individuals of *Tachinus corticinus* Gravenhorst captured per trap on different sampling weeks by pitfall and canopy traps in southern Ontario soybean fields and their adjacent hedgerows at: A) 2009 east sites (SG, SC1, SC2); B) 2009 west sites (LA, LG, LB); C) 2010 east sites (E, RA1, RA2); and D) 2010 west sites (GD1, GD2, GD3).

Figure 19. Individuals of *Anotylus tetracarinatus* (Block) captured per trap on different sampling weeks by pitfall and canopy traps in southern Ontario soybean fields and their adjacent hedgerows at: A) 2009 east sites (SG, SC1, SC2); B) 2009 west sites (LA, LG, LB); C) 2010 east sites (E, RA1, RA2); and D) 2010 west sites (GD1, GD2, GD3).

Figure 20. Individuals of *Scopaeus minutus* Erichson captured per trap on different sampling weeks by pitfall and canopy traps in southern Ontario soybean fields and their
adjacent hedgerows at: A) 2009 east sites (SG, SC1, SC2); B) 2009 west sites (LA, LG, LB); C) 2010 east sites (E, RA1, RA2); and D) 2010 west sites (GD1, GD2, GD3).

Figure 21. Individuals of *Aleochara verna* Say captured per trap on different sampling weeks by pitfall and canopy traps in southern Ontario soybean fields and their adjacent hedgerows at: A) 2009 east sites (SG, SC1, SC2); B) 2009 west sites (LA, LG, LB); C) 2010 east sites (E, RA1, RA2); and D) 2010 west sites (GD1, GD2, GD3).

Figure 22. Individuals of *Anotylus insecatus* (Gravenhorst) captured per trap on different sampling weeks by pitfall and canopy traps in southern Ontario soybean fields and their adjacent hedgerows at: A) 2009 east sites (SG, SC1, SC2); B) 2009 west sites (LA, LG, LB); C) 2010 east sites (E, RA1, RA2); and D) 2010 west sites (GD1, GD2, GD3).

Figure 23. Individuals of *Apocellus sphaericollis* (Say) captured per trap on different sampling weeks by pitfall and canopy traps in southern Ontario soybean fields and their adjacent hedgerows at: A) 2009 west sites (LA, LG, LB); B) 2010 east sites (E, RA1, RA2); and D) 2010 west sites (GD1, GD2, GD3). No individuals were captured at the east sites in either year.

Figure 24. Individuals of *Dinaraea angustula* (Gyllenhal) captured per trap on different sampling weeks by pitfall and canopy traps in southern Ontario soybean fields and their adjacent hedgerows at: A) 2009 east sites (SG, SC1, SC2); B) 2009 west sites (LA, LG, LB); C) 2010 east sites (E, RA1, RA2); and D) 2010 west sites (GD1, GD2, GD3).

Figure 25. Individuals of *Strigota* sp. 1 captured per trap on different sampling weeks by pitfall and canopy traps in southern Ontario soybean fields and their adjacent hedgerows at: A) 2009 east sites (SG, SC1, SC2); B) 2009 west sites (LA, LG, LB); C) 2010 east sites (E, RA1, RA2); and D) 2010 west sites (GD1, GD2, GD3).

Figure 26. Individuals of *Amischa* spp. captured per trap on different sampling weeks by pitfall and canopy traps in southern Ontario soybean fields and their adjacent hedgerows at: A) 2009 east sites (SG, SC1, SC2); B) 2009 west sites (LA, LG, LB); C) 2010 east sites (E, RA1, RA2); and D) 2010 west sites (GD1, GD2, GD3).

Figure 27. Individuals of *Drusilla canaliculata* (Fabricius) captured per trap on different sampling weeks by pitfall and canopy traps in southern Ontario soybean fields and their adjacent hedgerows at: A) 2009 east sites (SG, SC1, SC2); B) 2009 west sites (LA, LG, LB); C) 2010 east sites (E, RA1, RA2); and D) 2010 west sites (GD1, GD2, GD3).

Figure 28. Individuals of *Hoplandria lateralis* (Melsheimer) captured per trap on different sampling weeks by pitfall and canopy traps in southern Ontario soybean fields and their adjacent hedgerows at: A) 2009 east sites (SG, SC1, SC2); B) 2009 west sites (LA, LG, LB); and C) 2010 west sites (GD1, GD2, GD3). No individuals were observed at the 2010 east sites.

Figure 29. Mean number of Soybean Aphid (*Aphis glycines* Matsumura) per plant (±SE, n = 5) selected randomly in A) east, and B) west groups of southern Ontario soybean
fields over the growing season in 2009. Sampling occurred weekly and continued until fifty percent or more plants in the study area senesced. Aphids were first detected on July 14 in all fields.

Figure 30. Activity density of Bean Leaf Beetle (*Ceratoma trifurcata* (Forster)) per trap on different sampling weeks, calculated from captures in pitfall and canopy traps placed in soybean fields or adjacent hedgerows in southern Ontario in A) 2009, and B) 2010.

Figure 31. Individuals of *Mocyta fungi* (Gravenhorst) captured per trap on different sampling weeks by pitfall and canopy traps in southern Ontario soybean fields and their adjacent hedgerows at: A) 2009 east sites (SG, SC1, SC2); B) 2009 west sites (LA, LG, LB); C) 2010 east sites (E, RA1, RA2); and D) 2010 west sites (GD1, GD2, GD3). This species did not occur in fall hedgerows and was uncommon in soybean fields.

Figure 32. Individuals of *Tachyporus dispar* (Paykull) captured per trap on different sampling weeks by pitfall and canopy traps in southern Ontario soybean fields and their adjacent hedgerows at: A) 2009 east sites (SG, SC1, SC2); B) 2009 west sites (LA, LG, LB); C) 2010 east sites (E, RA1, RA2); and D) 2010 west sites (GD1, GD2, GD3).

Figure 33. Individuals of *Tachyporus nitidulus* (Fabricius) captured per trap on different sampling weeks by pitfall and canopy traps in southern Ontario soybean fields and their adjacent hedgerows at: A) 2009 east sites (SG, SC1, SC2); B) 2009 west sites (LA, LG, LB); C) 2010 east sites (E, RA1, RA2); and D) 2010 west sites (GD1, GD2, GD3).

Figure 34. Individuals of *Tasgius ater* (Gravenhorst) captured per trap on different sampling weeks by pitfall and canopy traps in southern Ontario soybean fields and their adjacent hedgerows at: A) 2009 east sites (SG, SC1, SC2); B) 2009 west sites (LA, LG, LB); and C) 2010 east sites (GD1, GD2, GD3). This species was not present at the 2010 east sites.

Figure 35. Individuals of *Dinothenarus badipes* (LeConte) captured per trap on different sampling weeks by pitfall and canopy traps in southern Ontario soybean fields and their adjacent hedgerows at: A) 2009 east sites (SG, SC1, SC2); B) 2009 west sites (LA, LG, LB); C) 2010 east sites (E, RA1, RA2); and D) 2010 west sites (GD1, GD2, GD3).

Figure 36. Individuals of *Tasgius melanarius* (Heer) captured per trap on different sampling weeks by pitfall and canopy traps in southern Ontario soybean fields and their adjacent hedgerows at: A) 2009 east sites (SG, SC1, SC2); B) 2009 west sites (LA, LG, LB); and C) 2010 east sites (E, RA1, RA2).

Figure 37. Individuals of *Tasgius winkleri* (Bernhauer) captured per trap on different sampling weeks by pitfall and canopy traps in southern Ontario soybean fields and their adjacent hedgerows at: A) 2009 east sites (SG, SC1, SC2); B) 2009 west sites (LA, LG, LB); C) 2010 east sites (E, RA1, RA2); and D) 2010 west sites (GD1, GD2, GD3).
Figure 38. Mean number (± SE, n=20) of individuals of: A) *Anotylus tetracarinatus* (Block), B) *Tachyporus dispar* (Paykull), C) other Staphylinidae, captured by suction sampling every 4 hours in 2009 soybean over two 48 hour periods. Captures in flowering soybean and pod-forming soybean were pooled. Mean canopy activity differed between time intervals for *Anotylus tetracarinatus* (ANOVA, d.f = 5, F = 9.63, p < 0.001), *Tachyporus dispar* (ANOVA, d.f = 5, F = 2.54, p = 0.03) and ‘other’ (ANOVA, d.f = 5, F = 6.43, p = 0.03). Different letters denote statistically different (p < 0.05) means in post hoc comparisons (Tukey’s HSD).

Figure 39. Mean number (± SE, n=40) of individuals of Staphylinidae captured by suction sampling in 2009 soybean over 48 hours in flowering and pod-forming stages. Within a species, different letters denote statistically different (p < 0.05) means by ANOVA.
Chapter I
Literature Review and Research Focus

1. Introduction

The natural enemy assemblage in North American soybean has long been recognized for its important role in the suppression of pest populations (Turnipseed and Kogan 1976), including those of Soybean Aphid (*Aphis glycines* Matsumura) (Fox et al. 2004). This species is a relatively recent introduction to the continent and was first detected in Wisconsin in 2000 (Ragsdale et al. 2004). Prior to the establishment of Soybean Aphid, most published work on predators of soybean pests dealt with the southern United States, where a great diversity of pests occurs (Kogan and Turnipseed 1987).

The appearance of Soybean Aphid in North America stimulated several studies of natural enemies in soybean fields of this region (e.g., Rutledge et al. 2004, Costamagna and Landis 2007), most of which emphasized the importance of ladybird beetles (Coccinellidae) and the Minute Pirate Bug, *Orius insidiosus* (Say) (Anthocoridae). The role of these predators in suppressing Soybean Aphid populations was further demonstrated by Rutledge et al. (2004) and Mignault et al. (2006).

Predators other than Coccinellidae and Anthocoridae have received relatively little mention in the literature on natural enemies of soybean pests. Carabidae have been recognized as abundant and diverse in soybean (Chen and Willson 1996, Hajek et al. 2007), but the family Staphylinidae has been reported as absent or rare (e.g., Rutledge et al. 2004; Fox et al. 2005; Costmagna and Landis 2007). As staphylinids form a dominant
component in most agroecosystems (Bohac 1999, Byers et al. 2000, Markgraf and Basedow 2002), it is very unlikely that soybean fields are uniquely poor in Staphylinidae. They were probably overlooked in the above-mentioned studies because of their inconspicuous habits and generally small size. Difficulties in identification might have also deterred some previous researchers from considering the Staphylinidae. Because studies of the impact of rove beetles on other pest arthropods, including mites (Frank et al. 1992), to horn flies (Hu and Frank 1995) and cereal aphids (Sopp and Wratten 1986) have shown them to be important control agents, their importance in the predator assemblage of soybean agroecosystems needs re-evaluation.

2. Ecology and life history of two major soybean pests and notes on others

Two insect species are considered to be the most important pests of soybean in Ontario and neighbouring areas: Soybean Aphid and Bean Leaf Beetle (*Cerotoma trifurcata* Forster). Other soybean pests in this region not discussed further in this section include Seedcorn Maggot (*Delia platura* Meigan), Japanese Beetle (*Popillia japonica* Newman), European Chafer (*Rhizotrogus majalis* Razoumowski), June beetles (*Phyllophaga* spp.), wireworms (Elateridae), Two-spotted Spider Mite (*Tetranychus urticae* Koch), green (*Nezara viridula* L.) and brown (*Euschistus* spp.) stinkbugs, Tarnished Plant Bug (*Lygus lineolaris* Palisot de Beauvois) and slugs (*Deroceras reticulatum* Müller) (OMAFRA 2011).

2.1 Soybean Aphid

Aphids are small, globular insects found in colonies on the surfaces of leaves, stems, flowers and pods. Fully mature individuals can be winged (alate) or wingless (apterous) (Miyazaki 1987). Soybean Aphids can be distinguished from other aphid
species by a combination of a yellow-green body and black cornicles, with soybean 
(Glycine max L.) as a secondary host and buckthorn (Rhamnus spp.) as a primary host 
(Voegtlin et al. 2004).

*Aphis glycines* (Aphididae) is a host-alternating aphid with sexual reproduction 
occuring once in an otherwise asexual, parthenogenetic life cycle (Blackman and Eastop 
2000). Sexual reproduction occurs on the primary host, *Rhamnus*, and asexual 
reproduction occurs on both *Rhamnus* and the second host, cultivated soybean (Blackman 
and Eastop 2000). In Ontario, there is a biannual population cycle during which aphid 
densities are high in odd years whereas populations fail to reach economic levels or are 
even completely absent during even years (Bahlai and Sears 2009). Soybean Aphids, like 
most other Aphididae, live together in clonal colonies on their host plants, from which 
they imbibe phloem using a proboscis (Klingauf 1987). Dense colonies (sometimes 
reaching 6800 individuals/plant) feeding on soybean cause changes in plant growth and 
reproduction, resulting in significant yield loss (Difonzo and Hines 2002).

Soybean Aphids overwinter as diapausing eggs on buckthorn shrubs (Blackman 
and Eastop 2000). Yellow-green eggs are laid mostly at the bud-twist interface and turn 
shining black over time (Welsman et al. 2007). In North America, two *Rhamnus* species 
are confirmed as suitable hosts: *R. alnifolia* L'Heritier and *R. cathartica* L. (Yoo et al. 
2005). However, the native *R. alnifolia* is uncommon and the European *R. cathartica* is 
likely the only primary host of ecological significance as it is very common in 
agricultural hedgerows within the North American range of Soybean Aphid (Yoo et al. 
2005). In Ontario, eggs hatch in mid-April (Bahlai et al. 2007), into nymphs which 
undergo four moults to reach adulthood, with wing buds appearing in the third instar if
that aphid will become an alate (Zhang et al. 2009). In Ontario, aphids were observed on buckthorn as late as May 30 (Welsman et al. 2007) and reached detectable levels in soybean fields by mid-June or mid-July (Welsman et al. 2007, Bahlai et al. 2010). As early as mid-September in eastern North America (Ragsdale et al. 2004) specialized, winged females called gynoparae and winged males are produced (Miyazaki 1987) and migrate to buckthorn. Gynoparae create a sexual generation of females called oviparae, which mate with the recently arrived male alatae (Miyazaki 1987). On average, slightly more than one oviparum is produced per gynoparum (Yoo et al. 2005). Colonies of the above aphid life-stages persist for several weeks, with oviparae depositing an average of three eggs (Yoo et al. 2005) and North American populations have been observed from late October until buckthorn leaf drop in mid-November (Ragsdale et al. 2004).

In addition to migration flights between host plants, aphids are also predictably distributed within individual fields and on single plants, over time. On buckthorn these distributional patterns over time are poorly known, but Welsman et al. (2007) noted that forests with greater soybean field edge had more aphid-colonized buckthorn. Conversely, Ragsdale et al. (2004) found that there was no colonization pattern from year to year and that in some years it was very difficult to locate any colonized buckthorn at all. More eggs were found on buckthorn at increasing heights (Welsman et al. 2007) but this may be an artefact of greater mortality lower on the host plant.

Spatial patterns are better known in soybean fields and a summary of those in North America is given below, with gaps in our knowledge filled by observations made from Chinese populations. In early summer, when winged aphids are colonizing fields, distributions within fields are patchy, but there is no relationship between colonization
site and distance to a buckthorn stand (Ragsdale et al. 2004; Welsman et al. 2007). This patchy distribution is thought to be due to winged aphids making quick depositions of offspring on multiple hosts (Ragsdale et al. 2004). However, at the landscape level, soybean fields with a higher ratio of buckthorn density to field area were more likely to be colonized (Bahlai et al. 2010). Quickly, this pattern breaks down as increasingly crowded plants act as population sources for uncolonized plants, creating a more uniform distribution (Wu et al. 2004). Crowded conditions and declining host health in late summer lead to short dispersal flights within the field or to nearby fields, with aphids settling preferentially near windbreaks; this creates a temporary edge effect with respect to density (Ragsdale et al. 2004). In China, populations peak between the end of the vegetative phase and the beginning of the reproductive phase of soybean (Wang 1962), and then distributions gradually begin to resemble the patchiness of earlier in the season (Shi et al., 1994).

In China, newly colonized soybean seedlings have aphids typically on the undersides of their upper leaves (Wu et al., 2004) and support a low density of aphids (Lin et al. 1992). Cereal aphids are known to spend some of the early season at the subterranean base of newly emerged plants, causing artificially low estimates of density in fields (Wiktelius 1987). There is no mention in the literature of a similar early season distribution for Soybean Aphid but such a discovery could improve our poor understanding of early season populations. In North America, vegetative phase Soybean Aphids occur on partially extended trifoliates, petioles and stems (Ragsdale et al. 2004). With the onset of reproductive growth, aphids distribute themselves more evenly and extend their coverage to the undersides of mature leaves, lateral branches and seedpods.
(Ragsdale et al. 2004). In general, aphids prefer to feed on younger (Hu et al. 1992) and less woody tissue (Hu et al. 1993). As the soybean plant grows, aphids feeding on mature growth seem to be malnourished and are thought to be less fecund than those feeding on younger growth (Ragsdale et al. 2004). It is possible that the potential for aphid population increase is stratified within an individual plant, with more growth near the apex. In China, there is a gradual trend for aphids to move from the upper to lower half early in the season, and to return upwards during the later season (Wu et al. 2004).

Relatively little attention has been paid to the factors influencing Soybean Aphid populations on *R. catharica*, especially mortality of eggs, reproductive individuals in fall and the new generation in spring. Soybean Aphids spend approximately eight months of their annual lifecycle on their overwintering host, with their populations being the lowest at this stage (Bahlai et al. 2007). Ragsdale et al. (2004) and Bahlai et al. (2007) have recognized this component of the Soybean Aphid lifecycle as critical to its management. Welsman et al. (2007) found that Soybean Aphid eggs on buckthorn experience an average of seventy percent mortality overwintering there. Overwintering success of eggs was lowest (17%) at the greatest height sampled (2m) but eggs close to the ground were less successful than those midway up the plant (Welsman et al. 2007). The temperatures measured at these heights differed by less than a degree and so it was concluded that temperature *per se* was not responsible for height effects on survival. They suggested that a combination of predation and exposure to wind and rain drove these effects. Before this study, nothing was known about the predator/parasitoid community in buckthorn hedgerows and the authors were unable to adequately address this knowledge gap. Three species of Coccinellidae: *Harmonia axyridis* (Pallas), *Coccinella*
*septempunctata* L. and *Propylea quatuordecimpunctata* L., the first being most common, were found ‘foraging near the study site’ in May. No other predators or parasitoids were observed and a survey of the predator assemblage in hedgerows containing buckthorn would provide an important foundation on which to begin an understanding of Soybean Aphid mortality during this poorly known part of its life cycle.

2.2 Bean Leaf Beetle

Bean Leaf Beetle adults are approximately 5mm in length and oval with a distinctive black marking on the scutellum. There are often 4-6 black spots on the elytra, which are also usually black on the lateral disc and epipleuron. Adults are usually found on the leaves of the soybean plant and readily drop to the ground when approached.

This species is native to North America, occurring from Ontario and Quebec, south to North Carolina and west to South Dakota and New Mexico (Riley et al. 2003). Over its wide range, this species may have from one (much of its Canadian range and Minnesota) to three or more generations (e.g., North Carolina) per year (Loughran 1986). In southern Ontario, available emergence data show an early peak of adult activity followed by a late summer peak, suggesting one generation (C. McCreary unpublished data). Bean Leaf Beetles cause economic damage to young soybean by chewing holes in early leaves and sometimes clip young plants off at the base; defoliation after this stage is generally not considered to affect yield (OMAFRA 2011). However, far more damage can be caused in late, pod-forming soybean, when adults feed on pods and the seeds within them (OMAFRA 2011). Feeding damage directly affects the marketability of beans through appearance and indirectly exposes seeds to pathogens (Obopile and Hammond 2001). Adults are the main vectors of bean pod mottle virus which reduces
seed quality and yield (Krell et al. 2004). The subterranean larval stages (see below) cause negligible damage to the roots (OMAFRA 2011) but may be relatively vulnerable to predation by staphylinids and other natural enemies due to their softer bodies and smaller size. Adults are typically distributed as single individuals and tend not to aggregate in patches or on specific plants (Boiteau et al. 1979).

Bean Leaf Beetle adults overwinter in litter in woodlots (~80%) and in crop residue in soybean fields (~20%), with greater survival in woodlots, possibly attributable to better insulation from low temperatures (Lam and Pedigo 2000). Adults emerge from overwintering sites and fly to nearby alfalfa fields or weedy areas containing native legumes on which they feed (Zeiss and Pedigo 1996). Thus, as with Soybean Aphid, Bean Leaf Beetles occur outside of the soybean growing season in hedgerow areas and an understanding of the natural enemy assemblage in hedgerows is again relevant to pest population dynamics.

Once soybean seedlings emerge (early to mid-June in Ontario), Bean Leaf Beetle adults begin to move into fields (Smelser and Pedigo 1991); individuals of this first generation typically remain in the colonized field for the rest of their lives, causing early season damage (Krell et al. 2003). Females oviposit in the soil around the base of the plant and then die shortly thereafter (Waldbauer and Kogan 1976). Most eggs are deposited as small clusters within 2.5cm of the roots (Levinson et al. 1979). Waldbauer and Kogan (1976) found that eggs were deposited in the greatest numbers only after peak adult abundance. First and second instar larvae typically remain near the oviposition site but third (final) instars may disperse up to 23cm away (Levinson and Kogan 1979). In Ontario, most individuals of this species are in the larval stage from late June to mid-July.
Mature larvae form pupation cells 2.5 – 10cm from the soil surface and newly eclosed adults remain in these subterranean chambers until their cuticle is hardened (Isely 1930). Although short, this is probably the period at which adults are most vulnerable to predation by arthropods and pathogens. Adults of this first generation emerge in Ontario as early as mid-July with some variation due to climatic factors (OMAFRA 2011); at this time, adults feed on leaves and pods. In areas where a second generation occurs, females will oviposit shortly after emerging with new adults appearing in mid to late-August (OMAFRA 2011). Bean Leaf Beetle adults feed on pods until the plants begin to senesce (turn yellow) and then either move to alternative hosts or overwintering sites (OMAFRA 2011).

3. Rove beetle biology and spatiotemporal distributions

Staphylinids (rove beetles) are a highly diverse group that are, in general, small in size (most 3-6mm) and brownish black or reddish in colour. There are some large and colourful species but these form a small minority, especially in temperate areas. Rove beetles inhabit a great range of habitats from alpine snow fields to tropical rainforests but most are constrained by requirements for moist environments or microhabitats (Thayer 2005). Staphylinids are also very diverse in shape, but can generally be identified by a distinctive, elongate and parallel form, a pronotum wider than the head, and truncate elytra that cover only the first 1-3 abdominal segments (Newton et al. 2000). A shortening of the elytra has allowed abdominal flexibility while maintaining the ability to fly (except in those groups in which wings have been secondarily lost) and protection of the delicate wings (Klimaszewski 2000).
Relatively little has been published on the non-adult stages of staphylinids. Life cycles are highly variable with some species having one generation per year and others having as many as four (Herman 1986; Smetana 1995) or five (Herman 1986). Additionally, there are both larva-overwintering and adult-overwintering species in temperate areas (Thayer 2005). While oviposition sites are probably diverse, some species (Staphylininae: Philonthina) lay their eggs in shallow soil crevices (Smetana 1995) or partially bury them in soil (Schmidt 1996). Larvae are poorly known, with a very small proportion described and associated with adults (Thayer 2005). In general, the larvae are elongate with well developed legs and mandibles (Thayer 2005). They have a well-sclerotized head capsule with 1-6 stemmata and short antennae with 3-4 segments (Klimaszewski 2000). Staphylinid larvae can usually be separated from the convergently similar carabids by their legs and urogomphi (terminal abdominal appendages). Carabids have six segmented legs and usually two tarsal claws, while staphylinid legs have five segments and always have one claw (Newton et al. 2000). Staphylinids always have 1-2 segmented urogomphi attached by an articulating constriction while carabid urogomphi are attached broadly; a few Carabidae have articulated filaments with more than two segments (Newton et al. 2000). Staphylinid pupae are usually unsclerotized and exarate, meaning the appendages and abdomen are freely moveable (Klimaszewski 2000). One derived subfamily, the Staphylininae differs in having a sclerotized obtect pupa (appendages and abdomen fixed to the body) (Schmidt 1996).

Staphylinidae are a mostly predaceous family but there are many evolutionarily independent exceptions of mycetophagy, saprophagy and, less commonly, phytophagy (mostly pollen feeders) (Thayer 2005). Some species combine either mycetophagy (some
Tachyporinae) or saprophagy (Oxytelinae) with carnivory, either within a life stage or between life stages (Thayer 2005). Diet is often reflected in various morphological modifications (or lack thereof for true generalists) of the mouthparts (Leschen and Beutel 2001; Weide et al. 2010). However, in most species adults live in the same habitats and have the same prey as their larvae (Thayer 2005). Many staphylinids use pre-oral digestion (Klimaszewski 2000). Prey is first masticated, then externally exposed to secreted digestive enzymes. The resulting digestate is ingested using a cibarial pump (Thayer 2005, Weide et al. 2010). Most predatory staphylinids are apparently generalists accepting a wide range of invertebrate prey in laboratory studies. However, in the field many of these species may only encounter or prefer a much narrower range of prey (Symondson et al. 2002). Philonthus Curtis is well known for its predation of larval Diptera (Hunter et al. 1986; Smetana 1995). However, this is only true for the species tested (mostly those associated with livestock) and most of the species of this large genus have completely unknown biologies (Smetana 1995). Some authors report high levels of cannibalism in staphylinid larvae but this is not supported by field observations and may be an artefact of laboratory rearing (Thayer 2005).

The activity patterns among staphylinid species found in agroecosystems are highly variable. Whereas some species in Oklahoma winter wheat fields are strongly associated with a particular season, most dominant species were active during most of the year (Elliot et al. 2006a). In European winter wheat, larger staphylinid species preferred hedgerows while smaller species (e.g. Tachyporus Gravenhorst) preferred the fields themselves (Balog et al. 2008). In a quantitative study of cereal aphid populations and their possible predators it was found that adult staphylinids formed highly unstable
distributional patches over the season, whereas larvae were found in stable patches (Holland et al. 2004). The authors suggested that this difference was due to the higher mobility of flight-capable adults. Staphylinid larvae were found to occupy smaller, more widely distributed and different patches than carabid larvae, suggesting that staphylinid larvae have different environmental requirements than carabids or that competitive exclusion had occurred (Holland et al. 2004). This also suggests that some staphylinids have narrower environmental tolerances than carabids, possibly with respect to moisture. As staphylinids were previously reported as rare or absent from soybean agroecosystems, nothing is known about the spatial patterns of dominant species. Do larger staphylinids occur only in hedgerow areas in North America or show decreasing abundance towards the field centre? Are most dominant species seasonal in their abundance or are they ubiquitous over the growing season? Do assemblages change according to the growth stages of soybean and the characteristic microclimatic factors that accompany them (i.e. closed canopy)? A quantitative survey of staphylinids in soybean fields would contribute greatly to our understanding of predator use of time and space.

In an agricultural landscape in central Germany, Markgraf and Basedow (2002) found that their most dominant species, *Tachyporus hypnorum* F., showed a distinct increase in flight activity during May and June. Although it is difficult to determine the significance of these flights, they were probably not related to dispersal, as there was no correlation between population density and flight activity (Markgraf and Basedow 2002). Smetana (1995) suggested that, in a different group (Staphylininae: Philonthina), high flight activity is related to foraging. Flight activity is also known to peak at different times, suggesting that there may be diel differences in the staphylinid community at a
single location. Several studies have examined flight activity in tropical rove beetles, all with similar results. For example, Chatzimanolis et al. (2004) sampled rove beetles with flight intercept traps in Panamanian rainforests during the ‘day’ and ‘night’. Most of the dominant species collected were diurnal, with some strictly nocturnal species and some without activity peaks (Chatzimanolis et al. 2004). The results of this study, although preliminary, suffer from a lack of temporal resolution. Whereas their sampling periods fit neatly into two categories (daylight and absence of daylight) rove beetle activity might not. In a more temperate climate, (Dennison and Hodkinson 1983) sampled the staphylinid flight activity patterns in a European forest. It was found that, although seven of ten dominant species were ‘diurnal’, all dominant species showed some crepuscular activity (Dennison and Hodkinson 1983). In laboratory assays, general activity levels of adult Tachyporus were found to drop in the afternoon and peak in the ‘evening before midnight’, whereas larvae were noted to be strictly nocturnal; adults were observed mostly resting on plants after midnight (Dennis and Sotherton 1994). Predominantly crepuscular activity of north temperate species may have combined with other factors to prevent previous surveys from recognizing staphylinid assemblages in soybean. Characterizing activity patterns of the dominant staphylinid species in soybean fields could improve future studies of staphylinid behaviour by focusing on the most ecologically important times.

4. Staphylinids as predators of agricultural pests

Staphylinids are most often recognized as generalist predators which, as a group, should provide biological control services at least equal to those of specialist predators (Symondson et al. 2002). Generalist predation pressure is more stable in an
agroecosystem because generalists can subsist on non-target prey if the target is
unavailable (Dennis and Wratten 1991). Generalist predators may be present before pest
species or arrive before pests attain large population sizes and prevent pest establishment
or retard pest population growth (Chang and Kareiva 1999). The idea that generalist
predators can complement specialists by creating predation pressure in different areas of
space and time is supported by theoretical models (Murdoch 1990) and discussed by
Symondson et al. (2002).

The only detailed account of a staphylinid as a generalist predator of soybean
pests was given by Van der Berg et al. (1997). In Indonesian soybean fields, *Paederus
fuscipes* Curtis was observed to consume an average of thirty-seven Soybean Aphids per
day at high aphid densities and was present even at low densities of this pest species (Van
der Berg et al. 1997). Other staphylinids were probably also predators of Soybean Aphid
in these fields but *P. fuscipes* was the only species observed, likely because of its brightly
coloured body and relatively large size.

**4.1 Staphylinids and cereal aphids**

Although reports of staphylinid predation of soybean pests remain limited to that
of Van der Berg et al. (1997), there are many other accounts of rove beetles acting as
important natural predators of aphids. Research on interactions between staphylinids and
cereal aphid (*Sitobion avenae* F.) is unique in the literature for its level of detail and
variety of laboratory and field studies. In this case, both foliar and ground predators are
considered important as cereal aphids drop off their plant if disturbed and frequently
travel to the ground (Dennis and Wratten 1991). This escape behaviour has not been
observed in Soybean Aphid but this species is known to occur low on the plant and on the ground (Hajek et al. 2007).

Four species in Europe are widely recognized as important to cereal aphid control: *Tachyporus obtusus* L., *Tachyporus hypnorum* F., *Tachyporus chrysomelinus* L. and *P. cognatus* Stephens, with only the last occurring in North America (Campbell and Davies 1991; Smetana 1995). Kollat-Palenga and Basedow (2000) found that the above *Tachyporus* and two other European species: *Tachyporus solutus* and *Paederus littoralis* Gravenhorst, consumed aphids on plants in ‘high numbers’ (9.9-21.9 aphids/day).

*Philonthus cognatus* was not observed to climb plant stalks in lab assays but consumed large quantities of aphids (29.6/day) (Kollat-Palenga and Basedow 2000), in agreement with another study in winter wheat (Balog et al. 2008). Dennis and Sotherton (1994) found that *P. cognatus* did climb plants but only to fly; however, it dislodged aphids as it climbed and still contributed to aphid mortality.

Vertical foraging was found to differ between *Tachyporus* species, larval instars and adult age categories (Dennis and Sotherton 1994). Of the three important *Tachyporus* species included in the assay, only *T. obtusus* climbed to the height of aphid colonies, with the other two climbing to this height only to fly (Dennis and Sotherton 1994). Larval *Tachyporus* from second instar onward were also observed foraging at the height of the colony, consuming up to 10.5 aphids/day as last instars (Kollat-Palenga and Basedow 2000). Adults of *T. hypnorum* collected early in the season were observed to climb more often than the new generation of adults collected later in the season (Dennis and Sotherton 1994). The number of aphids consumed by this species in lab assays also diminished over the season, demonstrating that a species’ importance can change with
age (Dennis and Sotherton 1994). With increasing prey size, handling time increased and capture efficiency (# of predation events/ # of contacts) decreased (Dennis and Sotherton 1994). Although Tachyporus larvae appeared more actively predaceous because they were in contact with aphids more frequently than adults, they had longer handling times (Dennis and Sotherton 1994).

Dennis and Wratten (1991) used predator exclusion cages to isolate the predation pressure of staphylinid species alone, finding that field densities of the dominant Tachyporus spp. and P. cognatus could reduce cereal aphid population growth before the exponential growth phase. Only P. cognatus was able to exert a strong enough effect to reduce population growth during the exponential phase (Dennis and Wratten 1991). In another predator exclusion cage experiment with staphylinid species at field densities, 9.5% of the aphid population had been eaten and a further 35% had been displaced to the ground (Dennis and Sotherton 1994). Holland et al. (2004) found a spatial correlation with both T. hypnorum and ‘adult Staphylinidae’ and aphid populations, but noted that because populations of highly mobile predator and prey were often disassociated, a spatial predatory response may be difficult to resolve without increasing their sampling interval.

When determining the potential of a predator to contribute to the management of a pest it is important to provide a variety of alternative prey options (Dennis et al. 1990). T. hypnorum was observed to consume a relatively high proportion of its bodyweight in cereal aphids (Sopp and Wratten 1986) and to prefer aphids when given alternative invertebrate prey (Dennis et al. 1990). However, T. hypnorum showed an equal preference for mildew on leaf surfaces (Dennis et al. 1990). Mildew growth on plants is
promoted by the secretion of honeydew by high population densities of aphid (Wu et al. 2004). In laboratory feeding assays on plants, *T. hypnorum* foraged mainly on fungi on the lower leaves rather than consuming cereal aphids near the top (Dennis and Sotherton 1994). Adults and larvae fed an aphid-only diet had reduced fecundity and shortened life spans, respectively. These effects were expected for polyphagous predators and were much less severe compared to other generalists (Dennis et al. 1990). Monsurd and Toft (1999) showed that *Tachyporus* species preferred to remain on plants with aphids only, compared to plants with just honeydew or control plants. Previous suggestions that *Tachyporus* aggregates to aphids to consume mildew resulting from the production of aphid honeydew were rejected (Monsurd and Toft 1999).

4.2 Staphylinids and pestiferous beetles

Most accounts of pestiferous beetle predation by rove beetles refer to the consumption of larvae and eggs. However, *Dinothenarus badipes* LeConte (as *Staphylinus*), were observed preying upon adults of the wheat wireworm (*Agriotes mancus* Say) (Hawkins 1936), a species not appreciably different in size to the Bean Leaf Beetle. Predation of larval *Agriotes sputator* L. by individuals of *Tachyporus, Staphylinus* and *Philonthus* was also reported (Fox and MacLellan 1956). Unfortunately, *Staphylinus* and *Philonthus* were large ‘catch-all’ genera in the 1950’s and it is impossible to ascertain much information from these genus-level identifications. Nevertheless, staphylinids are probably important predators of larval beetles, even those with subterranean habits. Adult and larval *Philonthus* species consumed more than 50% of the larval and egg-stage *Popillia japonica* and *Ataenius spretulus* (Haldeman) (Scarabaeidae) offered. Both of these species are important turf grass pests in North America (Terry et
al. 1993, Jo and Smitley 2003) and the former is known to cause economic damage to soybean (OMAFRA, 2011). Adult *Philonthus* preferred eggs while their larvae preferred scarabaeid larvae (Jo and Smitley 2003). The staphylinid assemblage of soybean fields may contribute to the control of pestiferous beetles and a survey of soybean fields to characterize this assemblage is the first step towards understanding these potential interactions.

4.3 Staphylinids and pestiferous *Delia* species.

Species in the staphylinid genus *Aleochara* Gravenhorst are very well known for their important role in the biocontrol of pestiferous cyclorrhaphous Diptera, especially those in the genus *Delia* Robineau-Desvoidy, including the soybean pest *D. platura* (seedcorn maggot). *Delia platura* can prevent large areas of soybean from sprouting when outbreak populations occur (Hammond 1991) but the adoption of no-till practices may prevent many of these outbreaks (Hammond 1997). However, not all Ontario fields are under a no-till regime (A. Brunke, personal observation) and could experience economic damage. Adults of *Aleochara* consume eggs and the late-instar larvae are external parasitoids of the pupa (within the puparium) (Klimaszewski 1984). Two species, *A. verna* Say and *A. bilineata*, are known to parasitize *D. platura* (Klimaszewski 1984), though nearly all North American literature has focused on their control of *D. radicum* L. (e.g., Turnock et al. 1995). *Aleochara bilineata* caused one third of the mortality to *D. radicum* eggs observed in a Canadian study (Mukerji 1971) but parasitism rates are highly variable, ranging from 4% to 94% in Canada (Turnock et al. 1995; Hemachandra et al. 2007). The genus *Aleochara* has not yet been reported in soybean fields but it likely occurs there in numbers comparable to other agricultural habitats and if
present, may be important to the dynamics of *D. platura* populations.

### 5. Staphylinid agroecology

Agroecosystems have been described as unstable, ephemeral habitats that challenge predators with frequent disturbance and unpredictable populations of specific prey species (Wiedenmann and Smith 1997). These challenges are likely responsible for the similarity between the assemblages of many different agroecosystems, with shared species possessing attributes that pre-adapt them to unstable habitats (Wiedenmann and Smith 1997). In soybean surveys of Carabidae in New York soybean fields, an introduced species dominated this ‘pre-adapted’ assemblage (Hajek et al. 2007) and surveys of this family in other crops (Shelton et al. 1983, Brunke et al. 2009) found similar assemblage structures in which exotic species comprised more than half of the individuals captured. Are staphylinid assemblages of similar structure? As native carabid species were found to be more characteristic of open, recently disturbed habitats than native staphylinids (Work et al. 2008), the staphylinid assemblage in soybean may be composed of an even higher percentage of exotic species. The presence of hedgerows at the edge of the field provides important overwintering habitat for staphylinids (Pfiffner and Luka 2000) and Balog et al. (2008) demonstrated that fields with 40 m wide hedgerows supported a greater abundance than those without them. Indeed, hedgerows supported spring and fall populations of the mite predator staphylinid *Oligota flavicornis* Boiselas when crop habitat was absent; the number of pestiferous mites moving into crops was also lower for landscapes that included hedgerows (Paoletti and Lorenzoni 1989). Hedgerows of different ages were found to support different groups of predators in Italy, with older hedgerows favouring greater numbers of Staphylinidae and Carabidae.
However, few surveys have compared the fauna of hedgerows and adjacent agricultural fields to verify that dominant species are actually shared between them. Identification of dominant staphylinid species that would actually benefit from hedgerows may assist landscape management decisions once individual predator species’ diets are known in greater detail. Thorbek and Bilde (2004) suggested that hedgerows function as staphylinid refugia during the growing season after a management-related disturbance, allowing for recolonization of crop habitat afterwards. Tilling and grass cutting caused staphylinids to temporarily abandon a patch of land; however, direct mortality caused by these management practices was found to be low. Compared to carabids and spiders, staphylinids were the most robust group with respect to how severely management practices (excluding insecticide application) influenced their populations (Thorbek and Bilde 2004), possibly due to the high dispersal capability of some species. The presence of weed cover per se is apparently not as important to staphylinid assemblages as it is for most Carabidae (Holland et al. 2004), although weed cover may simply provide food for seed-eating carabids (Kirk 1972) rather than shelter.

Staphylinidae are known to respond negatively to the application of fertilizers that reduce soil moisture and insecticides which cause non-target mortality (Bohac 1999). Some Tachyporus are partially mycophagous and are thought to abandon patches with foliar fungicides, as they eliminate an important food source (Balog et al. 2008). Staphylinids, as other predators, are susceptible to the non-target effects of insecticides, as reported for minute (Oligota minuta) (Braun et al. 1987), average-sized (Tachyporus hypnorum) (Wiles and Jepson 1994, Wang 2005) and larger (Paederus fuscipes) species (Wang 2005). One species, Aleochara bilineata, has become routinely used in the
assessment of non-target effects of insecticides (Samsoe-Peterson 1985; Hautier et al. 2005). Rove beetle susceptibility to insecticides can differ by two to three-fold depending on the substrate, with greater toxicity occurring on leaves compared to soil (Wiles and Jepson 1994). In Ontario, dimethoate is occasionally used against Soybean Aphid and Two-spotted Spider Mite simultaneously as a foliar application in years of high populations (OMAFRA, 2011) and seeds are pre-treated with thiamethoxam to combat early feeding by Bean Leaf Beetle (Magalhaes et al. 2009). The detrimental effects of these management tactics on rove beetles in soybean are unknown but dimethoate was shown to reduce adult and larval populations of Tachyporus species by 38-79% and 80%, respectively six weeks after application, in winter wheat field trials (Vickerman and Sunderland 1977). An investigation of non-target effects of insecticides on the staphylinid assemblage is a worthwhile endeavour but must follow the preliminary work of first characterizing the assemblage and its dominant elements. The rove beetle assemblages under conventional and organic agricultural regimes in one study did not differ in both overall abundance and richness, but organic did have a significantly higher diversity (Krooss and Schaefer 1998). It is unclear whether higher diversity translates into greater control of pest populations as two of the three most dominant species in the study were completely uninfluenced by regime (Krooss and Schaefer 1998).

6. Sampling Staphylinidae in agroecosystems

The most common method for sampling staphylinids in agroecosystems is the pitfall trap (Lang 2000). Pitfall traps are favoured because they are inexpensive, efficient to service and productive (Topping and Sunderland 1992). However, there are drawbacks, including an apparent overrepresentation of large species and the strong
dependence of trapping on insect activity levels (Lang 2000). Although the second criticism should logically apply to staphylinids, it is unknown whether the size bias holds true for groups other than Carabidae. An evaluation of staphylinid pitfall captures for potential size bias is necessary to further assess the limits of trapping with pitfalls. In a previous survey, pitfall traps with cup edges above the soil surface often had a greater proportion of large carabids than those that were properly installed at or below the surface (A. Brunke, personal observations). Rainfall and settling of the soil around the trap edge necessitates the routine re-building of the soil-trap interface (A. Brunke, personal observations) and failing to do so may result in some of the bias reported by many authors. Several methodological studies have revealed that regular pitfall traps underestimate true staphylinid abundance (Mommertz et al. 1996; Lang 2000). Halsall and Wratten (1988) noted that Tachyporus is adept at avoiding pitfall trap edges and is ineffectively sampled by this method. Therefore, future surveys of staphylinid assemblages should incorporate at least a supplementary collection method to ensure that certain species are not heavily under-sampled or completely missed.

In the interest of increasing the quantitative nature of field sampling, several techniques have been developed that sample a discrete unit of area. Two popular methods are fenced (or barrier) pitfalls and suction sampling. A fenced pitfall consists of a central cup surrounded by an enclosure of 0.25-1.0m³ with a screened top (Holland and Smith 1999). The enclosure is pushed into the substrate and invertebrates eventually encounter the cup (Mommertz et al. 1996). Holland and Smith (1999) suggested that a sampling duration of one week and one cup per enclosure was sufficient to effectively measure the chosen area. Lang (2000) emphasized the value of supplementing regular pitfalls with
fenced ones to gain true density information in addition to activity data. Rove beetles are more effectively sampled using fenced pitfalls compared to regular ones, possibly because an increase in escape behaviour within the trap creates more encounters with the central trap cup (Holland and Smith 1999). However, as vegetation in soybean fields is often dense, it is impractical to install large cages with frequent access to samples. Their presence would also prevent the regular growth of soybean plants and create an artificial habitat with different microclimate, among other factors. Also, heavy disruption of crop vegetation is undesirable in fields owned by growers.

Another popular, quantitative method is suction sampling. A lightweight suction sampler can be built from a gas-powered leaf-blower and has been used to capture both adult and larval *Tachyporus* (Macleod et al. 1994). Elliot et al. (2006b) sampled generalist predators in winter wheat using a commercial suction sampler (DVAC backpack model 24, Rincon-Vitova Insectaries Inc., CA) and found that Staphylinidae were sampled quite effectively, while other groups were poorly sampled. Before a sample is taken, a circular frame is pushed into the soil to delimit the sampling plot and enclose arthropods inhabiting the area (Elliot et al. 2006b). One criticism of suction sampling is that larger, heavier individuals and species are selected against and that a complex sampling area will cause some individuals to be missed (Mommertz et al. 1996). However, this would seemingly complement the apparent larger-size bias of pitfall traps (see above). Some studies have attempted to remedy these concerns with increased sampling time (two minutes) and augmentation of suction with hand searching of debris using an aspirator to collect (Elliot et al., 2006b). However, these time-intensive augmentations preclude suction sampling from regular applications in all-season surveys.
Importantly, suction sampling effectively captured a staphylinid taxon (*Tachyporus*) (MacLeod et al. 1994) that is reportedly ineffectively sampled by pitfall traps (Halsall and Wratten 1988).

Another ground sampling method is the use of ‘litter bags’: open mesh bags filled with moist litter (Prasifka et al. 2007). This method was found to sample Staphylinidae very well compared to regular pitfalls, as litter bags more successfully captured their larvae and more accurately sampled adults in one of the two sampling years (Prasifka et al. 2007). This technique may be very useful in certain ecosystems but it may create artificial communities when sampling ecosystems with little litter, such as soybean.

After the use of a suction sampler or litter bags, there are three main methods to retrieve arthropods from debris: hand sorting, Winkler extraction and Berlese funnelling (Smith et al. 2008). Although hand sorting was time efficient and less resource-intensive, it underestimated beetle densities (Smith et al. 2008). Though this may not be a problem in the very coarse debris present in soybean. All three methods were found to capture the same size range of arthropods but hand sampling small beetles can be difficult and time consuming (Smith et al. 2008). These authors demonstrated that Berlese funnels sampled more species per unit of debris compared to the other two methods. Berlese funnels were demonstrably the best overall method but they are also the most resource-intensive and would be best suited to less intensive sampling regimes or when long extraction times are not prohibitive (Smith et al. 2008).

Markgraf and Basedow (2002) sampled both ground active and flight active staphylinids using pitfalls and windowpane traps, respectively. Species commonly found in flight traps were rare at the soil surface and vice versa (Markgraf and Basedow 2002),
emphasizing the need for multiple and complementary sampling protocols to characterize a staphylinid assemblage fully. Complementary trapping along different height strata would be beneficial in soybean where the crop canopy is quite tall, especially in later stages. Sampling at multiple heights captures fluctuations in the vertical distributions of a given species, ensuring that movement at a different height is not interpreted as an absence from the habitat (Vega et al. 1990). Vega et al. (1990) emphasized the need to place sampling units at different heights to improve estimations of true field density and capture of rare species. A similar flight-based sampling technique is the flight intercept trap (FIT). FITs often sample staphylinid assemblages effectively by acting as a barrier to flying beetles, which hit the surface and fall into a pan of soapy water (Chatzimanolis et al. 2004). A highly portable, lightweight FIT design is described by Chatzimanolis et al. (2004). The capture of all staphylinids flying across a soybean field may not accurately characterize the crop assemblage and is probably more suitable for determining richness on a larger spatial scale.

7. Research Objectives

The presence of a staphylinid assemblage in soybean needs focused investigation as previous studies have overlooked this fauna or considered it of little importance relative to other predator groups. Staphylinids are recognized for their control of arthropod groups known to damage soybean and are probably important members of the generalist predator guild in soybean which includes the well documented Carabidae (Hajek et al. 2007). To acquire a context within which to consider the staphylinid assemblage encountered in soybean agroecosystems, a detailed taxonomic review of the Staphylinidae occurring in the geographic area of study was conducted and identification
keys were created to assist in future staphylinid research relying heavily upon surveys for data collection (Chapter II). A detailed, species-level survey (Chapter III) was conducted to characterize dominant members in such a way that the observations made are comparable to other studies and could potentially be useful to integrated pest management research. As major soybean pests also utilize the hedgerow in at least one event in their life cycles, this area was surveyed as well. Additionally, hedgerows were sampled to verify whether these areas provide overwintering habitat or refugia for common staphylinids. Canopy pan traps were used to augment traditional pitfall trapping to provide a more accurate characterization of the staphylinid assemblage. The spatiotemporal co-incidence of common species with that of major soybean pests was studied in detail (Chapter IV) to provide insight into the potential for these species to act as predators and also to verify assumptions made about their value as generalist predators (see above, or Symondson et al. 2002). Other staphylinids were also considered because of their known prey range reported in previous research (e.g. Tachyporus spp. and aphids, large staphylinids and adult beetles). The research results presented in this thesis will provide a foundation for future investigation of more complex ecological interactions between dominant predator species and soybean pests.
Chapter II

The Staphylinidae of Eastern Canada and Adjacent States: Key to subfamilies; Staphylininae: Tribes and Subtribes, and Species of Staphylinina


Abstract

Rove beetles (Staphylinidae) are diverse and dominant in many of North America’s ecosystems but, despite this and even though some subfamilies are nearly completely revised, most species remain difficult for non-specialists to identify. The relatively recent recognition that staphylinid assemblages in North America can provide useful indicators of natural and human impact on biodiversity has highlighted the need for accessible and effective identification tools for this large family. In the first of what we hope to be a series of publications on the staphylinid fauna of eastern Canada and the adjacent United States (ECAS), we here provide a key to the twenty-two subfamilies known from the region, a tribe/subtribe level key for the subfamily Staphylininae, and a species key to the twenty-five species of the subtribe Staphylinina. Within the Staphylinina, the Platydracus cinnamopterus species complex is defined to include P. praetermissus Newton spec. nov., P. cinnamopterus (Gravenhorst) and P. zonatus (Gravenhorst). Lectotypes are designated for Staphylinus cinnamopterus Gravenhorst, Staphylinus zonatus Gravenhorst and Staphylinus badius Mannerheim. One new

1 Taxonomic work on the Platydracus cinnamopterus complex, including redescription of P. cinnamopterus, P. zonatus, description of P. praetermissus, lectotype designations etc. was done by A. Newton, Field Museum of Natural History, Chicago, IL. A. Newton, J. Klimaszewski and C. Majka provided additional locality data.

2 This chapter appears here without figure plates; a version with all figures can be acquired via: http://www.biology.ualberta.ca/bsc/ejournal/bnkmm_12/otherpgs/downloads.html
Canadian record, one new record from eastern Canada, and thirty-nine new provincial or state records are presented.

1. Introduction

Rove beetles (Coleoptera: Staphylinidae) constitute the largest family of insects worldwide, with more than 55,440 described species (Grebennikov and Newton 2009) found in a great diversity of terrestrial and periaquatic habitats. In Canada, more than 1400 species are known and some large subfamilies (Staphylininae, Tachyporinae) have been nearly completely revised. An excellent synthesis of the staphylinid literature is given by Thayer (2005). However, our understanding of staphylinid ecology and habitat requirements is still very limited. Recent work has revealed that staphylinids are dominant organisms in Canadian forest ecosystems (Paquin and Duperre 2001) and because many species require continuous, mature or old growth stands, the composition of their species assemblages effectively communicates the degree of natural or human impact upon these systems (Pohl et al. 2008). In a recent review of the use of beetles in conservation, New (2010) highlighted the critical importance of species-level identifications in surveys aiming to document changes to ecosystems via human development or climate change. The continued ability of insect surveys to address important ecological and conservation-themed questions depends primarily on the correct identification of specimens, which in turn depends on the availability of effective keys.

Although several recent works such as Klimaszewski (2000) and Newton et al. (2000) include keys to the genus or subfamily level, accompanied by line drawings of important characters, keys to most staphylinid groups are poorly illustrated and cover
broad geographic areas (e.g. North America north of Mexico). Furthermore, many important staphylinid keys are scattered in the primary literature and can be time-consuming or difficult to locate. These obstacles can now be addressed using online, open-access publication to provide richly illustrated, digital keys to the species of Staphylinidae known to inhabit eastern Canada and the adjacent United States (ECAS). ECAS is defined here as Ontario eastward and includes the following states that are adjacent to eastern Canada: Michigan, Indiana, Ohio, Pennsylvania, New York, Vermont, New Hampshire and Maine. Although broader regions have been used in previous works (i.e., Northeastern North America of Downie and Arnett (1996)), ECAS corresponds well to a naturally delimited staphylinid fauna and has allowed the simplification of the keys through exclusion of southern or western taxa.

Despite the occurrence of some of largest and most conspicuous species in the Staphylinina (Staphylininae: Staphylinini), the taxonomy of this subtribe is currently far from settled. The largest genus, *Platydracus* C. G. Thomson, remains under revision by the second author and thus no working key exists for the fauna of ECAS. To remedy this, we provide a regionalized *Platydracus* key in advance of the upcoming revision and describe a new species that occurs in ECAS. Multiple accidental introductions (Newton 1987; Majka and Klimaszewski 2008), a history of incorrect names (Newton 1987), inadequate species descriptions, colour variation, and the presence of several rare or typically ‘southern’ species has further complicated the recognition of Staphylinina in this region. Despite this, we show here that most Staphylinina can be easily identified to species using high-resolution photographs of readily visible characters.
In this first publication we provide an overview of, and a key to, the twenty-two staphylinid subfamilies occurring in ECAS, and then review the tribes and subtribes of Staphylininae and the twenty-five species of Staphylinina occurring in ECAS. Keys presented here will also work for the fauna of Connecticut, Illinois, Massachusetts, Minnesota, Rhode Island and Wisconsin. We envision this first key as a nexus for future keys to link to, thus creating an integrated guide to the Staphylinidae of ECAS. Future publications are planned, with the most immediate ones covering the remaining groups of Staphylininae.

2. Methods

Specimen photographs were taken with a Visionary Digital imaging system and CombineZ or Helicon Focus software was used to combine multiple photographs into high depth-of-field images. Most photographs of living specimens were taken with digital SLR cameras and a 105mm macro lens, often with the addition of a 2X teleconverter or extension rings, but live photographs were also contributed by a number of collaborators using a variety of equipment (see acknowledgments). Online keys were created with Adobe Creative Suite 3 software, including Photoshop, Illustrator, Dreamweaver and Fireworks. Maps of species distributions were prepared using ARC MAP, with records previous to 1970 mapped separately from those occurring on or after this year in order to highlight possible distribution changes over time (this was not done for common species). Most species in potential decline reviewed herein showed a noticeable change beginning around 1970, with a few species ‘declining’ in records after 1980. Thus, 1970 was chosen as a standard division point with special cases discussed under those species.
Measurements were taken with an eyepiece micrometer using various dissecting microscopes. A list of institutions from which material was examined and a list of contributing photographers are given in the acknowledgements. Throughout, ‘abdominal segments 1-6’ corresponds to the segments numbered as visible and therefore represent anatomical segments 2-8. Unless otherwise stated, we follow the higher classification of Newton et al. (2000). Province and state abbreviations are as follows: Ontario (ON), Québec (QC), New Brunswick (NB), Nova Scotia (NS), Newfoundland and Labrador (NL), Prince Edward Island (PE), Michigan (MI), Indiana (IN), Ohio (OH), Pennsylvania (PA), Maine (ME), Massachusetts (MA), New York (NY) and New Hampshire (NH).

The following institutions and individuals made material available for study:

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3. Results and Discussion

3.1. Key to the subfamilies in ECAS

1 Body with one of the distinctive shapes and all corresponding important features:

   Oxyporinae (Fig. 1.1.1-1.1.2): Mandibles about as long as head, protruding forward and crossing; last segment of labial palpi crescent shaped (examine ventral surface of head)

   Scaphidiinae (Fig. 1.2.1-1.2.3): Head partly concealed from above; less than half the abdomen extending past the elytra; antennae originate between the eyes
Micropeplinae (Fig. 1.3.1): Antennae with 9 antennomeres, the last enlarged to form a club; entire dorsal surface with sculpturing of ridges and pits; body elongate oval in shape

Pselaphinae (Fig. 1.4.1): Antennae always at least loosely clubbed; with deep pits on the head, base of the elytra and usually pronotum; elytra far from reaching the apex of the abdomen; all tarsi with three segments; in most species, elytra and abdomen appear as an ‘apical section’, always distinctly wider than head and pronotum

Scydmaeninae (Fig. 1.5.1): Body characteristically ant-like; posterior of head without ocelli, elytra reaching or nearly reaching apex of abdomen; always smaller than 2.5mm

- Body unlike the shapes shown above ..................................................................................2

2 Dorsal surface of elytra with ridges (Fig. 1.6.1, 1.7.1); pronotum approximately equal in width at base and apex ........................................................................................................3

- If elytra with ridges (rarely), then pronotum distinctly narrower at apex OR at base ..4

3 With ridges on both pronotum and elytra (Fig. 1.6.1); two known species in ECAS, identical in appearance........................................................................................................Pseudopsinae: Pseudopsis

- With ridges on elytra only; two species, both red and black (Fig. 1.7.1) ...................... ..........................................................................................................................Olisthaerinae: Olisthaerus

4 With a unique habitus as in Fig. 1.8.1; antennae with a two-segmented club and inserted in front of the eyes (Fig. 1.8.1); eyes protruding from lateral head outline and
highly convex (Fig. 1.8.1); two species in ECAS, differing mostly in color
........................................................................................................................................... Megalopsidiinae: *Megalopinus*

- Unlike *Megalopinus* .................................................................................................................. 5

5 With a distinctive habitus (Fig. 1.9.1), rarely with eyes slightly less prominent (*Dianous*) (Fig. 1.9.2); antennae originate between the eyes (Fig. 1.9.3); second last segment of maxillary palpus swollen, wider apically than preceding segment .......... ........................................................................................................................................... Steninae

- Unlike Fig. 1.9.1 or *Dianous*; if antennae originate between eyes, then eyes not distinctly protruding from lateral head outline ..................................................................... 6

6 Habitus similar to Fig. 1.10.1; eyes located at the hind margin of the head, globular; second last segment of maxillary palpus swollen, wider apically than preceding segment (Fig. 1.10.2); mandibles long and thin, without teeth (Fig. 1.10.2); antennae with a two-segmented club (Fig. 1.10.2); always smaller than 2.5 mm ...Euaesthetinae

- Unlike Fig. 1.10.1; if similar to 1.10.1 and smaller than 2.5mm, then antennae without a two-segmented club ............................................................................................................. 7

7 Abdomen with 7 visible abdominal sternites (Fig. 1.11.1) OR with a unique habitus as in Fig. 1.11.2 or Fig. 1.11.3 .................................................................................................... Oxytelinae (most)

- Abdomen with 6 visible abdominal sternites (Fig. 1.12.1) .......................................................... 8

8 Antenna inserted behind the anterior margin of the eye (Fig. 1.13.1) ................................. ........................................................................................................................................... Aleocharinae (most)

- Antenna inserted in front of the anterior margin of the eye (Fig. 1.12.2) ......................... 9
9 Metasternum with small, rounded lobes near the apex (Fig. 1.13.2); appearance distinct (Fig. 1.13.3); found with termites of the genus *Reticulotermes* (Fig. 1.13.4); ............

.......................................................... Aleocharinae: Trichopseniini: *Trichopsenius*

- Metasternum without lobes (Fig. 1.14.1); not exactly like *Trichopsenius* ...........10

10 Ocelli present behind compound eyes (Fig. 1.15.1), often obscured in *Eusphalerum* and *Pycnoglypta*; see Fig. 1.15.2-3 to check if your specimen belongs to these two genera.................. .......................................................... Omaliinae

- Ocelli absent (Fig. 1.12.3); not similar to *Eusphalerum* or *Pycnoglypta* ............11

11 Body oval with elytra $\geq$ 2 times as long as the pronotum and covering one or more tergites (Fig. 1.16.1); pronotum strongly transverse, about 2 times as wide as long or wider (Fig. 1.16.1); antennomeres I and II expanded (Fig. 1.16.1); small beetles, 1-3mm in length.................. .......................................................... Proteininae

- Not with the above combination of characters ..............................................12

12 Antennae with 10 antennomeres (Fig. 1.13.5); size always < 2mm ......................

........................................................................................................ Aleocharinae: Hypocyphtini

- Antennae with 11 antennomeres (Fig. 1.12.4); always >2mm .........................13

13 Abdominal tergites unmargined (dorsally, without a longitudinal suture at each side) (Fig. 1.17.1); abdomen always parallel-sided................................................................14

- Abdominal tergites margined: most segments with a longitudinal suture at each side (Fig. 1.12.5); if unmargined then abdomen tapered posteriorly (Fig. 1.14.2); abdomen parallel sided or not.................................................................15
14 Abdominal surface with fish scale-like sculpturing (Fig. 1.18.1); last maxillary palpomere much larger than the preceding and slipper-shaped (Fig. 1.18.2) .......................................................... Paederinae: *Palaminus*

- Abdominal surface unlike fish scales but often with other textures (Fig. 1.17.2); last maxillary palpomere smaller than the preceding and not slipper-shaped (Fig. 1.17.3) .......................................................... Osoriinae

15 Procoxa much smaller and differently shaped than femur (Fig. 1.19.1)................. 16

- Procoxa large and elongate, similar to femur (Fig. 1.12.6)................................. 19

16 Elytra with at least one distinct row of fused punctures (Fig. 1.20.1); protibia with thick spines along outside edge (Fig. 1.20.2)............................... Piestinae: *Siagonium*

- Punctures of elytra not arranged in distinct rows (Fig. 1.19.2); protibia smooth, with only setae on outside edge (Fig. 1.19.3) ................................................................. 17

17 Pronotum, measured at midline, about as long as elytra or longer (Fig. 1.11.4); elytra convex.................................................................................................. Oxytelinae: Euphaniini

- Pronotum, measured at midline, about half as long as elytra (Fig. 1.19.4); elytra flattened........................................................................................................ 18

18 Sides of pronotum serrate; pronotum evenly covered with setae-bearing punctures (Fig. 1.19.5).......................................................... Phloeocharinae: *Charphyhus picipennis*

- Sides of pronotum smooth; pronotum with only a few setae-bearing punctures (Fig. 1.21.1).......................................................... Habrocerinae: *Habrocerus magnus*
19 Antennomeres 3-11 extremely elongate, with prominent long black setae much longer than the width of their corresponding segment (Fig. 1.21.2); body distinctly widest at elytra; antennomeres 1 and 2 much wider than 3-11 ..............................................20

- Antennomeres 5-11 with antennal setae almost always shorter than the width of their corresponding segment (Fig. 1.14.3); if with antennae similar to Fig. 1.21.2 (one genus), then body linear in form, with all body sections subequal in width...........21

20 Dorsal surface smooth, with only a few large bristles; without a 'neck' (Fig. 1.21.3)...

............................................................ Habrocerinae: Habrocerus

- Dorsal surface covered in punctures with hairs; with a constriction behind the eyes to form a 'neck' (Fig. 1.22.1).................................Trichophyinae: Trichophya pilicornis

21 Head constricted behind eyes to form a 'neck' clearly visible from above (Fig. 1.12.7) or sometimes forming a broad, weakly defined neck (Fig. 1.12.8) .................22

- Without a 'neck': head either straight behind the eyes or gradually meeting pronotum such that an extra section is not present (Fig. 1.11.5)......................................................23

22 Pronotum without a postcoxal process (Fig. 1.12.9) or with a small, translucent one (Fig. 1.12.10)............................................................ Staphylininae (most)

- Pronotum with a sclerotized, opaque postcoxal process (Fig. 1.18.3)...............Paederinae (most)

23 Elytral epipleuron with a carina (Fig. 1.14.4)............................................Tachyporinae

- Elytral epipleuron without a carina (Fig. 1.12.11).................................................24

24 Habitus as in Fig. 1.12.12; pronotum mostly glabrous.....................................Staphylininae: Atanygnathus bicolor
- Habitus as in Fig. 1.19.6; pronotum heavily pubescent .................................................................
  ................................................................................................................................Phloeoccharinae: Phloeoccharis subtilissima

3.2. Key to the tribes and subtribes of Staphylininae in ECAS

1  Elytra overlapping at midline; inside margin of elytra arcuate (Fig. 2.1.1) Xantholinini
   - Elytra meeting evenly at midline; inside margin of elytra straight (Fig. 2.2.1) ............2

2  Neck narrow: about 1/4 the width of the head (Fig. 2.3.1). Diochini: Diochus schaumi
   - Neck, if present, broader: at least one half the width of the head (Fig. 2.2.2) ............3

3  Antennal base separated by a distance less than that between the eye and antennal base (Fig. 2.4.1); mandibles (when closed) directed forward and blade-like; with a pair of plates anterior to the prosternum (Fig. 2.1.2) .................. Othiini: Atreces
   - Antennal base separated by a distance greater than that between eye and antennal base (Fig. 2.2.3); mandibles (when closed) not directed forward; without a pair of plates anterior to the prosternum (Fig. 2.2.4) .................. (Staphylinini) 4

4  With a unique appearance (Fig. 1.12.12); without a visible neck; maxillary and labial palpi extremely elongate (Fig. 2.2.5); tarsal formula 5-4-4 .................................................................
   ................................................................................................................................................. Tanygnathinina: Atanygnathus bicolor
   - Unlike A. bicolor; always with at least a weakly formed neck; maxillary and labial palpi not extremely elongate (Fig. 1.12.8); tarsal formula 5-5-5 ............................... 5

5  Dorsal surface of neck completely without setose punctures, often with non-setose micropunctures (Fig. 1.12.8) ...................................................................................................... 6
- Dorsal surface of neck with setose punctures on at least lateral portions (Fig. 1.12.7)..

 ................................................................. 8

6 Pronotum with dorsal rows of ≥4 punctures (Fig 2.2.6) OR with many punctures not arranged in pairs; without empodial setae between tarsal claws (Fig. 2.2.8) ..............

 ................................................................. Philonthina

- Pronotum with dorsal rows of 1-3 punctures (Fig. 2.2.7) OR impunctate; with empodial setae between tarsal claws (Fig. 2.2.9), sometimes very long (Fig. 2.2.10) ...

 ................................................................. 7

7 Last segment of maxillary palpus reduced, much narrower than the previous segment (Fig. 2.2.11).................................................................Amblyopinina: Heterothops

- Last segment of maxillary palpus normally developed, not markedly narrower than previous segment (Fig. 1.12.8) ................................................................. Quediina

8 Head narrow, about half the width of the pronotum (Fig. 2.2.12); last segment of labial palpus characteristically hoof-shaped, with a broad apical face (Fig. 2.2.14)......

 ................................................................. Anisolinina: Tympanophorus puncticollis

- Head much wider than half the width of the pronotum (Fig. 2.2.13); last segment of labial palpus not exactly like that of T. puncticollis, apical face narrow (Fig. 2.2.15)

 ................................................................. Staphylinina

3.3. Key to the genera of Staphylinina in ECAS

1 Pronotum smooth and glossy, except for margins (Fig. 3.1.1)..............................

 ................................................................. Creophilus (C. maxillosus)
- Most of pronotum punctate, often with an impunctate midline (Fig. 2.2.13).............2

2 Anterior angles of pronotum sharp, approximately 90 degrees or less (Fig. 3.2.1) .......................................................... Ontholestes

- Anterior angles of pronotum rounded, greater than 90 degrees (Fig. 3.3.1).............3

3 Large lateral setae of head not restricted to the anterior half of the temple (Fig. 3.3.2) ............................................................................. Platydracus

- Large lateral setae of head restricted to the anterior half of the temple (Fig. 3.4.1).....4

4 Body and femora completely black AND with elytra (measured at middle) longer than pronotum (Fig. 3.5.1); last segment of labial palpus stout with its apical margin at a distinct angle (Fig. 2.2.15) .......................................................... Tasgius

- Not completely black OR with elytra, at middle, distinctly shorter than pronotum (Fig. 3.6.1); last segment of labial palpus more elongate with its apical margin either truncate or pointed (Fig. 3.6.2) .......................................................... 5

5 Elytra red; head with eyebrow-like patches of golden setae (Fig. 3.7.1)..................

.......................................................... Staphylinus (S. ornaticauda)

- Elytra not red; head without eyebrow-like patches of golden setae (Fig. 3.4.2) .........6

6 Base of some abdominal segments with gold or silver setae (best seen ventrally) (Fig. 3.4.3); last maxillary palpomere spindle-shaped (Fig. 3.4.4) ............Dinothenarus

- Abdominal segments never with silver or gold setae (Fig. 3.6.3); last maxillary palpomere elongate and rectangular (Fig. 3.6.2) .............................................. Ocypus
3.4. **Key to the *Dinothenarus* species in ECAS:**

1. Head yellowish-red (Fig. 3.4.2), colour sometimes heavily muted in discoloured specimens (Fig. 4.1.1); pronotum grey and orange; abdomen with gold and silver setae .......................................................... *Dinothenarus capitatus*

   - Head and pronotum black (Fig. 4.2.1); abdominal segments with gold setae only ........

   .......................................................... *D. badipes*

3.5. **Key to the *Ocypus* species in ECAS**

1. Legs black, concolourous with rest of body (Fig. 3.6.1) ................. *Ocypus nitens*

   - Legs brownish red, contrasting with the rest of body (Fig. 5.1.1) .......... *O. brunnipes*

3.6. **Key to the *Ontholestes* species in ECAS**

1. Legs bicoloured, black and yellow (Fig. 6.1.1); apical half of antennae black; base of fifth abdominal tergite with golden setae ........................................ *Ontholestes cingulatus*

   - Legs completely dark; antennae entirely orange; base of fifth abdominal tergite with silver setae (Fig. 6.2.1) ......................................................... *O. murinus*

3.7. **Key to the *Platydracus* species in ECAS**

1. Eye about twice as long as the temple (Fig. 7.1.1) .................. *Platydracus femoratus*

   - Eye smaller, no more than marginally longer than the temple (Fig. 2.2.13) ............ 2
2 Punctures of pronotum spaced unevenly, creating smooth, glossy areas in addition to a median impunctate line (Fig. 7.2.1) ................................................................. 3

- Punctures of pronotum spaced evenly, with the exception of a median impunctate line in some species (Fig. 7.3.1) ................................................................. 4

3 Pronotum about as long as wide; at middle, impunctate line of pronotum obsolete (Fig. 7.2.2) ........................................................................................................ P. exulans

- Pronotum longer than wide; impunctate line of pronotum at least as wide as 5 punctures for most of its length (Fig. 7.4.1); found along or near ocean coastline ....

................................................................. P. praelongus  

4 Elytra reddish, with distinct, elongate patches of dark setae (Fig. 7.5.1); scutellum with a median gold line bordered by a pair of dark patches (Fig. 7.5.1) ................. 5

- Elytra at most, with broad, faint darker areas (Fig. 7.6.1); scutellum without a median gold line (Fig. 7.6.1) ................................................................. 6

5 Large species (22-35mm); impunctate area of pronotum interrupted over much of its length (Fig. 7.7.1) ........................................................................ P. maculosus

- Smaller species (13-19mm); impunctate area complete along the entire length of pronotum (Fig. 7.5.2) ........................................................................... P. comes  

6 Each elytron with an orange or gold spot (Fig. 7.8.1) ...... maculate form of P. fossator

- Elytra without such a spot (Fig. 7.9.1) .............................................................. 7

7 Abdominal tergites with areas of dense yellow or blonde setae (Fig. 7.10.1); impunctate median line of pronotum always absent or interrupted as in Fig. 7.7.1 .... 8
- Abdominal tergites with either sparse areas of yellow setae or none at all (Fig. 7.9.2); impunctate median line of pronotum variable ................................................................. 10

8 Body surface dull and without color (i.e., no part metallic) (Fig. 7.11.1); elytra red .... ................................................................. P. immaculatus

- At least pronotum metallic greenish-bronze to purple (Fig. 7.10.2); elytra not red ..... 9

9 Abdominal tergites 1-5 each with distinct tripartite yellow pubescence (Fig. 7.10.2); pronotum metallic bronze-green; ventral margin of elytral epipleuron pale (Fig. 7.10.3) ........................................................................ P. viridanus

- At least one of abdominal tergites 1-5 with a different pattern of yellow setae (Fig. 7.12.1); pronotum with a purple reflection (bronze in discoloured specimens); ventral margin of elytral epipleuron black (Fig. 7.12.2) ........................................ P. violaceus

10 Pronotum without a complete smooth median line (Fig. 7.6.2); if smooth area present, then interrupted along its length ................................................................. 11

- Pronotum with a complete impunctate median line, its narrowest point at least one puncture wide (Fig. 7.9.3) ....................................................... (P. cinnamopterus Complex) 13

11 Body dark brown, with reddish-brown elytra and paler abdominal apex (Fig. 7.6.3); antennomere I dark dorsally and pale ventrally (Fig. 7.6.4); eyes small, distinctly smaller than the temple (Fig. 7.6.3) ......................................................... P. mysticus

- Body entirely black (Fig. 7.13.1), rarely with sparse yellow setae at the base of the abdominal segments; antennomere I completely black (Fig. 7.13.2); eyes larger, subequal to distinctly longer than the temple (Fig. 7.13.2) ................................. 12
12 At least basal abdominal tergites with a pair of dark velvet spots (Fig. 7.13.1); eye subequal in length to temple ................................................................. *P. tomentosus*

- Abdominal tergites without dark velvet spots (Fig. 7.8.2); eye distinctly longer than temple........................................................................................................melanistic form of *P. fossator*

13 Head, pronotum and elytra completely bright red (Fig. 7.9.4) ................................................................. ..................... rufous form of *P. cinnamopterus*

- Some of these areas darker (Fig. 7.9.1) ............................................................................................................. 14

14 Impunctate median line of pronotum wide: 3 or more punctures could fit across its narrowest point (Fig. 7.14.1); antennomere 9 subquadrATE: its apical width nearly equal or equal to its length (Note: rotate antennae so that their segments are widest in profile) (Fig. 7.14.2); apex of median lobe of aedeagus widely truncate in parameral view (Fig. 7.14.3)...............................................................*P. praetermissus* Newton spec. nov.

- Impunctate median line of pronotum narrow: 2 or fewer punctures could fit across its narrowest point (Fig. 7.9.5); antennomere 9 at least slightly transverse: its apical width greater than its length (Note: rotate antennae so that their segments are widest in profile) (Fig. 7.3.2); apex of median lobe of aedeagus obtusely to acutely projected in parameral view (Fig. 7.9.6)......................................................................................... 15

15 Antennomere 9 distinctly transverse (Note: rotate antennae so that their segments are widest in profile) (Fig. 7.9.7); pronotum usually evenly coloured, light to dark red (Fig. 7.9.8); apex of median lobe of aedeagus acutely projected in parameral view (Fig. 7.9.6)..................................................................................................................... *P. cinnamopterus*
Antennomere 9 slightly transverse (Note: rotate antennae so that their segments are widest in profile) (Fig. 7.3.2); pronotum light to dark red with dark brown to black anterior angles, almost never evenly coloured (Fig. 7.3.3); apex of median lobe of aedeagus obtusely projected in parameral view (Fig. 7.3.4).......................... P. zonatus

3.8. Key to the *Tasgius* species in ECAS

1  Pronotum with punctures of two different sizes, most punctures well-separated (Fig. 8.1.1) .................................................................................................................. *Tasgius ater*

- Pronotum with punctures subequal in size, most punctures almost touching (Fig. 8.2.1) ..........................................................................................................................2

2  Pronotum with sides widest just before anterior angle, sides strongly converging (Fig. 8.3.1); basal half of antennomere 2 bicoloured (Fig. 8.3.2) ...............T. melanarius

- Pronotum widest at the anterior one third, sides weakly converging (Fig. 8.2.2); basal half of antennomere 2 solid red (Fig. 8.2.3) ......................................................... T. winkleri

3.9. The subfamilies of Staphylinidae in ECAS

**Aleocharinae Fleming 1821**

Most aleocharines can be recognized by antennae that are inserted posterior to a line drawn along the anterior margins of the eyes (Fig. 1.13.1), non-bulging eyes (unlike Steninae), male genitalia with complex parameres and their overall appearance, which is unlike that of the Scaphidiinae (Fig. 1.1.1). The following two aleocharine groups of ECAS are exceptions, because their antennae are inserted either anterior to the level of the anterior eye margin or ambiguously close to it:
• *Trichopsenus* Horn, with characteristic metasternal plates (Fig. 1.13.2) and a distinct habitus (Fig. 1.13.3)

• The tribe Hypocyptini, minute beetles (<2mm) with only 10 antennomeres (Fig. 1.13.5)

Aleocharinae is the most diverse subfamily of Staphylinidae in ECAS and also the least known. This subfamily is widely distributed in North America and occurs in almost all terrestrial habitats, but most species are forest dwelling. There they occur in leaf litter, under bark, in fungi, in moss and within the nests of ants, termites, mammals and birds. Elsewhere in ECAS they inhabit seashores, edges of water bodies, wetlands and prairies. *Drusilla canaliculata* Fabricius is a common species often found in disturbed areas under leaves and stones, usually near ants but often near water (Fig. 9.1.1). Species of *Gymnusa* Gravenhorst are uncommonly collected aleocharines that are associated with *Sphagnun* in wetlands and along streams. In undisturbed fens and bogs, lightly pressing on water-logged vegetation will sometimes reveal specimens of this genus (Fig. 9.1.2). *Tachyusa* Erichson are characteristically shaped beetles found along the margins of lakes, ponds, wetlands, and streams; they are sometimes collected from beaver lodges (Fig. 9.1.3). *Xenodusa* Wasmann species live with colonies of *Formica* ants during the warmer months and overwinter with colonies of the ant genus *Camponotus* (Wheeler 1911) (Fig. 9.1.4). In ECAS, Aleocharinae are primarily predaceous on a wide variety of invertebrates, however some groups are strictly mycophagous (Ashe 1981) or parasitoids of cyclorrhaphous Diptera (Klimaszewski 1984).
**Euaesthetinae Thomson 1859**

Euaesthetines can be recognized by the globular eyes that are located at the hind margin of the head (Fig.1.10.1), antennae that end in a two-segmented club, thin toothless mandibles, and a swollen second last maxillary palpomere (Fig. 1.10.2). Euaesthetines are also distinctive for their relatively small size: the largest in ECAS are 2.3mm long (Fig. 9.2.1).

This subfamily is widespread in North America, with two western endemic genera; three genera are known from ECAS. The most diverse is *Euaesthetus* Gravenhorst (Fig. 9.2.2), which can be found in leaf litter, moist fields, and wet meadows dominated by sedges, where they often co-exist with the related Steninae. *Stictocranius puncticeps* LeConte is the only eastern species of the genus and can be found in leaf litter. Several species of *Edaphus* Motschulsky are known from the northeastern US but are not yet recorded from Canada although they likely occur in the Carolinian forests of southern Ontario and Appalachian forests of New Brunswick and Nova Scotia. *Edaphus* occur in leaf and wood debris, treeholes, and stumps in moist forests (Puthz 1974). All members of this subfamily are best collected by sifting litter and then processing it in a Berlese funnel, but can also be captured by pan and pitfall trapping. Euaesthetines are predators of small invertebrates but their exact diet is unknown.

**Habrocerinae Mulsant and Rey 1877: Habrocerus Erichson 1839**

Species of *Habrocerus* can be recognized by antennomeres 3-11 that are extremely slender, with long black macrosetae (Fig. 1.21.2), and by their dorsal pronotum with few setae (Fig. 1.21.3). *Trichophya* Mannerheim (Trichophyinae) has similar
antennae; however its dorsal surface is covered with many setae (Fig. 1.22.1). *Habrocerus magnus* LeConte has broader antennomeres and lacks other important morphological features of the genus (Fig. 9.3.1) (Assing and Wunderle 1995), and probably belongs in a lineage of Tachyporinae (Assing and Wunderle 1995) or Olisthaerinae (Newton et al. 2000). We treat this species here as *Habrocerus* pending its formal transfer elsewhere.

In North America, this subfamily occurs in the northeast and southwest. There are currently three species found in ECAS: the relatively common, introduced *Habrocerus capillaricornis* Gravenhorst, the native *H. schwarzi* Horn, and the native but unplaced ‘*Habrocerus’ magnus’ (see above). Virtually nothing is known about the rarely collected *H. magnus*, although it shares features with known subcortical staphylinids (relatively flattened body, small globular coxae). *H. capillaricornis* is most often collected from forested areas in litter (Fig. 9.3.2), under bark, in fungi (Assing and Wunderle 1995) and in compost. *Habrocerus schwarzi* is also collected from forested areas, most often from decaying fungi in the later stages of decomposition but also from moose and grouse dung and leaf litter (Assing and Wunderle 1995). It has also been captured in great numbers in pitfall traps placed in parts of the ‘southern’ boreal forest of Québec undergoing the deciduous stage of succession (Paquin and Duperre 2001). Most records of *H. schwarzi* are from Canada and this species was found to be dependent on old growth forests (Spence et al. 1997). The diet of habrocerines is unknown.
Megalopsidiinae Leng 1920: *Megalopinus* Eichelbaum 1915

*Megalopinus* is immediately recognizable by its distinct habitus, bulging eyes occupying most of the lateral head margin, orange elytral markings, and clubbed antennae (Fig. 1.8.1). They are somewhat similar to Steninae but with antennae inserted in front of a line drawn at the anterior margin of the eyes (Fig. 1.8.1).

These beetles appear to be microhabitat specialists, living under dead logs with fungal growth (Leschen and Newton 2003). As they feign death and drop to the ground after disturbance (Leschen and Newton 2003), they are probably best collected by sifting fungussy debris under logs. Specimens have also been collected from pan traps near forest and hand-collected from fungus. Two species of this mostly tropical genus occur in the southeastern and south-central United States and reach their known northern limit in Indiana. However, they are very rarely encountered and they may eventually be found elsewhere in ECAS.

Individuals of *Megalopinus caelatus* Gravenhorst have been observed feeding on larval Diptera in the laboratory, slowly locating and capturing their prey during the day (Leschen and Newton 2003). They likely hunt invertebrates associated with fungus growing on the undersides of logs.

Micropeplinae Leach 1815: *Micropeplus* Latreille 1809

*Micropeplus* is easily recognized due to its nine segmented antennae with an enlarged terminal segment, forming a club (Fig. 1.3.1). The body is elongate oval in shape and the entire dorsal surface is covered with a variety of ridges (Fig. 1.3.1). The genus is widely distributed in North America.
In ECAS, species of *Micropeplus* can be sifted from leaf litter on the forest floor, in boggy areas (Campbell 1968), or along streams (Campbell 1973). They sometimes occur on carrion and in beaver lodges (Campbell, 1968). Sweeping field vegetation in the evening often yields specimens (Campbell 1968) that are probably dispersing. The species of *Micropeplus* are mycophagous, feeding on the spores and conidia of moulds and other fungi (Hinton and Stephens 1942; Thayer 2005).

**Olisthaerinae C.G. Thomson 1858: *Olisthaerus* Dejean 1833**

The genus *Olisthaerus* can be recognized by an elongate and parallel body, a dark head, red pronotum and abdomen, a parallel-sided pronotum, and the longitudinal striae of the elytron (Fig. 1.7.1). The genus *Siagonium* Kirby and Spence is loosely similar in appearance but is easily separated by the rows of coarse punctures on the elytra and the presence of cephalic horns in males.

Two rare Holarctic species occur in ECAS: *O. megacephalus* (Zetterstedt) and *O. substriatus* (Gyllenhal). *Olisthaerus megacephalus* differs from *O. substriatus* by the wider head and smaller, flat eyes (Fig. 9.6.1). They are found under the bark of dead conifers (Newton et al. 2000) within the boreal forest ecozone (both species) or in relict boreal forests found on mountains in New York and New Hampshire (*O. substriatus* only) (Fig. 9.6.2). In boreal forest surveys, *O. substriatus* (Paquin and Duperre 2001) and *O. megacephalus* (Hammond et al. 2004) were captured exclusively within ‘old’ (>100 years old) or old growth forests. The feeding habits of *Olisthaerus* are unknown. *Olisthaerus megacephalus* and the subfamily Olisthaerinae are newly recorded for the province of Newfoundland and Labrador.
Omaliinae MacLeay 1825

Omaliinae can be recognized easily by the presence of a pair of ocelli behind the compound eyes (Fig. 1.15.1). However, individuals of *Pycnoglypta* Thomson and *Eusphalerum* Kraatz sometimes lack ocelli. *Eusphalerum* species in ECAS are always yellowish-brown with a habitus as in Fig. 1.15.2. The two *Pycnoglypta* species in ECAS are similar in habitus to Fig. 1.15.3.

Omaliines are widely distributed in North America and can be collected year-round although the greatest diversity occurs in fall to early spring. They can be collected by sifting litter in forests and along wet areas (Fig. 9.7.1), in fungi, on flowers, in sweeps and pan traps placed in grassy areas, under stones near water (Fig. 9.7.2), and on the snow surface in late winter (Fig. 9.7.3). Some species aggregate on surfaces in fall and can be relatively conspicuous (Fig. 9.7.4). Many Omaliinae are predators (Fig. 9.7.5) or omnivores, but others seem to be strictly saprophagous or pollen-feeding.

Osoriinae Erichson 1839

Osoriines are characterized by a parallel-sided abdomen that lacks sutures on the dorsal surface (Fig. 1.17.1). The abdomen can either be flattened and with a single lateral suture (Fig. 1.17.1), or cylindrical and formed of fused tergites and sternites (Fig. 1.17.2). The only staphylinids with a similar abdomen are species of *Palaminus* Erichson (Paederinae), which do not have the last maxillary palpomere smaller than the previous
one (as in Fig. 1.17.3) and some *Stenus* Latreille (Steninae), which have large convex eyes that occupy most of the lateral head outline.

The Osoriinae is a widespread subfamily in North America but it remains taxonomically and biologically poorly known. The species inhabiting ECAS are generally found under bark, in leaf litter and in ant nests in decaying wood. Osoriinae are very poorly represented in collections of ECAS insects, possibly because they are really rare, or possibly because they are merely secretive; adults of some *Renardia* Motschulsky are winter-active under bark. The most common species in ECAS, *Thoracophorus costalis* Erichson (Fig. 9.8.1), is often found under bark (especially of large beech logs), but sometimes occurs in leaf litter and on conk fungi. Motter (1898) found a large number (up to 160 individuals) of *Eleusis pallida* LeConte adults and larvae in human graves in sandy soil, although this species too is normally found under bark. This strange report may indicate subterranean larval and/or pupal stages. Osorines are saprophagous or mycophagous as far as known.

**Oxyporinae Fleming 1821: Oxyporus Fabricius 1775**

Species of *Oxyporus* are easily recognized by their characteristic labial palpi (Fig. 1.1.2) and prognathous mandibles, which normally cross (Fig. 1.1.1). Their unique habitus makes them difficult to confuse with any other subfamily.

Widely distributed in North America, species of *Oxyporus* are associated with fleshy fungi and are almost exclusively collected from them. Both adults and larvae tear pieces of the stem and cap with their mandibles, digesting the fungus pre-orally (Hanley and Goodrich 1994). Females construct egg chambers within the host fungus and remain there after oviposition (Hanley and Goodrich 1995). Both females and males have been
observed to guard the egg chamber (Hanley and Goodrich 1995). To pupate, mature larvae drop off their host and bury themselves in the soil below (Hanley and Goodrich 1994). The common *O. vittatus* Gravenhorst (Fig. 9.9.1) utilizes a broad range of fungal host genera while *O. quinquemaculatus* LeConte (Fig. 9.9.2) exhibits a strong preference for fungi in the genus *Pluteus* Fries (Hanley and Goodrich 1995). Other species, such as *O. major* Gravenhorst (Fig. 9.9.3), are intermediate in the breadth of their host range (Hanley and Goodrich 1995). However, the larvae of all species seem to be found only from one or two host fungi (Hanley and Goodrich 1995). The males of some *Oxyporus* are dimorphic for mandible size, with the difference more pronounced in species with narrower host preferences (Hanley 2001). Hanley (2001) hypothesized that the two male types corresponded to differences in mate acquisition strategies.

**Oxytelinae Fleming 1821**

Most oxytelines can be recognized by their abdomens, which have seven fully developed sternites rather than the usual six (Fig. 1.11.1). The small tribes Euphanini and Coprophilini do not have seven sternites but, fortunately, the genera of these two tribes are distinctive in habitus (Figs 1.11.2, 1.11.3, 9.10.1). *Mitosynum* vockerothi Campbell is not illustrated in this paper but has only been collected once at the margin of a sphagnum bog in New Brunswick (Campbell 1982) and will key out with Euphaniini: *Syntomium* Curtis.

The Oxytelinae is widely distributed in North America. Species of *Bledius* Leach, the largest genus of Oxytelinae and the only members of tribe Blediini in ECAS (Makranczy 2006) burrow in sun-exposed, non-vegetated freshwater and marine shorelines where they graze upon algae scraped from particles of substrate (Herman...
1986) (Fig. 9.10.3). Females of some *Bledius* species provision for their larvae in these burrows (Wyatt 1986). *Bledius* are easily found by locating their small burrows and scooping the surrounding substrate into a pail of water; the beetle will then float to the surface.

The tribe Oxytelini contains most ECAS oxytelines (tribe Thinobiini is treated here as part of Oxytelini *sensu* Makranczy 2006), which are generally associated with decaying organic matter, leaf litter and moss. The genus *Thinodromus* Kraatz can be sifted from the litter around streams, rivers, and ponds (Fig. 9.10.2). *Anotylus* Thomson is a diverse genus in ECAS, with at least five species introduced from Europe and Asia (Fig. 9.10.4). *Apocellus* Erichson has a distinctive habitus and can be found in open grassy areas and along streams near moss (Fig. 9.10.5). Oxytelinae, in general, are best collected by bait trapping with dung, carrion, and compost, UV lighting, and sifting wet litter along riparian areas. This subfamily contains species of predators, algivores, and coprophages; some are probably saprophages or highly opportunistic omnivores.

**Paederinae Fleming 1821**

The species of Paederinae in ECAS can be recognized by the following combination of characters: a well-sclerotized postcoxal process (Fig. 1.18.3), an apical maxillary palpomere that is 1/3 the length of the previous segment or shorter (Fig. 1.18.4), or distinctively flattened and broadened (Fig. 1.18.2), a well-defined neck (Fig. 2.2.2), and the pronotal base distant from the humeral angles of the elytra (Fig. 1.18.5). One paederine genus, *Palaminus*, does not key out with the rest because it lacks sutures on the abdominal tergites. However, the characteristically shaped apical maxillary
palpomere (Fig. 1.18.2) and the fish scale-like sculpturing of the abdomen (Fig. 1.18.1) will distinguish it from all others.

Paederinae are widely distributed in North America in a variety of habitats, with a large number of species living at the margins of or near water. Two of the most conspicuous riparian genera are *Homaeotarsus* Hotchhuth (Fig. 9.11.1) and *Paederus* Fabricius (Fig. 9.11.2). Endosymbionts in the haemolymph of the latter genus produce the toxin pederin (Kellner 2001), with females of some species normally possessing up to ten times that of males (Kellner and Dettner 1995). Pederin can cause severe dermatitis if the beetle is crushed against the skin (Gelmetti and Grimalt 1993). *Astenus* Dejean is a distinctive genus normally found in wetlands and along shoreline habitat although some species prefer drier, open areas (Fig. 9.11.3). Occurring in a variety of litter and decaying organic matter, *Achenomorphus corticinus* Gravenhorst is a common species in southern Canada and eastern United States (Fig. 9.11.4); it is also attracted to lights. One of the most common staphylinids under bark in ECAS is *Sunius confluentus* (Say), a species sometimes brought indoors with recently cut firewood (Fig. 9.11.5). As far as known, all paederines are predaceous.

**Phloeocharinae Erichson 1839**

The subfamily Phloeocharinae is poorly defined and is therefore best recognized by a combination of characters shared by many other groups. The two species found in ECAS key out separately but each can be recognized by habitus alone (Fig. 1.19.6, 9.12.1). Additionally, *Charhyphus picipennis* LeConte is distinctive for its small, globular procoxae (Fig. 1.19.1), extremely flattened body and serrate lateral pronotal margins (Fig. 1.19.5). *Phloeocharis subtilissima* Mannerheim can be distinguished from
similar groups by its loosely clubbed antennae lacking long black macrosetae (as present in *Trichophyia*), lack of ocelli, and elytral epipleuron without a carina (Fig. 1.12.11).

Phloeocharines occur in western and eastern North America, but do not occur in most of the central United States. For most of ECAS, Phloeocharinae is represented only by *C. picipennis*, a species frequently found under the bark of hardwood trees (oak, beech, and others), especially in the earlier stages of decay when the sap is fermenting. Recently, the widespread Palearctic species *P. subtilissima* has been reported as established in a small park in Halifax, Nova Scotia (Majka and Klimaszewski 2004). In Nova Scotia it was collected from under and on the bark of dead trees and sometimes within the burrows of scolytine beetles (Majka and Klimaszewski 2004). Future collecting is necessary to confirm its long-term establishment in Nova Scotia and its possible establishment elsewhere. The diet of *C. picipennis* is unknown but *P. subtilissima* has been reported (in its native range) to feed on scolytine beetles within their galleries (Mazur 1995).

**Piestinae Erichson 1839:** *Siagonium* Kirby and Spence 1815

*Siagonium* can be recognized by the small, globular procoxae (Fig. 1.19.1), protibia with thick spines (Fig. 1.20.2) and the hornlike projections in front of the eyes in males (Fig. 9.13.1, major male; 9.13.2, minor male). The genus *Olisthaerus* DeJean is loosely similar in appearance but lacks the rows of coarse punctures on the elytra and does not possess cephalic horns in either sex.

The subfamily Piestinae is widely distributed in North America and represented in ECAS by three species of *Siagonium*. Very little is known about the biology of this group. All species occur under the bark of dead trees, especially conifers, and are
sometimes collected at lights. *Siagonium stacesmithi* Hatch appears to be trans-boreal in distribution and one individual was captured in a 'northern' boreal forest consisting of mature black spruce trees (Paquin and Duperre 2001). *Siagonium americanum* (Melsheimer) and the more common *S. punctatum* (LeConte) are found in a greater variety of forest types, with the latter species extending into Mexico. Although the exact diet of *Siagonium* has never been experimentally determined, its mandibles and maxillae bear striking similarity to those of the mycophagous silvanid *Dendrophagus crenatus* (Paykull) and gut contents were found to contain fungal fragments (Crowson and Ellis 1969). The mandibles of *Siagonium* and other Piestinae also possess invaginations, similar to the fungal spore-transmitting mycangia of scotyline and cucujoid beetles (Crowson and Ellis 1969).

**Proteininae Erichson 1839**

Proteininae can be recognized by the following combination of characters (Fig. 1.16.1): size small (1-3mm long), body oval with elytra at least twice as long as the pronotum and covering at least one tergite, pronotum strongly transverse (at least twice as wide as long at the base), and antennomeres 1 and 2 much wider than 3 and 4. Proteinines somewhat resemble some omaliines but always lack ocelli (proteinines do not resemble those few Omaliinae that sometimes lack ocelli).

Two genera are widely distributed in North America: *Proteinus* Latreille and *Megarthrus* Stephens. The former has the hind angles of the pronotum rounded and in the latter they are pointed (Fig. 9.14.1). Both genera can be found on decaying fungi and in leaf litter; however *Megarthrus* can also be collected from carrion and dung (Cuccodoro
and Löbl 1996). *Megarthrus* has been collected successfully with window, flight intercept, and pan traps, especially when baited with fungi, carrion, or dung. Several species of *Proteinus* were captured in pitfall traps in New Brunswick red spruce forests; two of these were recently described as new (*P. pseudothomasi* Klimaszewski and *P. acadiensis* Klimaszewski) (Klimaszewski et al. 2005). The proteinine species of ECAS are probably mainly mycophagous and/or saprophagous (Thayer 2005) but some species are at least partly predaceous on nematodes (Cuccodoro 1995).

**Pselaphinae Latreille 1802**

Most Pselaphinae are distinctive for their body shape (9.15.1), where the elytra and abdomen appear as an ‘apical section’, which is always distinctly wider than the head and pronotum (Fig. 1.4.1). In a few genera (Fig. 1.4.1, top left), the body is more linear in shape but these groups always have deep pits on the head, pronotum and elytral base, and always have clubbed antennae (Fig.1.4.1). All tarsi possess three segments. Pselaphinae loosely resemble the Scydmaeninae in body outline but the elytra of pselaphines are shorter and do not cover most of the abdomen. Pselaphinae are widely distributed in North America.

A great diversity of pselaphines can be collected in damp, forested microhabitats, and wetlands, especially if the debris is removed, sifted, and processed in a Berlese funnel. They are sometimes collected at lights. Various favoured microhabitats include leaf litter, flood debris, under bark (Fig. 9.15.2), grass clumps, in rotten logs or stumps (9.15.3), treeholes, in *Sphagnum*, and under stones (Fig. 9.15.4). Many species live occasionally or exclusively in the nests of ants and termites, feeding on the host larvae or
engaging in trophallaxis with the host ants themselves (Akre and Hill 1973). All pselaphines are predators; mostly of small arthropods such as springtails and mites but the myrmecophilous and termitophilous species derive nutrients from their host colonies (see above).

**Pseudopsinae Ganglbauer 1895: *Pseudopsis* Newman 1834**

*Pseudopsis* Newman can be recognized by its distinctive habitus (Fig. 9.16.2), longitudinal ridges on the pronotum and elytra (Fig. 1.6.1), and a last (sixth visible) abdominal tergite that is notched apically with an apical comb of setae (Fig. 9.16.1).

This genus is widely distributed in North America, with two northern transcontinental species (Herman 1975). Two species of *Pseudopsis* (*P. subulata* Herman and *P. sagitta* Herman) are known from ECAS and can only be separated by differences in male genitalia. However, individuals south of Canada are most likely to be *P. subulata*. Two undescribed species were reported from boreal forest in Québec but no diagnosis was given to distinguish them from described species (Paquin and Duperre 2001). In ECAS, *Pseudopsis* has been collected from sifted leaf litter and from underneath dung. Elsewhere the genus has been found in mammal burrows, fungi, mouldy pine cones, and in streamside litter (Herman 1975). One species, *P. sagitta*, was found to be dependent on old growth forests (Spence et al. 1997) and both species are collected in numbers in mature forests (A. Brunke personal observations). The feeding habits of *Pseudopsis* are unknown.
Scaphidiinae Latreille 1807

The Scaphidiinae have a distinctive body shape, oval in outline and highly convex (Fig. 1.2.1), with long elytra that conceal half of the abdomen or more (dead specimens often have very little abdomen visible dorsally) (Fig. 1.2.2). Other distinguishing features include the head, which is partially concealed dorsally (Fig. 1.2.1) and the antennae that arise between the eyes (Fig. 1.2.3).

Scaphidiines are widely distributed in North America and inhabit decaying wood and fungi, especially fungus-covered logs. They also occur generally in leaf litter, under bark, and in compost. This subfamily may be profitably collected by gathering leaf litter and fungi beside and under old rottting logs or stumps, sifting the coarse material, and finally processing the siftate in a Berlese funnel. Larger species can be collected easily by hand as they are slow to escape. Some species can be collected by lightly tapping on the fruiting bodies of polypore fungi and mushrooms (Fig. 9.17.1). All scaphidiines feed on fungi and/or slime moulds (Newton 1984) (Fig. 9.17.2).

Scydmaeninae Leach 1815

Scydmaeninae are best recognized by their habitus (Fig. 1.5.1) and small size (2.5mm or less) (Fig. 9.18.1), but some are similar to Pselaphinae and even some Omaliinae in which the elytra nearly cover the abdomen. However, pselaphines always have short elytra and those Omaliinae with elytra nearly reaching the abdominal apex are always much larger than 2.5mm and possess ocelli.

Scydmaeninae are widely distributed in North America and can be found in leaf litter, rotting logs and stumps, in treehole debris, moss, and under stones (Fig.
Some species are associated with ant colonies, but are probably preying upon other arthropods rather than the ants themselves (O’Keefe 2000). They are common locally (Campbell and Davies 1991) but, due to their small size, they are most often collected when deep pockets of damp litter or moss are processed in a Berlese funnel. Until recently, the Scydmaeninae were considered their own family within Staphylinoidea but are now placed within the staphylinine group of subfamilies in Staphylinidae (Grebennikov and Newton 2009). Scydmaenines are predators of orbatid mites (O’Keefe 2000), and some use their modified mandibles like a can-opener on the genital and anal plates of their prey (Schmid 1988).

**Steninae McLeay 1825**

Steninae are easily recognized by their habitus, particularly their globular eyes and cylindrical pronotum (Fig. 1.9.1). They loosely resemble *Megalopinus* (Megalopsidiinae) but in Steninae the antennae insert between the eyes and are not strongly clubbed (Fig. 1.9.3).

Two genera are widespread in North America, the very diverse *Stenus* Latreille and the rarely seen *Dianous* Leach (two similar species). *Dianous* differ from *Stenus* in having smaller but still globular eyes (Fig. 1.9.2). *Stenus* species can be collected from a variety of moist habitats but *Dianous* seems to prefer the edges of smaller, headwater streams. *Stenus* can be swept or beaten from various periaquatic plants (Fig. 9.19.1), hand-collected from the shores of lakes and ponds, sifted from debris beside streams and rivers (Fig. 9.19.2), and found under bark (Fig. 9.19.3). Some species are highly generalist in their habitat choice but others appear to prefer certain substrates or wetlands.
such as fens or seeps. Individuals of some species escape by propelling themselves across the water surface using secretions from their pygidial glands (Stevens and DeKimpe 1993). Other species can also slowly swim at the surface using lateral undulations of the abdomen. Stenines are predators of small arthropods including springtails and most use a protrusable, adhesive labium to capture prey; some species simply use their mandibles (Betz 1998). Use of the modified labium is most prevalent in species, which hunt for prey in complex vegetation (Betz 1998).

**Tachyporinae McLeay 1825**

Tachyporines can be usually recognized by their tapering abdomen, but identification should be confirmed by the following combination of characters: abdomen with six sternites (Fig. 1.12.1), elytral epipleuron with a carina (Fig. 1.14.5), neck absent (Fig. 1.11.3), procoxae similar in shape to profemora (Fig. 1.12.6), antennomeres not extremely elongate (i.e., unlike *Habrocerus*), antennae inserted in front of the eyes (Fig. 1.12.2), pronotal margins smooth, and dorsal abdomen margined (Fig. 1.12.5) (except in one genus with a strongly tapered abdomen [Fig. 1.14.2]).

Tachyporines are widespread in North America and these small to medium-sized Staphylinidae are most often noticed as they disperse to their preferred microhabitat. Common species that are relatively general in their habitat requirements include *Tachinus corticus* Gravenhorst, found in leaf litter, fields, decomposing organic matter, and under stones (Fig. 9.20.1), and *Sepedophilus littoreus* (L.), found in rotting wood, compost, flood debris, under loose bark, and in rotting fungi (Fig. 9.20.2); both species are native to Europe. *Coproporus ventriculus* (Say), is a very common native species
found under the bark of both deciduous and coniferous trees, especially when slime
moulds are present (Fig. 9.20.3). Sifting or flooding patches of leaves or very wet
sphagnum moss near creeks, bogs, or waterfall areas will sometimes yield Nitidotachinus
scutator (Gemminger & Harold), (Fig. 9.20.4). Many genera of Tachyporinae, including
the common Lordithon kelleyi (Mälkin) (Fig. 9.20.5), can be collected from various types
of fungal fruiting bodies. Some species of Tachyporus Gravenhorst inhabit prairies, old
fields, and agricultural crops where they can by swept from the vegetation in the evening
(Fig. 9.20.6). Tachyporines can also be found in dung, in carrion, and along the margins
of lakes and ponds. They are readily sampled from litter and fungi using a sifter. Some
tachyporines are exclusively predaceous or mycophagous but many appear to be largely
opportunistic on both arthropods and fungi.

Trichophyinae C.G Thomson 1858: Trichophya pilicornis (Gyllenhal 1810)

Trichophya pilicornis can be recognized by a combination of the characteristic
antennae (Fig. 1.21.2), the heavily setose dorsal surface, body widest at elytra and the
distinct neck (Fig. 1.22.1). This species resembles some Tachyporinae but possesses
specialized antennae and strongly enlarged first and second antennomeres (Fig. 1.21.2).

This species also occurs in the Palearctic region and is suspected of being
introduced into northeastern North America via human activity (Ashe and Newton
1993). It was first recorded in 1895 from New York and was known from Canada
(Ontario) by 1905 (Ashe and Newton 1993). Unlike most other non-native Staphylinidae,
it is very common in the boreal forest (Paquin and Duperre 2001) and apparently less
common south of this ecozone. Trichophya pilicornis can be collected by sifting leaf
litter (Fig. 9.21.1) or by pitfall trapping. Species of *Trichophya* are mycophagous and facultatively predaceous (Ashe and Newton 1993).

3.10. The tribes and subtribes of Staphylininae in ECAS

**Diochini Casey 1906: Diochus schaumi Kraatz 1860**

*Diochus schaumi* is distinctive among Staphylininae for its combination of a thin neck (about ¼ the width of the posterior head) (Fig. 2.3.1), broad and flattened pronotum, and elytra that do not overlap (Fig. 10.1.1). This species is variable in colour (Fig. 10.1.2).

This species is widely distributed in eastern and southern North America, but is not found west of the Rocky Mountains (Smetana 1982). Its distribution is distinctly south of the boreal forest region and is most typically found in forests with southern characteristics (Map 1). Data from Map 1 includes localities found in Smetana (1982).

Eastern Canada: ON, QC
Adjacent U.S: WI, MI, IN, OH, PA, NY, NH, ME

*Diochus schaumi* has been collected in ECAS from March to December, with most individuals collected in April and May. However, copulation occurs in fall, as late as November (Fig. 10.1.3).

This species is frequently collected by sifting litter and other debris in wet areas including slough forests, swamps, marshes, and bogs. Smetana (1982) also reported it from the nests of *Microtus pennsylvanicus* (meadow vole) and from ‘debris at the base of grass tufts’.
Map 1. Distribution of *Diochus schaumi* Kraatz in eastern Canada and adjacent United States. Records include data from Smetana (1982).
Othiini C.G. Thomson: *Atrecus* Jacquelin du Val 1856

*Atrecus* is distinguished from other Staphylininae by the following combination of characters: a pair of plates anterior to the prosternum (Fig. 2.1.2), thick neck (Fig. 2.4.1), antennal bases closer to each other than to the nearest eye (Fig. 2.4.1), mandibles projecting forward (Fig. 2.4.1), and elytra not overlapping (Fig. 10.2.1).

Two species occur in ECAS (*A. americanus* (Casey) and *A. macrocephalus* (Nordmann)) mainly under the bark of coniferous trees (Fig. 10.2.2). They can sometimes be collected in debris around the bases of old trees (Smetana 1982). *Atrecus* is transcontinental in Canada and occurs in eastern and western United States. This genus was revised by Smetana (1982) and will be reviewed in a future publication on Othiini and Xantholinini.

Anisolinina Hayashi 1993: *Tympanophorus puncticollis* (Erichson 1840)

*Tympanophorus puncticollis* can be distinguished from other Staphylininae by the combination of a neck with coarse lateral punctures (Fig. 2.2.12), lack of plates anterior to the prosternum, elytra that do not overlap (Fig. 10.3.1), small head (Fig 2.2.12), and hoof-like apical labial palpomere (Fig. 2.2.14). The distinctive labial palpi will quickly distinguish this species from all other Staphylininae.

This species is transcontinental in Canada in the boreal ecozone; it inhabits more southern forests in eastern North America, occurring west to Minnesota and as south as Alabama. Its range in ECAS is given by Map 2. *Tympanophorus puncticollis* is newly recorded from Indiana, Pennsylvania and New York:
Map 2. Distribution of *Tympanophorus puncticollis* (Erichson) in eastern Canada and adjacent United States.


Eastern Canada: ON, QC, NB, NS, NL

Adjacent U.S.: MI, IN, PA, ME, NY, NH

*Tympanophorus puncticollis* has been collected in ECAS from May to September with an increase in abundance occurring in June-July.

This species is rarely collected and consequently very little has been published about its natural history. The scant habitat data suggest that it occurs in moist (with ferns) or boggy areas within forested habitat but it has also been collected at the mouth of a fox burrow, along a cobblestone shoreline of a lake, in a 'lumber yard', and in rotting sawdust in an abandoned sawmill (Fig. 10.3.2). Specimens have been caught by pitfall, window pane, and raised malaise (six feet high) traps, suggesting that it is highly mobile. One individual was extracted from moss on a dead balsam fir using a Berlese funnel (Paquin and Duperre 2001) and *T. puncticollis* was newly reported from Maine by Majka et al. (2011) from a black spruce plantation. Paquin and Duperre (2001) suggested a possible association with the forest canopy as several individuals were captured in their canopy funnel traps.
**Philonthina Kirby 1837**

Members of the subtribe Philonthina can be recognized among the Staphylininae by the following combination of characters: elytra not overlapping, without plates anterior to the prosternum, neck present and impunctate (Fig. 2.2.2), antennae closer to the nearest eye than to each other (Fig. 2.2.3), punctures of pronotum either not arranged in dorsal rows or these rows consisting of at least 4 punctures (Fig. 2.2.6), and without empodial setae between the tarsal claws (Fig. 2.2.8).

Philonthina is a widespread and diverse subtribe of Staphylininae in North America that was revised by Smetana (1995), Frank (1975) and Frank (1981) and contains many abundant species that are associated with human activity. One large species, *Philonthus politus* (L.), is often found in compost, around livestock, and on carrion (Fig. 10.4.1). *Philonthus caeruleipennis* Mannerheim is a common species found in rotting organic (especially fungi) matter in or near forests; this one (Fig. 10.4.2) was found in a compost heap in a wooded backyard. *Bisnius blandus* (Gravenhorst), a forest specialist, occurs mainly in rotting fungi but also at carrion (Fig. 10.4.3). These and many other Philonthina can be captured in abundance using pitfall or pan traps baited with dung, mushrooms, or carrion. Some species are associated with older trees: adults and larvae of *Hesperus apicialis* (Say) can be collected from debris in old tree holes and stumps (Fig. 10.4.4), and *Laetulonthus laetulus* (Say) is attracted to large, freshly killed trees where it hunts invertebrates attracted to sap (Fig. 10.4.5). The majority of Philonthina species in ECAS inhabit moist debris near or at the edge of lakes, ponds, rivers, and streams. Sifting this debris often yields many *Erichsonius* Fauvel species, the
largest in ECAS being *E. rosellus* Frank (Fig. 10.4.6). The biology, identification and distribution of ECAS Philonthina will be reviewed in a future publication.

**Quediina Kraatz 1857**

Members of the subtribe Quediina can be recognized among the Staphylininae by the following combination of characters: elytra not overlapping, without plates anterior to the prosternum, neck present, impunctate and usually very broad (Fig. 1.12.8), antennae closer to the nearest eye than to each other (Fig. 2.2.3), pronotum impunctate or with dorsal rows of three or fewer punctures (Fig. 2.2.7), with empodial setae between the tarsal claws (Fig 2.2.9) and last maxillary palpomere not distinctly narrower than the preceding (Fig. 1.12.8).

The Quediina in the classic sense have been shown to be an artificial grouping of genera (Solodovnikov and Schomann 2009, Chatzimanolis et al. 2010) but all included genera occurring in ECAS, except *Heterothops*, belong in this subtribe *sensu* Chatzimanolis et al. (2010); *Heterothops* has been placed in the subtribe Amblyopinina. Species of this group were revised by Smetana (1971a) and inhabit a diversity of habitats similar to those frequented by Philonthina but most are quite infrequently collected relative to the latter. One commonly encountered species is *Quedius plagiatus* (Mannerheim), which occurs under the bark of conifers, beech, and larger birch trees (Fig 10.5.1). *Quedius mesomelinus* (Marsham) is a European species often found in compost, gardens, and rotting fungi (Fig. 10.5.2). Some Quediina are strongly associated with the edges of lakes, wetlands, and streams. Sifting or treading old rotting leaves, moss, and other debris at these edges will often yield many individuals of *Acylophorus* Nordmann, distinctive in Staphylinini for its elbowed antennae (Fig. 10.5.3). Several species of
Quediina are obligate or frequent inhabitants of beaver and muskrat lodges; *Hemiquedius ferox* (LeConte) is commonly encountered this way but also occurs in debris along lakeshores and in bogs (Fig. 10.5.4). The species of Quediina will be covered in greater detail in a future publication.

**Tanygnathinina Reitter 1909: *Atanygnathus bicolor* (Casey 1915)**

*Atanygnathus bicolor* can be easily recognized among the Staphylininae by the lack of a visible neck, elongate maxillary palpi (Fig. 2.2.5), and its unique habitus (Fig. 1.12.12). It is also unique for its 5-4-4 tarsal formula. In overall appearance, it loosely resembles some Tachyporinae but lacks an epipleural ridge on the lateral portion of the elytron (Fig. 1.12.11).

This species is distributed mainly in the south-central and southeastern United States, extending along the east coast to New Hampshire and westward to Michigan. It is newly recorded from Canada (Ontario) from a single specimen collected in Algonquin Provincial Park, and from the state of Michigan, both considerable distances from the northernmost record previously known in New Hampshire (Smetana 1990) (Map 3).


**UNITED STATES: MI**: *Berrien Co.*, Mud Lake Bog, 28-IV-1984, sphagnum, L. E. Watrous, 10 (FMNH).

Eastern Canada: ON

Adjacent U.S.: NH, MI
Map 3. Distribution of *Atanygnathus bicolor* (Casey) in eastern Canada and adjacent United States. Records include data from Smetana (1990).
Based on the small number of specimens from ECAS, this species appears to have both a spring and late summer/fall peak in adult activity.

This species is strongly associated with very wet moss and debris in wetlands and lakes (Smetana 1971a). Specimens have been sifted from grass, sphagnum and litter in bogs, 'swept from grass by a pond' (Smetana 1990), and collected in a pan trap placed in a sphagnum mat on a lake. The specimens from Ontario and Michigan likely represent true populations for an otherwise southeastern species, as they were collected in the typical specialized habitat and further collecting may reveal that *A. bicolor* occurs broadly across ECAS.

**Amblyopinina Seevers 1944: Heterothops Stephens 1829**

The genus *Heterothops* can be recognized by the combination of: elytra not overlapping, without plates anterior to the prosternum, neck present, impunctate and usually very broad (Fig. 1.12.8), antennae closer to the nearest eye than to each other (Fig. 2.2.3), pronotum impunctate or with dorsal rows of three or fewer punctures (Fig. 2.2.7), with empodial setae between the tarsal claws (Fig 2.2.9) and last maxillary palpomere distinctly narrower than the preceding (Fig. 2.2.11) – compared with that of Quediina (Fig. 1.12.8).

*Heterothops* is the only representative in ECAS of the otherwise south-temperate Amblyopinina. This genus is broadly distributed in North America and has the highest diversity in the West. *Heterothops* are generally rarely collected and sifting moist litter is the most productive method to obtain specimens. *Heterothops fusculus* (LeConte) is an easily recognized, large *Heterothops* (Fig. 10.7.1) that can be found in yard compost in addition to more natural habitats, while the other four species in ECAS are darker and
more obscure. One of these species, *Heterothops marmotae* Smetana, has only been collected in groundhog (*Marmota monax*) burrows in the vicinity of Ottawa, Ontario, Canada (Smetana 1971b). It is surely more widespread but its apparently restricted habits have probably prevented its collection elsewhere. The species of *Heterothops* were revised by Smetana (1971a) and will be reviewed in a future publication.

**Xantholinini Erichson 1839**

Xantholinini may be easily recognized among the Staphylininae by their slender, linear habitus (Fig.10.8.2), thin neck (Fig.2.1.2), overlapping elytra (Fig.2.1.1), elbowed antennae (Fig.10.8.2), and a pair of plates anterior to the prosternum (also in Othiini) (Fig.2.1.2).

This is a poorly collected group that is broadly distributed in North America. Species of Xantholinini generally live within litter or in decaying organic matter and are therefore best collected by sifting different types of litter or debris. Passive methods of collection such as Winkler extractors or Berlese funnels are even more effective as many species adopt a coiled position upon disturbance and remain motionless for a long time (for a detailed account of this behaviour see Yamazaki 2007). *Stictolinus flavipes* (LeConte) (Fig. 10.8.1) and *Lithocharodes longicollis* (LeConte) (Fig. 10.8.2) are both commonly collected in various types of litter using these passive techniques. In contrast, species associated with livestock or compost are more active and are easily collected in great numbers using an aspirator or soft forceps. Two such species include the introduced *Gyrohypnus fracticornis* (O.F. Müller) (Fig. 10.8.3) and *Gauropterus fulgidus* (Fab.) (Fig. 10.8.4). Peeling the bark of conifer or beech trees will usually yield individuals of the native *Nudobius cephalus* (Say) (Fig. 10.8.5). Some species including *Oxybleptes*
kiteleyi Smetana have only be captured in small numbers by using flight intercept or pan traps in open areas with large trees (Fig. 10.8.6). The biology of these and most Xantholinini remains very poorly known. The species were revised by Smetana (1982) and will be reviewed in an upcoming publication.

3.11 The species of Staphylinina in ECAS

*Creophilus maxillosus* (Linnaeus 1758)

*Creophilus maxillosus* is easily distinguished from other Staphylinina by its largely impunctate pronotum (Fig. 3.1.1) and thick covering of black and yellow setae (Fig. 11.1.1). It cannot be confused with any other species of the subtribe.

This is a very widespread species, which occurs across North America, northern Central America, the West Indies, the entire Palearctic region (Newton et al. 2000), Chile, Argentina (Navarrete-Heredia et al. 2002), and Peru (Asenjo and Clarke 2007). Its range in ECAS is given by Map 4.

Eastern Canada: ON, QC, NB, NL, NS, PE (All ECAS Provinces)
Adjacent U.S.: MI, IN, OH, PA, NY, VT, NH, ME (All ECAS States)

In ECAS, *Creophilus maxillosus* has been collected from February to December, with no apparent seasonality. This species overwinters as an adult.

Adults and larvae of this species are found primarily on carrion of all kinds and rarely on dung, compost, or at UV lights. Larvae are typically found on larger, more persistent carrion. *C. maxillosus* inhabits grassy and open forested habitats and is often encountered on lake and ocean shorelines (Majka et al. 2008). Adults and larvae are
Map 4. Distribution of *Creophilus maxillosus* (L.) in eastern Canada and adjacent United States.
predators, mainly of maggots and adult flies, but also of other arthropods attracted to carrion. Adults will form their bodies into a tight ball and roll off carrion into leaf litter when disturbed (Fig. 11.1.2). For defense against other arthropods, *C. maxillosus* has an eversible Y-shaped gland at the apex of the abdomen that produces iridodiols and other repellant compounds (Huth and Dettner 1990). Other species of Staphylinina also have this gland and produce similar secretions dominated by iridodial (Huth and Dettner 1990).

Two subspecies occur in ECAS: the native and widespread *villosus* Gravenhorst and the Palearctic *maxillosus* L., which is known from scattered records from Ontario, Québec, and Massachusetts as early as 1929 (Québec). *Creophilus m. maxillosus* can be most reliably differentiated from *C. m. villosus* by the dark pubescence on the hind angles of the head (Fig. 11.1.3), which is pale yellow in the native subspecies (Fig. 11.1.4).

*Dinothenarus badipes* (LeConte 1863)

*Dinothenarus badipes* is distinguished from other species of Staphylinina in ECAS by its entirely black body (Fig. 4.2.1), entirely orange legs (Fig. 11.2.1), golden setae at the bases of each abdominal segment (Fig. 3.4.3) and a spindle-shaped apical maxillary palpomere (Fig. 3.4.4). *Ocypus brunnipes* Fab. is similar in colouration but lacks the golden abdominal setae and its apical maxillary palpomere is rectangular.

This species is broadly distributed over eastern North America. Its range in ECAS is given in Map 5. It is newly recorded from the province of Prince Edward Island:
Map 5. Distribution of *Dinothenarus badipes* (LeConte) in eastern Canada and adjacent United States.

Eastern Canada: ON, QC, NB, NS, PE
Adjacent U.S.: MI, IN, PA, NY, VT, NH, ME

This is a common species that has been collected from under logs and stones, leaf litter, moss, and loose bark in a wide variety of habitats including forests, the shores of wetlands and lakes, along streams and rivers, orchards, oak savannah, and tallgrass prairies. However, *D. badipes* does not occur in the boreal forest, though it may occasionally occur in transition areas. This species is rarely found at carrion traps. Snider (1984) successfully cultured *D. badipes* on a diet consisting solely of millipedes, but this species is likely a generalist predator of ground-dwelling arthropods and it is also known to consume adult click beetles (Hawkins 1936).

*Dinothenarus capitatus* (Bland 1864)

*Dinothenarus capitatus* is easily distinguished from other Staphylinina by its reddish-orange head and darker body (Fig. 3.4.2). Specimens with heads secondarily darkened due to chemical killing agents or drying (Fig. 4.1.1) can be identified to *Dinothenarus* using the characters in the key, and distinguished from *D. badipes* (LeConte) by the variegated pattern of light and dark setae on the dorsal pronotum, and the dark tibiae (Fig. 3.4.2).
This species is transcontinental in Canada and occurs as far south as West Virginia in the eastern United States. Its range in ECAS is given in Map 6.

Eastern Canada: ON, QC, NB, NL, NS
Adjacent U.S.: MI, OH, PA, NY, VT, NH, ME

*Dinothenarus capitatus* is collected in ECAS from April to November, with peaks in abundance in May and August-September.

This forest-inhabiting species has been collected primarily on the dung of various mammals or on carrion, but sometimes occurs on decaying fungi. It can be sifted from forest litter and, although it has occasionally been collected in disturbed areas as it disperses between forest patches, it is a strong indicator of undisturbed forest conditions (Klimaszewski et al. 2008) and many specimen labels bear the words "mature" or "old growth forest". The current range of *Dinothenarus capitatus* in ECAS appears to be shrinking relative to its historical distribution, especially near developed areas.

*Ocypus brunnipes* (Fabricius 1781)

*Ocypus brunnipes* can be easily recognized by its all black body and dull orange legs (Fig. 5.1.1). The only similar species is *Dinothenarus badipes* (LeConte), from which it can be distinguished by the lack of golden setae at the bases of the abdominal segments (Fig. 3.6.3), and by its rectangular apical maxillary palpomere (Fig. 3.6.2).

This species is native to Europe, Russia, the Caucasus, and Turkey (Herman
Map 6. Distribution of *Dinothenarus capitatus* (Bland) in eastern Canada and adjacent United States.
2001) and has been accidentally introduced into North America, where it is so far recorded only from New Hampshire and Massachusetts (newly reported) (Map 7).

**UNITED STATES: MA:** *Essex Co., Ipswitch, 42.68\(^\circ\)-70.85\(^\circ\), 26-VII-1973, L.L. Pechuman, 1 (CUIC).*

Both North American collections of *O. brunnipes* have been in late summer. This non-native species was first recorded from North America by Newton (1987), based on a single collection of one male and one female from New Hampshire in 1966. In 1973 this species was collected again (1 male) but this time from Massachusetts. *Ocypus brunnipes* may be established in New England at very low densities. This species is flightless and inhabits both forested and open, disturbed areas in its native Palearctic range (Deichsel 2006).

**Ocypus nitens (Schrank 1781)**

*Ocypus nitens* is unique among the Staphylinina in ECAS for its combination of black body, black legs, and distinctively short elytra (distinctly shorter than the pronotum when measured at the middle) (Fig. 3.6.1).

This species is native to Europe, Russia, the Caucasus, Turkey, and Iran (Herman 2001). Its range in North America is mostly limited to the coastal northeastern United States and we record it here for the first time from Maine and New York. Its range in ECAS is given in Map 8.
Map 7. Distribution of *Ocypus brunnipes* (Fab.) in eastern Canada and adjacent United States.

Adjacent U.S.: NY, NH, ME

This species has been collected in North America year-round, with a large peak in abundance in April-May and a smaller peak in September. *Ocypus nitens* is a non-native species that was first reported in North America from Massachusetts and southeastern New Hampshire (Newton 1987). It was first collected in Massachusetts in 1944 from sifted debris and has since become common in forested and open habitat in Massachusetts and New Hampshire (Fig. 11.5.1). This species is also found at carrion-baited pitfall traps and often wanders into dwellings. It has similar habits in its native range (Balog et al. 2003) and is pronouncedly synanthropic. All examined specimens with exposed hind wings were brachypterous. *Ocypus nitens* has since expanded its range to Maine by 1989, Rhode Island by 1995 (Sikes 1995) and New York by 2010. This species will likely continue to spread westwards into eastern Canada in the near future.

*Ontholestes cingulatus* (Gravenhorst 1802)

*Ontholestes cingulatus* can be distinguished from other Staphylinina by its distinctive golden abdominal apex (Fig. 6.1.1). Older, contracted, or dirty specimens may
Map 8. Distribution of *Ocypus nitens* (Schrank) in eastern Canada and adjacent United States.
be identified to *Ontholestes* by the sharp anterior angles of the pronotum (Fig. 3.2.1) and distinguished from *O. murinus* (L.) by the bicoloured legs and antennae (Fig. 11.6.1).

This species is transcontinental in Canada and occurs in the central and eastern United States. Although this species is widespread, it had not been officially recorded from Michigan, Ohio, Vermont, or Prince Edward Island. Its range in ECAS is given by Map 9. The occurrence of *Ontholestes cingulatus* in these states and province is confirmed based on numerous historical and recent collections.


Adjacent U.S.: MI, IN, OH, PA, NY, VT, NH, ME (All ECAS states)

Eastern Canada: ON, QC, NB, NL, NS, PE (All ECAS provinces)
Map 9. Distribution of *Ontholestes cingulatus* (Gravenhorst) in eastern Canada and adjacent United States.
*Ontholestes cingulatus* has been collected in ECAS from February to September, with a peak in abundance in May-June. This species is common and most often collected on dung and smaller carrion but also regularly occurs in decaying fungi and in compost piles. This species is a strong flier and is captured frequently in flight-intercept and malaise traps, and infrequently at UV lights.

Males guard recently mated females as they oviposit, chasing and 'grappling' with any males that approach her (Alcock 1991). Mating occurs with males on top of females and both sexes facing the same direction (Alcock 1991); quite different from smaller staphylinids that typically mate end-to-end. Both larvae and adults can be reared on a diet of muscoid flies (Schmidt 1999). *Ontholestes cingulatus* was considered a moderate indicator of undisturbed forest by Klimaszewski et al. (2008) and was observed to prefer shaded carrion by Hobischack et al. (2006); however, collection data suggest it also occurs in open forests and backyards.

*Ontholestes murinus* (Linnaeus 1758)

Among the species of Staphylinina, *Ontholestes murinus* can be identified to genus by its acute anterior pronotal angles (Fig. 3.2.1) and distinguished from *O. cingulatus* (Gravenhorst) by the dark legs, completely pale antennae and apex of the abdomen with silver setae (Fig. 6.2.1).

This species is native to Europe, Russia, Georgia, Armenia, Turkey, Iran, Kazakhstan, Kyrgyzstan, and China (Herman 2001). In North America, it is only known from the Avalon Peninsula of Newfoundland (Map 10) where it has been collected in May to September.
Map 10. Distribution of *Ontholestes murinus* (L.) in eastern Canada and adjacent United States.
North American specimens of *Ontholestes murinus* were first collected in 1949 in a meadow, on cow dung and in a barn (Smetana 1981). One additional specimen was collected in 1986 and the continued establishment of this exotic species needs reaffirmation.

**The *Platydracus cinnamopterus* Complex**

**Diagnosis:**

Small (12-19 mm), slender, parallel-sided *Platydracus*; body and appendages generally light to dark reddish brown, uniformly colored or not on head and pronotum to always variegated on abdomen, with darker venter (except abdominal apex, more or less reddish) and black scutellum; pubescence light to dark, on abdomen forming more or less distinct, paired black pubescent lines near middle and diffuse lighter pubescence laterally; head and pronotum with dense umbilicate punctures except for a complete mid-longitudinal impunctate line on the pronotum at least one puncture diameter wide; antenna pubescent from 4th antennomere; mandibles stout, apically acute, each bearing three stout median teeth (two dorsal, one ventral on left, one dorsal and two ventral on right mandible, in both cases with only two teeth visible in dorsal view); mentum brown, sclerotized, anterior edge emarginate; pronotum about as wide as long; sutural length of elytra about 0.6 times as long as pronotum; protibia usually with two stout setae in row on external edge and one posteriorly; apex of 6th visible abdominal sternite in male with broadly rounded emargination, in female with broadly rounded, non-emarginate apex, sexual dimorphism otherwise absent externally and limited to venter of genital segment and genitalia; aedeagus not or very inconspicuously asymmetrical.
A species known as *Staphylinus* or *Platydracus cinnamopterus* (Gravenhorst) meeting the above diagnosis was for nearly two centuries considered the most common and widespread *Platydracus* species in eastern North America. In the early stages of a revision of this genus for the New World, it became apparent to the second author (Newton 1973) that three species with quite different male genitalia were being confused under this name. After further study of type material of all relevant names, including several that were long considered synonyms of *P. cinnamopterus*, it was established that two of the species had available names and the third was undescribed. The three species are broadly sympatric in eastern North America and all occur within at least the southern part of ECAS. They are closely similar externally and difficult to distinguish (especially older or darker specimens in poor condition) without use of male genitalia (but see external characters in key). In order to clarify the status of the available names and allow recognition of these species, the new species (*P. praetermissus* Newton, spec. nov.) is formally described here and the other two species (*P. cinnamopterus* and *P. zonatus*, both Gravenhorst 1802) are redescribed and their identities fixed by review of type material, including designation of lectotypes where necessary.

*Platydracus cinnamopterus* (Gravenhorst 1802)

*Staphylinus cinnamopterus* Gravenhorst, 1802: 164; *Platydracus cinnamopterus*: Newton 1973, Smetana and Davies 2000, Herman 2001, etc. (see Herman 2001: 3447 for additional literature citations)

**Type material:** Lectotype, male, in ZMHB, here designated by Newton, with labels: "5959" [white printed label]; "cinnamopterus Gr. Am. Spt." [green, bordered,
handwritten label]; and red lectotype designation label by Newton dated 1978.
Paralectotypes: 1 male and 2 females, in ZMHB, with no original labels, each with yellow paralectotype designation labels by Newton dated 1978.

Other material examined: 1386 specimens throughout the range of the species, all but a few being males with examined aedeagus. Full data will be presented in the pending revision of *Platydracus* by Newton, but all records that could be georeferenced are shown in Map 11.

**Description:**

With the characters of the *P. cinnamopterus* Complex (see above), plus: average pronotal length 2.53 mm (n = 10); head, pronotum and elytra usually light to medium reddish, less often dark red, pronotum evenly colored; antenna not reaching middle of pronotum when extended posteriorly, antennomere 9 distinctly transverse; impunctate median line of pronotum at least one puncture diameter wide at narrowest point, usually about two puncture diameters wide; emargination of sixth visible male sternite in ventral view moderately deep, about 1/4 as deep as wide; apex of median lobe of aedeagus projected, the converging sides of the projection in parameral view slightly convex and forming an acute angle, the apex broadly rounded; sides of median lobe in lateral view even, not toothed.

*Platydracus cinnamopterus* may be distinguished from all other species of the genus in ECAS by the combination of generally reddish color (light to very dark) with uniformly colored head and pronotum (Fig. 7.9.1, 7.9.4), black scutellum, and variegated
Map 11. Distribution of *Platydracus cinnamopterus* (Gravenhorst).
abdomen with sparse gold setae only, and paired, patches of black velvet setae on the first five visible segments (Fig. 7.9.2); antennae with distinctly transverse antennomere 9 (Fig. 7.9.7); and the narrow but complete impunctate medial line of pronotum about 2 puncture diameters wide at narrowest (Fig. 7.9.5). However, it is definitively distinguished from the other members of the *P. cinnamopterus* Complex, *P. praetermissus* and *P. zonatus*, by the structure of the aedeagus (Fig. 7.9.6 and 11.8.2).

The species is widely distributed in the forested areas of eastern North America: from Nova Scotia, west to southern Manitoba, south to Texas and east to the Florida panhandle (Map 11). Its range in ECAS is shown in greater detail in Map 12. Note that historical records of *P. cinnamopterus* in the literature up to the present time are unreliable since they may refer to any of the three species of the *P. cinnamopterus* Complex.

Eastern Canada: ON, QC, NB, NS
Adjacent U.S.: MI, IN, OH, PA, NY, NH, ME

In ECAS, *P. cinnamopterus* has been collected from January through November, with a majority (55%) found in May or June.

This common species is most frequently found under the loose bark of hardwood trees but is also collected in leaf litter, under stones and logs and in rotten wood. It also frequents decaying plant matter such as flood debris (Fig. 11.8.1) and grass clumps. Other specimens have been collected on beaches of the Great Lakes under drift, from fungi, at a UV light, and from a beaver lodge. Unlike the other two species of the
Map 12. Distribution of *Platydracus cinnamopterus* (Gravenhorst) in eastern Canada and adjacent United States.
complex, *P. cinnamopterus* is often found in disturbed areas under patio stones, in gardens and in compost. The relatively short antennae compared to the other members of the *cinnamopterus* complex may be correlated with greater maneuverability within subcortical microhabitats and under objects. The presence of a rufous morph (Fig. 7.9.4) is unique to *P. cinnamopterus* within the *cinnamopterus* Complex. The description of larvae and pupae of this species by LeSage (1977) may be correctly assigned to *P. cinnamopterus* since over 85% of the specimen records of the *P. cinnamopterus* Complex from Ontario and Québec are *P. cinnamopterus*, and *P. praetermissus* n. sp. is not known from Canada.

*Platydracus comes* (LeConte 1863)

*Platydracus comes* may be distinguished from other species of the genus in ECAS by the combination of elongate, dark spots on the elytra (Fig. 7.5.1), the median line of golden setae on the scutellum (Fig. 7.5.1), and the complete impunctate median line of the pronotum (Fig. 7.5.2). This species is easily confused with the similarly coloured *P. maculosus* (Gravenhorst) (Fig. 11.9.1) but it is much smaller (13-19 mm) and has a complete impunctate median line of the pronotum.

This species is eastern in distribution, with most specimens collected in the southeastern United States. It reaches the northern limit of its distribution in ECAS (Map 13), with most of the northeastern records pre-1940. *Platydracus comes* is newly recorded from Ohio based on these records.
Map 13. Distribution of *Platydracus comes* (LeConte) in eastern Canada and adjacent United States.

The tentative record of Platydacus comes from the province of Québec listed in Campbell and Davies (1991) as ‘?’ represents a misidentification of P. viridanus. Platydacus comes probably does not occur regularly in Canada, but occasional migrant individuals might be found in southernmost Ontario.

Adjacent U.S.: IN, OH, PA, NY

In ECAS, Platydacus comes has been collected in July to September, with nearly all specimens taken in July.

This species lives in pine or mixed-pine forests, usually occurring with dung and carrion communities and infrequently collected at compost-baited traps or UV lights.

**Platydacus exulans** (Erichson 1839)

*Platydacus exulans* is distinguished from congeners by its bronze-green metallic head and pronotum (Fig. 11.10.1), and the unevenly spaced pronotal punctures (Fig. 7.2.1). The only other Platydacus with uneven pronotal punctures is *P. praelongus*, however, *P. exulans* differs by the narrower median impunctate area of the pronotum (Fig. 7.5.2) and by general habitus. The metallic colour gives it some similarity to *P.*
Map 14. Distribution of *Platydracus exulans* (Erichson) in eastern Canada and adjacent United States.
viridanus but the latter has evenly spaced pronotal punctures and a different abdominal pubescence pattern.

*Platydracus exulans* is an eastern species, occurring as far north as Ontario and extending southwest to Louisiana. Its range in ECAS is given by Map 14. This species is newly recorded from Michigan, Ohio, and Pennsylvania. It was reported from Québec by Downie and Arnett (1996) without data, but we have seen no specimens from that province and this record is probably based on a misidentified specimen.

**UNITED STATES: MI:** Ingham Co., East Lansing, 42.7333 -84.4833, Date Unknown, C.F.B, 1 (FMNH). **OH:** Hamilton Co., Cincinnati, 39.1 -84.52, V-1934, 1 (UMMZ).


*Westmoreland Co.*, Jeannette, 40.3333 -79.6166, 14-IV-1931, 1 (FMNH); 16-IV-1931, 2 (AMNH), 1 (FMNH).

Eastern Canada: ON

Adjacent U.S.: IN, MI, NY, OH, PA

*Platydracus exulans* has been collected from late March to late June, with the majority of records in April and May.

Most available specimens with collection data are from dung or dung-baited pitfall traps in mixed oak-pine forest. However, Newton (1973) reported it from carrion, including opossum, chicken, and rabbit. Watson (2004) found this species in Louisiana on carcasses of alligator, bear, deer, and pig during the winter and spring. *Platydracus*
exulans was found most frequently on pig carcasses in the advanced to dry stage of decay (Watson 2004). Newton (1973) suggested that the relatively early season occurrence and scant appearance at baits may indicate that P. exulans dwells primarily within vertebrate nests or a similar microhabitat.

This species has been collected twice in Ontario, both times in the same location near Ottawa but forty-four years apart. Further collecting is needed to determine whether the Canadian specimens of P. exulans represent sporadic migrants or part of a stable Canadian population.

Platydracus femoratus (Fabricius 1801)

Platydracus femoratus is easily recognized by the large eyes, which are about twice as long as the temple (Fig. 7.1.1). Although the specimen figured in Fig. 11.11.1 has its abdominal apex paler, most North American individuals of this species have a uniformly coloured abdomen.

Platydracus femoratus is distributed broadly from Pennsylvania to Brazil, but occurs only sporadically in ECAS (Map 15); it is unlikely that it will be encountered in Canada. Individuals collected in ECAS are probably migrants from the southern United States where they regularly occur. This species is newly recorded from Pennsylvania:

Map 15. Distribution of *Platydracus femoratus* (Fab.) in eastern Canada and adjacent United States.
Adjacent U.S.: IN, OH, PA

Specimens in ECAS have been taken in May to October with no apparent pattern in seasonality.

This species is most frequent at dung but also often occurs on carrion. Several specimens have been collected in rotting fruit and at lights.

**Platydracus fossator** (Gravenhorst 1802)

Individuals with the typical apical orange spot on the elytron are distinguished from other Staphylinina (Gravenhorst) by that character alone (Fig. 7.8.1). Specimens lacking the spot (with a completely black body) are identified as *Platydracus* using the characters in the key, and to *fossator* using the following combination of characters: elytra completely black (Fig. 7.8.2), abdomen lacking dense patches of golden or black velvet setae (Fig. 7.8.2), pronotum lacking complete impunctate median line (Fig. 7.6.2), and eyes distinctly longer than the temple.

This species is widespread, occurring from central North America east to the coast and south to Arizona, Texas and Florida. Specimens from west of the Great Plains were all collected at high elevations. *Platydracus fossator* is quite common south of the Canadian border and occurs regularly at some sites in southern Canada (Map 16). This species is newly recorded from Nova Scotia, Ohio, and Pennsylvania:

Map 16. Distribution of *Platydracus fossator* (Gravenhorst) in eastern Canada and adjacent United States.


PA: 69 specimens.

Eastern Canada: ON, QC, NB, NS
Adjacent U.S.: MI, IN, OH, PA, NY, VT, NH, ME (All ECAS states)

*Platydracus fossator* has been collected in ECAS from March to October, with a marked increase in abundance during July and August. While this species inhabits a variety of forest types (except boreal), a large proportion of specimens were collected from open forests with conifers and/or oak trees, including oak savannah. *Platydracus fossator* occurs at carrion, dung, and at decaying soft fungi including *Pleurotus ostreatus* Fries (Cline and Leschen 2005), and is often encountered flying or walking as it disperses between these microhabitats (Fig. 11.12.1). Both adults and larvae have been reared on a diet of muscoid flies (Schmidt 1999).
*Platydracus immaculatus* (Mannerheim 1830)

*Platydracus immaculatus* is a distinctive species that can be differentiated from other Staphylinina by a combination of a reddish head, red elytra without distinct and elongate dark spots, abdominal tergites with dense, paired patches of golden setae, and a non-metallic body (Fig. 7.11.1). Species of the *P. cinnamopterus* complex are similar in colouration but lack the distinct, paired patches of golden setae on the abdominal tergites.

This species is eastern in distribution: Ontario to North Carolina and west to Utah. Historically, it was quite commonly collected in ECAS but *Platydracus immaculatus* is now infrequently collected over much of its range. Although this is only subtly apparent in Map 17, the change is quite apparent after the early 1980’s.

Eastern Canada: ON, QC
Adjacent U.S.: MI, IN, OH, PA, NY, VT, NH, ME (All ECAS states)

In ECAS, *P. immaculatus* has been collected from February to November, with a relatively early peak in abundance during April-May.

*Platydracus immaculatus* is an open habitat species, occurring especially in stony areas with sandy soil. It can be collected from under stones, leaves, and other debris in old fields, savannah, edges of open wetlands, and the grassy areas along the shores of lakes and rivers. This species' range in Canada has always been restricted to the southern half of Ontario and Québec; however, *P. immaculatus* now seems to be rare in this area, with only 5 records from Canada after 1980 (Fig. 11.13.1). Further collecting in sandy, grassy habitat with stones is necessary to verify this species' apparent decline in Canada. Unlike many other species of *Platydracus*, *P. immaculatus* does not visit baited traps and
Map 17. Distribution of *Platydracus immaculatus* (Mannerheim) in eastern Canada and adjacent United States.
is primarily captured by lifting debris or in pitfall traps. *Platydracus immaculatus* was generally known by the younger name *P. vulpinus* (Nordmann, 1837) until Smetana and Davies (2000) noted that the name *immaculatus* was older, and Herman (2001) adopted *immaculatus* as the valid name.

**Platydracus maculosus** (Gravenhorst 1802)

*Platydracus maculosus* can be easily distinguished from all other species of Staphylinina in ECAS (LeConte) by its large size (22-35 mm) and the distinct, dark and elongate spots on its elytra (Fig. 11.14.1). It can also be differentiated from the similar *P. comes* by the incomplete impunctate median line of the pronotum (Fig. 7.7.1) and from *P. femoratus* by its smaller eyes (Fig. 11.14.1).

This species is widespread in eastern North America, ranging south to the Florida panhandle. Its range in ECAS is given in Map 18.

Eastern Canada: ON, QC
Adjacent U.S.: MI, IN, OH, PA, NY, VT, NH, ME (All ECAS states)

*Platydracus maculosus* has been collected in ECAS from January to November, with a large peak in abundance in May and a second, smaller increase in September.

*Platydracus maculosus* is the largest and one of the most commonly encountered *Platydracus* species in ECAS. It primarily inhabits deciduous forests and open areas, where it occurs on carrion (Fig. 11.14.2), on dung, in leaf litter and sometimes in rotting fungi. A few individuals have been collected under bark and at lights. They are often
Map 18. Distribution of *Platydacus maculosus* (Gravenhorst) in eastern Canada and adjacent United States.
observed in flight and their dark blue hindwings give them a wasp-like appearance.

Adults overwinter under logs and rocks and can be found there in the late fall and early spring (Voris 1939). Smetana and Davies (2000) noted that P. maculosus had an older synonym, P. viduatus (Fabricius, 1801), and used that as the valid name for this species, but P. maculosus was conserved as the valid name by Opinion 2039 of the International Commission on Zoological Nomenclature (ICZN 2003).

**Platydracus mysticus (Erichson 1840)**

*Platydracus mysticus* can be recognized by the combination of small eyes (much smaller than the temple) (Fig. 7.6.3), elytra without elongate dark spots, pronotum without an impunctate median line (Fig. 7.6.2), abdominal tergites lacking distinct patches of golden setae, and first antennomere distinctly bicoloured (Fig. 7.6.4). The darkest individuals resemble *P. tomentosus*, but that species has eyes that are subequal in length to the temple.

This species ranges over most of northeastern North America: southern Ontario and Quebec, southwest to central Texas. Its range in ECAS is given by Map 19.

Specimens reported by Klimaszewski et al. (2005) as *P. mysticus* were later found to be misidentified *P. viridanus* (A. Smetana *pers. comm.*). Thus *P. mysticus* does not occur in the Maritime Provinces of Canada as far as known. *Platydracus mysticus* is newly recorded from Michigan and Maine.
Map 19. Distribution of *Platydracus mysticus* (Erichson) in eastern Canada and adjacent United States.
UNITED STATES: MI: 57 specimens. ME: Penobscot Co., Orono, 44.8833 -68.6667, 24-V-1948, 1 (UAIC).

Eastern Canada: ON, QC
Adjacent U.S.: MI, IN, OH, PA, NY, VT, NH, ME (All ECAS states)

_Platydracus mysticus_ has been collected in ECAS in March to December, with a relatively early peak in abundance in April-May.

This species is typically found under rocks and logs in forested or field habitat, although the vast majority of specimens lack label data. It may also be found on beaches and shoreline in 'washup' and under drift. Newton (1973) suggested that _Platydracus mysticus_ may generally be cursorial and surface active; the fact that most collections are made singly and many labels state 'on ground' or 'on path' (or similar) supports this. This species is a competent flier as it has been collected by a flight intercept trap (Watrous 2008). _Platydracus mysticus_ is common in collections until about 1960 and later records are increasingly less numerous, suggesting that this species is in decline over much of its range in ECAS, especially in densely populated areas; focused collecting is needed to verify this. Possible factors contributing to this apparent decline include urbanization and competition with introduced species of nearly identical adult habits (i.e. _Tasgius spp._).
Platydracus praelongus (Mannerheim 1830)

Platydracus praelongus is distinctive among Platydracus species for its pronotum with an uneven punctation and wide (at least as wide as five punctures) impunctate line (Fig. 7.4.1); both the head and pronotum are dull-metallic (Fig. 11.16.1).

This species occurs along the eastern coast of the United States and Mexico, north to Maine, but it may be eventually found in the extreme southern portions of Atlantic Canada. Its range in ECAS is given by Map 20. It is recorded from the state of New York for the first time based on study of 77 specimens collected until 1975.

Adjacent U.S.: NY, NH, ME

Platydracus praelongus has been collected in ECAS from February to December, with a large increase in abundance in May and smaller peak in August.

Platydracus praelongus is a seashore specialist of and is the only North American Platydracus associated with marine coastal environments. In ECAS it has been collected on beaches under debris and logs (Fig. 11.16.2), swept from dune grass, and found along the edges of salt marshes under stones and in litter.

Platydracus praetermissus Newton, spec. nov.

Type material: Holotype, male, in FMNH, with labels: "ARK: Wash. Co., 3 mi S Devils Den St. Park, 28-31.V.79 litter, S&J Peck, oak-hickory" [white printed label]; "A. Newton collection" [green printed label]; "♂ GENITALIA 51, to J. Klimaszewski for drawing, 1993" [red printed label]; and red handwritten holotype label by A. Newton
Map 20. Distribution of *Platydracus praelongus* (Mannerheim) in eastern Canada and adjacent United States.
dated 2010 [note: genital segment and aedeagus removed and stored in glycerin in a microvial pinned with the specimen].

Paratypes, 198, all males, all but a few with aedeagus examined:

1976, Marshall and Justice, 1 (UAAM); Tallahassee, 30.43 -84.28, hardwood litter, 4-III-
1976, G.B. Marshall, 1 (FMNH); Tallahassee, 30.43 -84.28, hardwood litter, blacklight
trap, 6-XII-1976, G.B. Marshall, 1 (FMNH); Tallahassee, 30.43 84.28, mixed hardwood
litter, 20-IV-1976, C.W. O’Brien and Justice, 1 (FMNH); Tallahassee, 30.43 -84.28,
mixed hardwood litter, 2-IV-1976, C.W. O’Brien and G.B. Marshall, 1 (FMNH);
Tallahassee, 30.43 -84.28, hardwoods, berlesate hardwoods, 77-204, 14-X-1977, L.
Justice and E. Healy, 1 (UAAM); Tallahassee, 30.43 -84.28, mixed hardwood litter, 11-
III-1977, G.B. Marshall, 1 (FMNH); Tallahassee, 30.43 -84.28, mixed hardwood litter, 6-
X-1977, C.W. O’Brien, 1 (FMNH); Okaloosa Co., Destin, 30.40 -86.50, 13-II-1976, E.J.
Kiteley, 1 (CNC); Destin, 30.40 -86.50, 10-III-1980, E.J. Kiteley, 1 (CNC); Destin, 30.40
-86.50, 23-III-1982, E.J. Kiteley, 1 (CNC); Orange Co., Winter Park, 28.60 -81.33, 4-III-
1939, F.E. Lutz, 1 (AMNH); Polk Co., in steiner trap, 14-III-1961, R.E. Vild, 1 (FSCA);
Suwannee Co., 15 mi SW of Live Oak, Hwy 51, pine and hardwood litter, 24-III-1977,
C.W. O’Brien et al., 1 (FMNH); Taylor Co., 5 mi E of Gainesville, Hatchet Creek, 29.65
-82.25, UV light, 27-V-1983, R.M. Reeves, 2 (DENH). GA: Fulton Co., Atlanta, 33.75 -
84.38, 1-VI-1929, P.W. Fattig, 1 (INHS); Liberty Co., Riceboro, 31.73 -81.43, 27-IV-
4, 4-VI-1960, 1 (INHS); Mahomet, Hart Memorial Woods, 40.20 -88.40, trap 13, 1-VII-
1966, 1 (INHS); Mahomet, Hart Memorial Woods, 40.20 -88.40, trap 3, 7-VI-1967, R.T.
Allen and J.D. Unzicker, 1 (INHS); Clark Co., Rocky Branch, 39.47 -87.77, pitfall trap, 1
to 13-V-1996, M.A. Goodrich, 1 (EIU); Rocky Branch, 39.47 -87.77, pitfall trap, 12 to
26-VII-1998, M.A. Goodrich, 1 (EIU); Rocky Branch, 39.47 -87.77, pitfall trap, 14 to 28-
VI-1998, M.A. Goodrich, 3 (EIU); Rocky Branch, 39.47 -87.77, pitfall trap, 24 to 31-
V-1998, M.A. Goodrich, 1 (EIU); *Coles Co.*. Charleston vicinity, 39.50 -88.18, 6-VI-2001, N.L. Owens, 1 (EIU); *Cook Co.*. Des Plaines, Carlé Woods, 42.03 -87.88, rotten oak log, 12-X-1957, O. Park, 1 (FMNH); *Edgar Co.*. 4 mi SSE of Kansas, 39.50 -87.92, ‘from part of forest NOT burned in fall 1999’, pitfall trap, 25-VIII to 1-IX-2000, M.A. Goodrich, 1 (EIU); 4 mi SSE of Kansas, 39.50 -87.92, ‘from part of forest burned in 1999’, pitfall trap, 13 to 20-X-2000, M.A. Goodrich, 1 (EIU); 4 mi SSE of Kansas, 39.50 -87.92, ‘from part of forest NOT burned in 1999’, pitfall, 31-V to 7-VI-2000, M.A. Goodrich, 1 (EIU); *Jackson Co.*. Carbondale, 37.73 -89.22, 5-V-1959, M. Stibitz, 1 (SIUC); Carbondale, 37.73 -89.22, 28-V-1963, C.S. Adams, 1 (SIUC); *Piatt Co.*. White Health, 40.08 -88.52, ground no. 24, 1-I-1983, J.C. Dirks, 1 (INHS); *Pope Co.*. Dixon Springs Park, Ghost Dance Canyon Trail, 37.38 -88.67, 125m, mixed hardwood forest in ravine near stream, under rock, 1043, 22-VI-2002, A. Newton, 1 (FMNH); *St. Clair Co.*. 4-VII-1901, G.W. Block, 1 (UMRM); 5-VI-1902, G.W. Block, 1 (UMRM); *Vermillion Co.*. Catlin, Camp Drake, 40.10 -87.75, ground, 12-VI-1940, J.E. Porter, 1 (INHS). **IN:** *Jasper Co.*. Jasper-Pulaski State Game Area, 41.15 -86.93, sweeping vegetation, grassy area, 19-V-1996, R.M. Brattain, 1 (Brattain); *Tippecanoe Co.*. 17-V-1959, N.M. Downie, 1 (FMNH); *Vigo Co.*. 8-VI-1893, W.S. Blatchley, 1 (PURC). **KS:** *Douglas Co.*. Lecompton, 39.05 -95.40, 10-X-1933, 1 (FMNH); *Jefferson Co.*. University of Kansas Natural History Reserve, 39.05 -95.18, forest, litter, 6-V-1986, J. Pakaluk, 1 (KSEM); *Leavenworth Co.*. 18-V-1956, G.W. Byers, 1 (KSEM). **KY:** *Meade Co.*. 0.5 mi S of Route 1158 on Route 333, 7-VI-1986, R. A. Mattingly, 1 (ULKY). **LA:** *West Feliciana Co.*. Feliciana Preserve near Freeland, 30.78 -91.25, pitfall traps, 17-V-1995, D. Pashley, 4 (LSAM); Feliciana Preserve near Freeland, 30.78 -91.25, pitfall traps, 5-X-1995, D.
Occoquan, 38.68-77.27, 2-V-1943, E.S. Ross, 1 (CNC); Virginia Beach Co., Little Creek Amphibious Base, 36.92-76.17, 12-V-1989, K.A. Buhlmann, VDNH survey, 1 (VNMH); Virginia Beach, Seashore State Park, 36.90-76.02, scrub pitfall site, 21-VI-1989, K.A. Buhlmann VDNH survey, 5 (VNMH).

**Description:** With the characters of the *P. cinnamopterus* Complex (see above), plus: average pronotal length 2.51 mm (n = 13); head, pronotum and elytra usually dark reddish, pronotum not bicolored; antenna reaching or exceeding middle of pronotum when extended posteriorly, antennomere 9 subquadrate; impunctate median line of pronotum at least three puncture diameters wide at narrowest point, usually about four puncture diameters wide; emargination of sixth visible male sternite in ventral view shallow, about 1/6 as deep as wide; apex of median lobe of aedeagus in parameral view broadly and slightly convexly truncate; sides of median lobe in lateral view distinctly toothed near apex.

**Etymology:** From the Latin adjective praetermissus, meaning "neglected" or "overlooked", in reference to the late discovery of this widespread species which had been generally misidentified as *P. cinnamopterus.*

*Platydracus praetermissus* may be distinguished from all other species of the genus in ECAS by the combination of generally dark reddish color (Fig. 11.17.1); black scutellum; variegated abdomen with only sparse gold setae and paired areas of black velvet setae on the first five visible segments (Fig. 7.9.2); antennae with subquadrate antennomere 9 (Fig. 7.14.2); and the complete impunctate medial line of pronotum about
3-4 puncture diameters wide at narrowest (Fig. 7.14.1). It is definitively distinguished from the other members of the *P. cinnamopterus* Complex, *P. cinnamopterus* and *P. zonatus*, by the structure of the aedeagus (Fig. 7.14.3, 11.17.2).

*Platydracus praeternissus* is widely distributed in the forested areas of eastern United States: from Long Island, New York, west to Nebraska, south to Texas and east to peninsular Florida (Map 21). Its distribution in ECAS is shown in greater detail in Map 22. The distribution of this species is generally more southern than the other species of the *cinnamopterus* Complex and is not yet known to include Canada. However, it may occur in the few, relatively mature hardwood forest patches left in southern Ontario.

Adjacent U.S.: MI, IN, OH, PA, NY

In ECAS, *P. praeternissus* specimens have been collected from April through October, with most (10 of 15 records) found in May or June.

The four specimens of *P. praeternissus* from ECAS with collection data were obtained from forest leaf litter (2), in a barrier pitfall trap (1), and sweeping vegetation in a grassy area (1). In its entire range, this species has been collected most often in ground pitfall traps or in forest leaf litter, and rarely associated with decaying logs or in UV light traps at night (twice each). Unlike *P. cinnamopterus*, this species is not known to occur under bark. Note that some historical records of *P. cinnamopterus* in the literature may refer to this species.

*Platydracus tomentosus* (Gravenhorst 1802)

This species is distinguished from other *Platydracus* by the combination of a completely black body and setae, eyes subequal to the temple (Fig. 7.13.2) and paired
Map 21. Distribution of *Platydracus praetermissus* sp. nov.
Map 22. Distribution of *Platydracus praetermissus* sp. nov, in eastern Canada and adjacent United States.

Records previous to 1970 are coded black and those from this year onwards are coded blue.
patches of black velvet setae on the abdominal tergites (Fig. 7.13.1). The immaculate form of *P. fossator* could be confused with *P. tomentosus*, but the former lacks patches of black velvet setae on the abdominal tergites and has eyes that are distinctly longer than the temple. The darkest individuals of *P. mysticus* are also similar, but have eyes that are distinctly shorter than the temple.

This species occurs in eastern North America, from Ontario to Florida, and west to Nebraska; it also occurs in Cuba. Its range in ECAS is given by Map 23. *Platydracus tomentosus* is newly recorded from New York and Ohio.


Eastern Canada: ON
Adjacent U.S.: MI, IN, OH, NY

*Platydracus tomentosus* has been collected in ECAS from January to November, with a peak in abundance in May.

*Platydracus tomentosus* (Gravenhorst) primarily inhabits the edges of lakes and ponds, and slow-moving waterways, where it can be found under stones, wood, and flood debris. It sometimes occurs in forests or in prairies but these individuals may only be dispersing through to the nearest water body. Schmidt (1994) found many adults within 3 meters of a large creek in a pasture, where they were found singly or in pairs in small
Map 23. Distribution of *Platydracus tomentosus* (Gravenhorst) in eastern Canada and adjacent United States.
'discus-shaped' excavations under objects. This species is probably a generalist predator of riparian arthropods, and Schmidt (1994) fed them lampyrid larvae, isopods, adult flies, and elaterid larvae collected from the same location. Larvae burrow readily in soil (Schmidt 1994), unlike the adults, and could be primarily fossorial. There are very few recent records of this species from the northeastern portion of its range (Map 20) and further collecting in favored habitat is necessary to determine whether *P. tomentosus* is in decline.

*Platydacus violaceus* (Gravenhorst 1802)

This species is easily recognized by the combination of a purple-blue metallic dorsal body and characteristic pattern of pale abdominal setae (Fig. 7.12.1). It may be confused with *P. viridanus* (Horn), which normally has a bronze metallic reflection but can appear purple in specimens from traps with killing agents. *Platydacus viridanus* also has a more transverse pronotum that is distinctly wider than the head, while in *P. violaceus*, the pronotum is subequal in width to the head. *Platydacus violaceus* also has a dark elytral epipleuron (Fig. 7.12.2) and completely dark legs, while in *P. viridanus* the ventral margin of the epipleuron is paler than the rest of the elytron and the legs are usually at least partially pale.

This species is distributed broadly in eastern North America. Its range in ECAS is given by Map 24. It is newly recorded from the state of Vermont based on a historical record; it very likely still occurs there:

**UNITED STATES: VT**: Addison Co., Salisbury, 43.9°-73.1°, 5-VII-1895, 1 (MCZ)
Map 24. Distribution of *Platydracus violaceus* (Gravenhorst) in eastern Canada and adjacent United States.
Platydracus violaceus has been collected in ECAS from April to December, with an increase in abundance occurring in May. *Platydracus violaceus* is a common species found in mesic to swampy forests, primarily under the loose bark of dead hardwood trees including oaks, maples, basswood, horse chestnut, hackberry, beech, and hickory. It occurs less frequently under the bark of white pine, in rotting wood, and under logs. The few records in rotting fungi, on carrion, or on dung probably do not reflect habitat preferences. Larvae were found to readily consume various insect larvae occurring under bark (Newton 1973) and it is likely that adults have similar dietary habits. Mature larvae are collected in the early spring (Hoebeke 1978; A. Brunke *personal observations*) indicating that this species overwinters in this stage. Larvae form pupal cells out of frass and wood debris and are sometimes parasitized by the proctotrupid *Codrus carolinensis* (Ashmead) (Hoebeke 1978). Adults appear to emerge later in spring (April-May). Jennings and Tallamy (2006) found this species in a relatively undisturbed secondary forest but not in an isolated woodlot of similar tree species composition. Similarly, Majka (2010) found this species in an old growth forest remnant in Prince Edward Island, a province where it was not known previously. It was hypothesized that forestry practices were responsible for this species’ absence in previous collections made elsewhere in the province. Based on our collection data, this species does not require old growth but is usually found in forests with at least some mature trees. Smetana and Davies (2000) noted that *P. violaceus* was a preoccupied name and replaced it with a younger synonym,
P. cupripennis (Melsheimer, 1844), but P. violaceus was conserved as the valid name for this species by Opinion 2039 of the International Commission on Zoological Nomenclature (ICZN 2003).

Platydracus viridanus (Horn 1879)

The combination of the small eyes (no longer than the temple), bronze metallic dorsal reflection, evenly punctate pronotum, elytra without spots (Fig. 7.10.2), an elytral epipleuron with a pale ventral margin (Fig. 7.10.3), and the distinctive pattern of abdominal setae (Fig. 7.10.1) distinguish Platydracus viridanus from all congeners. For characters differentiating this species from P. exulans, see comments under that species. Specimens of P. violaceus sometimes appear bronze if discoloured by killing agents but have a different pattern of abdominal setae, a dark elytral epipleuron, and other differences noted under that species.

Platydracus viridanus occurs across northeastern North America, from Minnesota to Nova Scotia, extending south in the Appalachian mountains to northern Georgia.

Map 25. Distribution of *Platydracus viridanus* (Horn) in eastern Canada and adjacent United States.
Eastern Canada: ON, QC, NB, NS
Adjacent U.S.: MI, IN, OH, PA, NY, VT, NH, ME (All ECAS states)

This species has been collected in ECAS from May to September, with nearly all records occurring in July-August.

*Platydracus viridanus* is a mesic forest-dwelling species that is typically localized in distribution and occurs in decaying fungi, on carrion, and dung. Individuals have also been collected in decaying plant matter (with larvae), under logs, in a buzzard nest (with larvae), in forest floor pitfall traps, along a grassy river margin (Fig. 11.20.1), and in a dry field. Jennings and Tallamy (2006) found this species in a relatively undisturbed secondary forest but not in an isolated woodlot of similar tree species composition. This species was also commonly collected in pitfall traps in an old-growth white pine forest in Ontario.

*Platydracus zonatus* (Gravenhorst 1802)

Staphylinus zonatus Gravenhorst, 1802: 162; synonym of *S. cinnamopterus*, Erichson 1839; as valid species of *Platydracus*: Newton in Smetana and Davies 2000, Herman 2001, etc. (see Herman 2001: 3473 for additional literature citations)

Type material: Lectotype, male, in ZMHB, here designated by Newton, with labels "7087" [white printed label]; "America s. Topp" [green handwritten label]; and red lectotype designation label by Newton dated 1978 [note: right antennomeres 4+, most of right elytron and both metathoracic legs missing, genital segment and aedeagus removed and glued on card with abdomen]. A second specimen, female, in ZMHB associated with the lectotype, with green
handwritten label "var. zonatus Gr. A. spt.", in poor condition with parts of abdomen glued to card below specimen, was not designated a paralectotype although assumed to be conspecific.

*Staphylinus badius* Mannerheim, 1830: 23 (attributed to Dejean, 1821: 21 [nomen nudum]); synonym of *S. cinnamopterus*: Erichson 1839; synonym of *Platydracus zonatus*: Newton in *Smetana and Davies* 2000, *Herman* 2001, etc.


*Staphylinus quadraticeps* Casey, 1924: 149 [preoccupied name, not *Staphylinus quadraticeps* Ménétries 1832]; synonym of *S. caseyi*: Scheerpeltz 1933; synonym of *Platydracus zonatus*: Newton in *Smetana and Davies* 2000, *Herman* 2001, etc.

**Type material:** Holotype, female, in USNM, with labels "Fla."; "Casey bequest 1925"; "TYPE USNM 48271", "quadraticeps Csy"; and red holotype label dated Newton 1978 [note: considered holotype because Casey indicated only one female was seen].

*Staphylinus caseyi* Scheerpeltz 1933: 1392 [replacement name for *Staphylinus quadraticeps* Casey 1924]; synonym of *Platydracus zonatus*: Newton in *Smetana and Davies* 2000, *Herman* 2001, etc.
Note on synonymy: The only located type material of *P. badius* (Mannerheim) and *P. quadraticeps* (Casey) consists of single females. These specimens are identified as *P. zonatus* based on general agreement with the external characters cited in the *Platydracus* species key and the diagnostic description of *P. zonatus*, and because their pronotal punctation does not agree with that of *P. praetermissus*.

Other material examined: 445 specimens throughout the range of the species, all being males with an examined aedeagus. Full data will be presented in the pending revision of *Platydracus* by Newton, but all records that could be georeferenced are shown in Map 26.

**Description:** With the characters of the *P. cinnamopterus* Complex (see above), plus:

- average pronotal length 2.31 mm (n = 9); head, pronotum and elytra usually medium to dark reddish, less often light red, pronotum more or less distinctly bicolored (darkest at anterior angles and sides and sometimes along median, rest of disc lighter); antenna reaching middle of pronotum when extended posteriorly, antennomere 9 slightly transverse; impunctate median line of pronotum at least one puncture diameter wide at narrowest point, usually about two puncture diameters wide; emargination of sixth visible male sternite in ventral view deep, about 1/3 as deep as wide; apex of median lobe of aedeagus projected in parameral view, the converging sides of the projection in ventral view usually slightly concave and forming an obtuse angle, the apex narrowly rounded; sides of median lobe in lateral view distinctly toothed near base of projection.

*Platydracus zonatus* may be distinguished from all other species of the genus in ECAS by the combination of generally reddish color (medium to very dark) (Fig.
Map 26. Distribution of *Platydracus zonatus* (Gravenhorst).
11.21.1) with a more or less distinctly bicolored pronotum (Fig. 7.3.3), black scutellum, and variegated abdomen with only sparse gold setae and paired areas of black velvet setae on the first five visible segments; antennae with slightly transverse antennomere 9 (Fig. 7.3.2); and the narrow but complete impunctate medial line of pronotum about 2 puncture diameters wide at narrowest (Fig. 7.9.5). It is definitively distinguished from the other members of the *P. cinnamopterus* Complex, *P. cinnamopterus* and *P. prae termissus*, by the structure of the aedeagus (Fig. 7.3.4, 11.21.3).

*Platydracus zonatus* is widely distributed in the forested areas of eastern North America: from southern Québec, west to Kansas, south to Texas and east to peninsular Florida. Unlike *P. cinnamopterus*, its northern range is apparently constrained by the distribution of the Carolinian forest and is therefore regularly known in Canada only from a few sites in southern Ontario (Map 27).

Eastern Canada: ON, QC

Adjacent U.S.: MI, IN, OH, PA, NY, NH

In ECAS, *P. zonatus* specimens have been collected from March through November, with a majority (56%) found in May or June.

A majority of specimens of *P. zonatus* from ECAS with microhabitat data have been collected in forests in various kinds of ground debris including forest leaf litter (Fig. 11.21.2) and under stones and logs; one specimen was found in *Sphagnum* moss, one at blacklight at night, several in prairie and old field areas, and several were collected in flight intercept traps. Unlike *P. cinnamopterus*, this species is not known to occur under
Map 27. Distribution of *Platydracus zonatus* (Gravenhorst) in eastern Canada and adjacent United States.
bark. Note that some historical records of *P. cinnamopterus* in the literature may refer to this species. The partially illustrated larva of *P. zonatus* in Newton (1990) is based on a series of larvae collected with four confirmed adults of this species.

*Staphylinus ornaticauda* LeConte 1863

This species is unique among the species of Staphylinina with red elytra for its head with patches of golden setae (Fig. 3.7.1). It cannot be confused with any other species of the subtribe in ECAS.

This species is spottily distributed in North America and records exist for Minnesota (historical), Iowa (no date), Michigan, Manitoba, Ontario, Québec and Nova Scotia. Its distribution in ECAS is given by (Map 28).

Eastern Canada: ON, QC, NS

Adjacent U.S.: MI

*Staphylinus ornaticauda* has been collected in ECAS from May to September, with a majority of the specimens being collected in June to mid-July.

*Staphylinus ornaticauda* is the only species of the genus in the New World. It is restricted to wetlands (bogs and fens) with an abundance of sphagnum moss, that occur south of the boreal forest zone; therefore its entire known range is relatively small (Map 28) and most of the known habitat exists in Canada. Specimens with label data indicate it can be captured by pitfalls at the edges of bogs/fens and by sifting sphagnum moss. It was last collected in the United States in 1922 (Michigan) and most recently from Canada.
Map 28. Distribution of *Staphylinus ornaticauda* (LeConte) in eastern Canada and adjacent United States.
in 1981 (Nova Scotia). Ten individuals (the most collected at one time) were collected by pitfall trapping, south of the Richmond area, Ottawa, Ontario, Canada in 1978. This species is flightless and probably has limited dispersal capabilities. Its restricted distribution, narrow habitat requirements and apparent rarity suggest that this species warrants further study as a possible species at risk of extinction.

**Tasgius ater (Gravenhorst 1802)**

*Tasgius ater* is easily recognized among the species of *Tasgius* and other all-black Staphylinina by the presence of smaller punctures between the normal, larger punctures of the head and pronotum (Fig. 8.1.1), and the wide spacing of these punctures; this produces an overall glossy appearance (Fig. 11.23.1).

This species is native to the Palearctic region but was first described by Gravenhorst (1802) from North America. Thus, it has been on the continent for a very long time and has since become widely distributed and established in ECAS (Map 29). *Tasgius ater* is newly recorded from Michigan, Ohio, and Vermont based on the study of 68 specimens.

Eastern Canada: ON, QC, NB, NS, PE, NL (All ECAS provinces)

Adjacent U.S.: MI, IN, OH, PA, NY, VT, NH, ME (All ECAS states)

*Tasgius ater* has been collected in ECAS from January to November, with an increase in abundance in July-August.
Map 29. Distribution of *Tasgius ater* (Gravenhorst) in eastern Canada and adjacent United States.
*Tasgius ater* is found under rocks and logs in a variety of environments including woodlands, near water, and in open fields. Specimens have also been collected under loose bark, in rotting grass piles, and on beaches. This species often occurs in human-disturbed areas in gardens and occasionally in dwellings (Fig. 11.23.2) but is less synanthropic than the other *Tasgius* occurring in ECAS.

*Tasgius melanarius* (Heer 1839)

*Tasgius melanarius* may be distinguished from other *Tasgius* occurring in ECAS by the combination of the pronotal punctures of subequal size (Fig. 8.3.1), the pronotum widest near the apex (Fig. 8.3.1) and the second antennomere darkened at its base (Fig. 8.3.2). The dense and subequal punctation of the pronotum causes an overall dull appearance (Fig. 3.5.1).

North American specimens of this species were misidentified as *T. globulifer* until Newton (1987) clarified the matter, and reported that all previous North American records of *T. globulifer* were actually *T. melanarius* or *T. winkleri* (Bernhauer). *Tasgius melanarius* has been collected on both east and west coasts and was taken as early as 1935 in Québec. The Québec record is still the oldest known and *T. melanarius* has since expanded its range in eastern North America. Consequently, *T. melanarius* is here newly recorded from New York, Vermont, and Maine. Its distribution in ECAS is given by Map 30.

**UNITED STATES: ME:** *Waldo Co.*, Camden 4mi N, 44.2833 -69.0667, 16 to 17-VII-1987, J.K. Liebherr, 1 (CUIC). **NY:** *Columbia Co.*, Kinderhook, 42.4 -73.7, 9-VI-1978,
Map 30. Distribution of *Tasgius melanarius* (Heer) in eastern Canada and adjacent United States.

Eastern Canada: ON, QC, NB, NS
Adjacent U.S.: OH, NY, VT, NH, ME

*Tasgius melanarius* has been collected in ECAS from March to December, with peaks in abundance occurring in May and September.

This species is native to Europe and is found in disturbed woodlands, coastal areas, urban areas and old fields under rocks, boards, litter, loose bark, and logs. It often occurs in yards (Fig. 11.24.1), sometimes falling into swimming pools. In autumn this species, together with *T. winkleri*, is regularly observed on sidewalks and lawns, likely looking for favorable overwintering sites.
**Tasgius winkleri** (Bernhauer 1906)

*Tasgius winkleri* is distinguished from other *Tasgius* occurring in ECAS by the combination of the pronotal punctures of subequal size (Fig. 8.2.2), the pronotum widest near the middle (Fig. 8.2.2) and the second antennomere not darkened at its base (Fig. 8.2.3). As in *T. melanarius*, the dense and subequal punctation of the pronotum causes an overall dull appearance (Fig. 11.25.1).

This species was first correctly recognized in eastern and western North America by Newton (1987), who indicated that it had been collected as early as 1938 in New York. Prior to 1987, both this species and *T. melanarius* had been misidentified as *T. globulifer*. Additional specimens from Syosset, NY indicate that *Tasgius winkleri* has been in North America at least since 1931 and new records from eastern Canada (Ontario), Michigan, and Pennsylvania suggest that it is expanding its range in North America. Its range in ECAS is given by Map 31.

**CANADA: ON**: 176 specimens.


Eastern Canada: ON

Adjacent U.S.: MI, PA, NY, NH
Map 31. Distribution of *Tasgius winkleri* (Bernhauer) in eastern Canada and adjacent United States.
*Tasgius winkleri* has been collected in ECAS in April to November, with an increase in abundance during September.

*Tasgius winkleri* inhabits open woodlots, old fields, shorelines, wetland edges, and backyards, where it is found under rocks and in leaf litter. It has also been collected from a pile of rotting grass and in a compost heap. It is pronouncedly synanthropic and generally only occupies habitats that have been degraded by human activity.
Chapter III

Rove beetles (Coleoptera: Staphylinidae) in southern Ontario soybean fields and adjacent hedgerows: assemblage composition, seasonality and habitat use

1. Introduction

The natural enemy assemblage of soybean pests in northeastern North America has received considerable attention since the recent introduction of Soybean Aphid (*Aphis glycines* Matsumura) to North America. Predation has been determined to be one of the most important factors driving Soybean Aphid population dynamics (Costamagna and Landis 2006), able to suppress Soybean Aphid population growth considerably (Fox et al. 2004). The importance of generalist predators in northeastern soybean has recently been recognized and the largely exotic ground beetle (Carabidae) assemblages of Ohio (Chen and Willson 1996) and New York (Hajek et al. 2007) have been well characterized.

Based on predator surveys by Rutledge et al. (2004), Fox et al. (2005), and Costmagna and Landis (2007), rove beetles (Staphylinidae) appear to be absent or rare amongst the previously documented soybean predator assemblages in North America, although Halaj et al. (2000) captured staphylinids (undetermined beyond family) throughout the growing season in Ohio soybean fields by hand-searching soil. It seems unlikely that soybean fields present conditions that exclude staphylinids, given the dominance of these beetles in most terrestrial ecosystems (Bohac 1999, Thayer 2005). The biocontrol services of rove beetles are recognized globally as important in the mitigation of agricultural yield loss by a diversity of pest arthropods such as spider mites in Japan (Kishimoto and Adachi 2008), cereal aphids in central Europe (Dennis and
Wratten 1991), Horn Flies in Florida (Hu and Frank 1995) and Cabbage Maggots in central Canada (Andreassen et al. 2010). This predator group forms a diverse assemblage in central European agroecosystems (Clough et al. 2007, Balog et al. 2008) and much is now known about their spatiotemporal distributions and habitat preferences. Some species have been observed to have wide ecological tolerances while others occur more frequently near the herbaceous margins of field crops (Balog et al. 2008). Rove beetle populations in Europe are supported by the provision of adjacent non-crop habitat (hedgerows or fallow fields), which serve as alternative habitat outside of the growing season (Paoletti and Lorezoni 1989, Pfiffner and Luka 2000). However, hedgerow age and vegetation structure influences population numbers of different predator groups including Staphylinidae (Burgio et al. 2006).

Unfortunately, knowledge of staphylinid agroecology in northeastern North America remains relatively fragmentary compared to that of other generalist predator groups such as ground beetles. The majority of existing studies suffer from a lack of species-level comparisons, likely due to difficulties in identification, with only a few, relatively recent exceptions dealing with rove beetles in dairy pastures (Byers et al. 2000), vegetable fields (Leslie et al. 2007) and raspberry plantations (Levesque and Levesque 1995, 1996). Individual staphylinid species in these studies were observed to differ in their seasonal activity patterns, habitat use and proportional abundance.

To address this poor understanding of rove beetle agroecology in North America and to re-evaluate their role in the soybean natural enemy assemblage, a species-level investigation of Staphylinidae was conducted in soybean fields to elucidate the composition of the assemblage, the spatiotemporal distribution of its common species and
their utilization of non-crop habitat (hedgerows) outside of the growing season. Several important soybean pests including Soybean Aphid and Bean Leaf Beetle (*Ceratoma trifurcata* Forster) occur in hedgerows in the spring and fall, overwintering on buckthorn (*Rhamnus cathartica* L.) shrubs (Welsman et al. 2007) and in ground litter (Lam and Pedigo 2000), respectively. Therefore, in the present study, the rove beetle assemblage of adjacent hedgerows was additionally surveyed in detail. The composition of the staphylinid hedgerow assemblage is described and the potential biocontrol services of its common species are discussed further in Chapter 4.

2. Materials and Methods

2.1 Study sites

Twelve sites (six in each year), each consisting of a soybean field and corresponding hedgerow, were selected for study in southern Ontario in 2009 and 2010 (Fig. 12, Table 1). Fields at all sites were planted to corn in the previous year, except SG, which was planted to soybean. At all sites, soil in hedgerows contained more dry organic matter than that in soybean fields, as determined by the Walkley-Black method (Walkley and Black 1934) (Table 2). Except for site LB, fields were not sprayed with insecticides. LB was sprayed once in the week of August 27 (2009) with a broad-spectrum insecticide (*λ*-cyhalothrin, Matador, Syngenta, Guelph, Ontario) to control soybean populations; the plot area and a 5m buffer were left unsprayed.

2.2 Sampling protocol

Field sites were sampled for one week every other week, in order to ameliorate trapping pressure on invertebrates. In 2009, sampling began first at SG, SC1 and SC2 and occurred on alternate weeks at LG, LB and LA began on odd weeks. In 2010, sampling
Figure 12. Location of east and west field site groups in southern Ontario.
Table 1. Summary of southern Ontario field site locations and sampling periods.

<table>
<thead>
<tr>
<th>Year</th>
<th>Site</th>
<th>Location</th>
<th>GPS Co-ord.</th>
<th>Spring Hedgerow</th>
<th>Soybean</th>
<th>Fall Hedgerow</th>
</tr>
</thead>
<tbody>
<tr>
<td>2009</td>
<td>East</td>
<td>SC1</td>
<td>Cambridge</td>
<td>43.374 -80.397</td>
<td>May 5 - Jun 16</td>
<td>June 23 - Sep 15</td>
</tr>
<tr>
<td></td>
<td></td>
<td>SC2</td>
<td>Cambridge</td>
<td>43.390 -80.374</td>
<td>May 5 - Jun 16</td>
<td>June 23 - Sep 15</td>
</tr>
<tr>
<td></td>
<td></td>
<td>SG</td>
<td>Guelph</td>
<td>43.589 -80.274</td>
<td>May 5 - Jun 16</td>
<td>June 23 - Sep 15</td>
</tr>
<tr>
<td>West</td>
<td>LA</td>
<td>Auburn</td>
<td>43.729 -81.528</td>
<td>May 11 - Jun 22</td>
<td>Jun 29 - Sep 21</td>
<td>Sep 27 - Nov 23</td>
</tr>
<tr>
<td></td>
<td>LB</td>
<td>Brucefield</td>
<td>43.509 -81.517</td>
<td>May 11 - Jun 8</td>
<td>Jun 22 - Sep 14</td>
<td>Sep 21 - Nov 23</td>
</tr>
<tr>
<td></td>
<td>LG</td>
<td>Benmiller</td>
<td>43.691 -81.610</td>
<td>May 11 - Jun 22</td>
<td>Jun 29 - Sep 21</td>
<td>Sep 27 - Nov 23</td>
</tr>
<tr>
<td>2010</td>
<td>E</td>
<td>Eramosa</td>
<td>43.616 -80.215</td>
<td>May 4 - Jun 1</td>
<td>Jun 15 - Sep 7</td>
<td>Sept 21 - Nov 2</td>
</tr>
<tr>
<td></td>
<td>RA1</td>
<td>Cambridge</td>
<td>43.370 -80.364</td>
<td>May 4 - Jun 1</td>
<td>Jun 15 - Sep 7</td>
<td>Sept 21 - Nov 2</td>
</tr>
<tr>
<td></td>
<td>RA2</td>
<td>Cambridge</td>
<td>43.369 -80.359</td>
<td>May 4 - Jun 1</td>
<td>Jun 15 - Sep 7</td>
<td>Sept 21 - Nov 2</td>
</tr>
<tr>
<td>West</td>
<td>GD1</td>
<td>Auburn</td>
<td>43.745 -81.508</td>
<td>May 12 - Jun 9</td>
<td>Jun 23 - Sep 1</td>
<td>Sep 15 - Nov 10</td>
</tr>
<tr>
<td></td>
<td>GD2</td>
<td>Auburn</td>
<td>43.743 -81.514</td>
<td>May 12 - Jun 9</td>
<td>Jun 23 - Sep 1</td>
<td>Sep 15 - Nov 10</td>
</tr>
<tr>
<td></td>
<td>GD3</td>
<td>Auburn</td>
<td>43.736 -81.507</td>
<td>May 12 - Jun 9</td>
<td>Jun 23 - Sep 1</td>
<td>Sep 15 - Nov 10</td>
</tr>
</tbody>
</table>
Table 2. Soil attributes of southern Ontario field sites. Organic matter content determined using the Walkley-Black method (Walkley and Black 1934) and soil textures derived from Ontario Soil Maps (AAFC 2008).

<table>
<thead>
<tr>
<th>Year</th>
<th>Site</th>
<th>Location</th>
<th>% Dry Organic Matter</th>
<th>Soil Texture</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td>Hedgerow</td>
<td>Soybean</td>
</tr>
<tr>
<td>2009</td>
<td>East</td>
<td>SC1</td>
<td>Cambridge</td>
<td>9.0</td>
</tr>
<tr>
<td></td>
<td></td>
<td>SC2</td>
<td>Cambridge</td>
<td>6.2</td>
</tr>
<tr>
<td></td>
<td></td>
<td>SG</td>
<td>Guelph</td>
<td>4.5</td>
</tr>
<tr>
<td></td>
<td>West</td>
<td>LA</td>
<td>Auburn</td>
<td>12.8</td>
</tr>
<tr>
<td></td>
<td></td>
<td>LB</td>
<td>Brucefield</td>
<td>10.4</td>
</tr>
<tr>
<td></td>
<td></td>
<td>LG</td>
<td>Benmiller</td>
<td>8.3</td>
</tr>
<tr>
<td></td>
<td></td>
<td>GD1</td>
<td>Auburn</td>
<td>8.5</td>
</tr>
<tr>
<td></td>
<td></td>
<td>GD2</td>
<td>Auburn</td>
<td>6.9</td>
</tr>
<tr>
<td></td>
<td></td>
<td>GD3</td>
<td>Auburn</td>
<td>5.6</td>
</tr>
<tr>
<td>2010</td>
<td>East</td>
<td>E</td>
<td>Eramosa</td>
<td>6.5</td>
</tr>
<tr>
<td></td>
<td></td>
<td>RA1</td>
<td>Cambridge</td>
<td>7.8</td>
</tr>
<tr>
<td></td>
<td></td>
<td>RA2</td>
<td>Cambridge</td>
<td>7.5</td>
</tr>
<tr>
<td></td>
<td>West</td>
<td>GD1</td>
<td>Auburn</td>
<td>8.5</td>
</tr>
<tr>
<td></td>
<td></td>
<td>GD2</td>
<td>Auburn</td>
<td>6.9</td>
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<tr>
<td></td>
<td></td>
<td>GD3</td>
<td>Auburn</td>
<td>5.6</td>
</tr>
</tbody>
</table>
began first at E, RA1 and RA2 and then on alternate weeks at GD1, GD2 and GD3. Sampling in hedgerows began in spring as soon as logistically possible and traps were installed in the last week of April. Spring sampling in hedgerows was continued until 50% of soybean plants in the adjacent field were at stage V1 (one node on main stem, with fully developed trifoliates); at this time, soybean sampling began (Table 1). Sampling in soybean fields continued until 50% or more plants had begun senescence, visualized by the yellowing of leaves. Fall hedgerow sampling followed this and continued until canopy traps failed to capture rove beetles to decreasing average daily temperatures.

Rove beetles were sampled using canopy (i.e., raised pan traps) and unfenced pitfall traps, placed in pairs along a transect. Different trap types were used in combination in order to reduce pitfall trap biases (Lang 2000). Both traps were constructed from clear plastic Polypro Deli Containers (10cm diam. x 7cm ht) (Solo Cup Company, Lake Forest, IL) that acted as catch basins, filled one-quarter with propylene glycol (Alchem, Alachua, FL) diluted 50% with water. Canopy traps were held on an adjustable support attached to a wooden stake (Fig.13). Pitfall containers were placed in the soil with the top lip level with or below the soil surface, and protected from weather with a plastic canopy. The interface between pitfall trap and soil was actively maintained each sampling period to prevent exposure of the container lip above the soil surface as a result of rainfall.

In hedgerows, canopy traps were placed among buckthorn branches at approx. 1m height, but were never placed above the nearest buckthorn plants. A pitfall trap was placed within two meters of the canopy trap, under another buckthorn shrub if possible.
Figure 13. Basic construction of canopy trap and placement in buckthorn (*Rhamnus cathartica* L.) canopies within a hedgerow. Canopy traps in soybean were constructed identically.
Trap pairs were separated by 5m in a single transect along the hedgerow. Pairs were further apart if buckthorn plants did not occur at intervals of 5m. Fifteen trap pairs were deployed in hedgerows, except at LB (10 pairs) and LA (14 pairs) where there was insufficient buckthorn presence for 15 pairs. Preliminary observations of hedgerows in southern Ontario revealed patches of ground generally characterized by either herbaceous plant cover or sparse leaf litter. This was apparently a result of differing degrees of canopy closure above by trees and shrubs. To examine possible preferences of species for different hedgerow floor types, the immediate area around pitfall traps was categorized as ‘field’ or ‘open woodland’ based on the dominance of herbaceous vegetation or leaf litter as cover, respectively.

In each soybean field, a total of fifteen trap pairs were arranged in transects 5, 20 and 35 m from the field edge to allow for comparisons of spatial distributions of species within crop habitat. Five trap pairs were placed along each transect, with 5 m between each pair. Within a pair, trap position was randomized and traps were placed 4 m apart to reduce the effects of trampling during trap servicing. Canopy traps were adjusted throughout the sampling period so that they were always located in the top third of the crop canopy.

2.3 Specimen identification and categorization

Trap contents were washed lightly with water through a coarse (425 µm mesh, Fisher Scientific, Ottawa, Canada) and then fine (180 µm mesh) sieve. Staphylinids were transferred to ethanol and identified by the author with some exceptions noted below. Both sexes of aleocharine staphylinids were dissected and sorted on the basis of genitalic characters. Specimens of difficult groups were sent to experts for identification (some
Omaliinae: M. Thayer, Field Museum of Natural History, Chicago IL; most
Aleocharinae: J. Klimaszewski, Laurentian Forestry Centre, Sainte-Foy, PQ). The
unrevised and taxonomically difficult genera Amischa Thompson and Acrotona
Thompson were not treated at the species level. Voucher specimens were deposited in the
University of Guelph Insect Collection. Spring and fall hedgerow assemblages and those
of soybean fields were all analyzed separately, with individuals pooled within these three
assemblages. ‘Common’ beetle species were characterized as those that comprised ≥1%
of the total number of individuals. As the number of individuals captured in passive traps
depends on both their activity and density, this will hereafter be referred to as activity-
density (AD) (Saska et al. 2008). The lower limit of 1% was chosen to include those
species that were characteristic of their respective assemblage but not optimally sampled
with pitfall and canopy traps, and also to exclude those with too few individuals to realize
statistically significant patterns. To elucidate general patterns in seasonality for common
soybean staphylinids, captures from geographically approximate sites were pooled within
sampling year into ‘east’ (SG, SC1, SC2 and E, RA1, RA2) and ‘west’ (LA, LG, LB and
GD1, GD2, GD3) groups.

2.4 Statistical analyses

Species classified as common were included in the analyses outlined below.
Saprophagous, algivorous, mycophagous or specialized microhabitat-inhabiting species
were not examined further (see Results) but are listed in Appendix 1 (hedgerows) and 2
(soybean fields) as members of the staphylinid assemblage. All statistical analyses were
performed using R 2.12.1 (R Core Development Team 2010).
Differences in species richness and proportion of exotic species between hedgerows and soybean fields were assessed using a Chi-square goodness of fit test, with a ratio of 50:50 expected if no such differences exist. Hedgerow floor type was modeled as a predictor for activity density of common soybean species using a Poisson regression as the dataset deviated from a normal distribution and involved count-type data (O’Hara and Kotze 2010). A zero-inflated model was found to perform markedly better (AIC = 2614.179) than a regular Poisson (AIC = 4794.945) when tested using the species with the least amount of zeroes in the dataset (Omalium rivulare (Paykull)). Thus a zero-inflated Poisson distribution was used in the analysis with site as a predictor of excess zeroes in the dataset. Species occurring in both spring and fall assemblages were analyzed separately for each season.

Patterns in spatial distribution of common species within soybean fields were also examined using the above methodology. Distance from field edge was modeled as a predictor of AD and site was modeled as a predictor of excess zeroes. Statistical significance was taken at $\alpha = 0.05$.

3. Results

3.1 Assemblage abundance, richness and origin

One hundred and fifty-four species of Staphylinidae were captured in southern Ontario soybean-hedgerow landscapes. A total of 7306 individuals representing 80 species were captured in southern Ontario soybean fields (2009 – 3918; 2010 – 3388). Only nine species were captured exclusively in soybean fields, with eight of these being singletons or infrequent captures; none were common species. A total of 6733 individuals representing 145 species were captured in hedgerows adjacent to soybean fields (2009 –
Table 3. Species richness and percent exotic species of twelve soybean fields and their adjacent hedgerows, in southern Ontario.

<table>
<thead>
<tr>
<th>Year</th>
<th>Site</th>
<th>Location</th>
<th>Richness</th>
<th>% Exotic</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td>Hedgerow</td>
<td>Soybean</td>
</tr>
<tr>
<td>2009</td>
<td>East</td>
<td>SC1 Cambridge</td>
<td>40</td>
<td>29</td>
</tr>
<tr>
<td></td>
<td></td>
<td>SC2 Cambridge</td>
<td>32</td>
<td>23</td>
</tr>
<tr>
<td></td>
<td></td>
<td>SG Guelph</td>
<td>37</td>
<td>39</td>
</tr>
<tr>
<td></td>
<td>West</td>
<td>LA Auburn</td>
<td>41</td>
<td>24</td>
</tr>
<tr>
<td></td>
<td></td>
<td>LB Brucefield</td>
<td>39</td>
<td>23</td>
</tr>
<tr>
<td></td>
<td></td>
<td>LG Benmiller</td>
<td>49</td>
<td>20</td>
</tr>
<tr>
<td>2010</td>
<td>East</td>
<td>E Eramosa</td>
<td>61</td>
<td>23</td>
</tr>
<tr>
<td></td>
<td></td>
<td>RA1 Cambridge</td>
<td>44</td>
<td>26</td>
</tr>
<tr>
<td></td>
<td></td>
<td>RA2 Cambridge</td>
<td>44</td>
<td>30</td>
</tr>
<tr>
<td></td>
<td>West</td>
<td>GD1 Auburn</td>
<td>51</td>
<td>32</td>
</tr>
<tr>
<td></td>
<td></td>
<td>GD2 Auburn</td>
<td>58</td>
<td>24</td>
</tr>
<tr>
<td></td>
<td></td>
<td>GD3 Auburn</td>
<td>48</td>
<td>37</td>
</tr>
</tbody>
</table>
With the exception of site SG, more species were captured in hedgerows than soybean fields (Table 3) but this pattern was not statistically significant. In both hedgerows and soybean fields, considerable variability in richness was observed between sites such that nearly twice as many species were collected at the most species rich site compared to the least (Table 3). With the exception of site E where they were nearly equal, soybean field assemblages were numerically more exotic in composition than their adjacent hedgerow assemblages (Table 3), though this pattern was not statistically significant.

3.2 Species excluded from study

The following species occur in specialized microhabitats or have exclusively non-predatory habits and were excluded from further consideration: Bisnius pugetensis Hatch and Aleochara ocularis Klimaszewski primarily inhabit the burrows of mammals (Klimaszewski 1984, Smetana 1995) and were probably captured during dispersal events; Eleusis pallida is a rarely encountered subcortical species that is probably saprophagous like the rest of the subfamily (Newton et al. 2000); Meronera venustula feeds on fungal mycelia and rejected live prey in laboratory trials (Ashe 1985). Undoubtedly, further research will determine other species to be myceto- or saprophagous but with the current, fragmentary knowledge of staphylinid feeding habits (Newton et al. 2000), most species have been included here as predatory.

3.3 Common species

In hedgerows, spring assemblages were dominated by Omalium rivulare and fall assemblages were dominated by Tachinus corticinus Gravenhorst, both exotic species (Table 4). Soybean field assemblages were dominated by Strigota sp. 1, a native
Table 4. Percent activity density (AD) of common species collected in pitfall and pan traps (pooled) in soybean fields and adjacent hedgerows in 2009-2010. Common species were those that comprised ≥1% of total individuals captured. Exotic species denoted by “+”.

<table>
<thead>
<tr>
<th>Species</th>
<th>Spring Hedgerow</th>
<th>Soybean</th>
<th>Percent AD</th>
<th>Species</th>
<th>Fall Hedgerow</th>
<th>Percent AD</th>
</tr>
</thead>
<tbody>
<tr>
<td>Omalium rivulare (Paykull)+</td>
<td>28.4</td>
<td>Strigota sp. 1</td>
<td>35.4</td>
<td>Tachinus corticinus Gravenhorst+</td>
<td>40.4</td>
<td></td>
</tr>
<tr>
<td>Anotylus tetracarinatus (Block)+</td>
<td>10.4</td>
<td>Apocellus sphaerocollis (Say)</td>
<td>13.3</td>
<td>Omalium rivulare (Paykull)+</td>
<td>11.6</td>
<td></td>
</tr>
<tr>
<td>Drusilla canaliculata (Fabricius)+</td>
<td>9.0</td>
<td>Drusilla canaliculata (Fabricius)+</td>
<td>9.1</td>
<td>Tasgius winkleri (Bernhaeur)+</td>
<td>7.0</td>
<td></td>
</tr>
<tr>
<td>Anotylus nanus (Erichson)</td>
<td>6.6</td>
<td>Dinaraea angustula (Gyllenhal)+</td>
<td>5.9</td>
<td>Arpedium cribratum (Fauvel)</td>
<td>4.5</td>
<td></td>
</tr>
<tr>
<td>Tachinus corticinus Gravenhorst+</td>
<td>6.3</td>
<td>Hoplandria lateralis (Melsheimer)</td>
<td>4.9</td>
<td>Tasgius melanarius (Heer)+</td>
<td>4.0</td>
<td></td>
</tr>
<tr>
<td>Apocellus sphaerocollis (Say)</td>
<td>5.2</td>
<td>Aleochara verna Say</td>
<td>4.9</td>
<td>Drusilla canaliculata (Fabricius)+</td>
<td>3.7</td>
<td></td>
</tr>
<tr>
<td>Dinaraea angustula (Gyllenhal)+</td>
<td>4.1</td>
<td>Strigota ambigua (Erichson)</td>
<td>4.4</td>
<td>Olophrum obtectum Erichson</td>
<td>3.5</td>
<td></td>
</tr>
<tr>
<td>Strigota sp. 1</td>
<td>3.3</td>
<td>Oxypoda brachyptera (Stephens)+</td>
<td>2.6</td>
<td>Xantholinus linearis (Olivier)+</td>
<td>3.3</td>
<td></td>
</tr>
<tr>
<td>Dinothenarus badipes (LeConte)</td>
<td>2.5</td>
<td>Anotylus tetracarinatus (Block)+</td>
<td>2.1</td>
<td>Anischa spp.</td>
<td>2.4</td>
<td></td>
</tr>
<tr>
<td>Callicerus rigidicornis Erichson+</td>
<td>1.8</td>
<td>Anotylus insecatus (Erichson)+</td>
<td>1.8</td>
<td>Strigota sp. 1</td>
<td>1.4</td>
<td></td>
</tr>
<tr>
<td>Ilyobates benetti Donisthorpe+</td>
<td>1.7</td>
<td>Anischa spp.</td>
<td>1.6</td>
<td>Tachyporus canadensis Campbell</td>
<td>1.3</td>
<td></td>
</tr>
<tr>
<td>Tasgius melanarius (Heer)+</td>
<td>1.4</td>
<td>Anotylus rugosus (Fabricius)+</td>
<td>1.5</td>
<td>Tachinus luridus Erichson</td>
<td>1.2</td>
<td></td>
</tr>
<tr>
<td>Mocyta fungi (Gravenhorst)+</td>
<td>1.4</td>
<td>Stethusa spuriella (Casey)</td>
<td>1.5</td>
<td>Anotylus nanus (Erichson)</td>
<td>1.1</td>
<td></td>
</tr>
<tr>
<td>Anotylus insecatus (Erichson)+</td>
<td>1.2</td>
<td>Scopaecus minutus Erichson+</td>
<td>1.1</td>
<td>Tachyporus nitidulus (Fabricius)</td>
<td>1.1</td>
<td></td>
</tr>
<tr>
<td>Anischa spp.</td>
<td>1.1</td>
<td>Tachinus corticinus Gravenhorst+</td>
<td>1.0</td>
<td>Omalium repandum Erichson</td>
<td>1.0</td>
<td></td>
</tr>
<tr>
<td>Stethusa spuriella (Casey)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Acidota subcarinata Erichson</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>0.95</td>
<td></td>
</tr>
</tbody>
</table>
species as far as known. In all three assemblages, a single species comprised about one third or more of all individuals. *Acidota subcarinata* Erichson, which comprised 0.95% of all individuals in fall hedgerows, was included in analyses and was the only instance of a marginally ‘common’ species. Species of *Amischa* were treated together, but the introduced *Amischa analis* (Gravenhorst) was most abundant. *Apocellus sphaerocollis* had the second highest AD in soybean but nearly all individuals were captured at the western sites in 2010. Despite this localization, *Apocellus sphaerocollis* was retained as a common species because it has been commonly collected elsewhere in open, disturbed habitat (A. Brunke, personal observations) and may be an important predator under certain environmental conditions. *Oxypoda lacustris* Casey comprised 1.28% of all individuals in spring hedgerows, but nearly all individuals were captured at site LB and on two sampling dates. This species is mostly associated with litter in wetland areas (Klimaszewski et al. 2006, Webster et al. 2009) and a slow-moving stream was present beside the hedgerow at site LB. Thus, *Oxypoda lacustris* was not considered further as a species typical of southern Ontario hedgerows and was excluded from analyses.

### 3.4 Seasonality and habitat use of common soybean species

*Anotylus rugosus* (Fabricius), *Oxypoda brachyptera* (Stephens), *Strigota ambigua* (Erichson) and *Stethusa spuriella* (Casey) did not show any consistent seasonal pattern in AD (Fig. 14-17). *Anotylus rugosus* was most frequently captured in hedgerows during the spring while *Oxypoda brachyptera*, *Strigota ambigua* (Erichson) and *Stethusa spuriella* rarely occurred in hedgerows (Fig. 14-17). *Tachinus corticinus* was restricted to the beginning of the growing season in soybean (peaking in June) and occurred mostly in hedgerows during the coldest parts of the year sampled (Fig. 18). *Anotylus tetracarinatus*
Figure 14. Individuals of *Anotylus rugosus* (Fabricius) captured per trap on different sampling weeks by pitfall and canopy traps in southern Ontario soybean fields and their adjacent hedgerows at: A) 2009 east sites (SG, SC1, SC2); B) 2009 west sites (LA, LG, LB); C) 2010 east sites (E, RA1, RA2); and D) 2010 west sites (GD1, GD2, GD3).
Figure 15. Individuals of *Oxypoda brachyptera* (Stephens) captured per trap on different sampling weeks by pitfall and canopy traps in southern Ontario soybean fields and their adjacent hedgerows at: A) 2009 east sites (SG, SC1, SC2); B) 2009 west sites (LA, LG, LB); C) 2010 east sites (E, RA1, RA2); and D) 2010 west sites (GD1, GD2, GD3).
Figure 16. Individuals of *Strigota ambigua* (Erichson) captured per trap on different sampling weeks by pitfall and canopy traps in southern Ontario soybean fields and their adjacent hedgerows at: A) 2009 east sites (SG, SC1, SC2); B) 2009 west sites (LA, LG, LB); C) 2010 east sites (E, RA1, RA2); and D) 2010 west sites (GD1, GD2, GD3).
Figure 17. Individuals of *Stethusa spuriella* (Casey) captured per trap on different sampling weeks by pitfall and canopy traps in southern Ontario soybean fields and their adjacent hedgerows at: A) 2009 east sites (SG, SC1, SC2); B) 2009 west sites (LA, LG, LB); C) 2010 east sites (E, RA1, RA2); and D) 2010 west sites (GD1, GD2, GD3).
Figure 18. Individuals of *Tachinus corticinus* Gravenhorst captured per trap on different sampling weeks by pitfall and canopy traps in southern Ontario soybean fields and their adjacent hedgerows at: A) 2009 east sites (SG, SC1, SC2); B) 2009 west sites (LA, LG, LB); C) 2010 east sites (E, RA1, RA2); and D) 2010 west sites (GD1, GD2, GD3).
(Block), *Scopaeus minutus* Erichson and *Aleochara verna* Say were also early season species and peaked in AD during June to mid-July (Fig. 19-21). In hedgerows, only one individual of *Scopaeus minutus* was captured and *Aleochara verna* was rarely collected, while *Anotylus tetracarinatus* was abundant in spring. *Anotylus insecatus* (Erichson), *Apocellus sphaericollis*, *Dinaraea angustula* (Gyllenhal) and *Strigota* sp. 1 were mostly early season species: occurring in spring hedgerows and generally decreasing in AD over the soybean growing season (Fig. 22-25). The genus *Amischa* was most abundant in July and occurred in hedgerows in both spring and fall (Fig. 26). *Drusilla canaliculata* (Fabricius) and *Hoplandria lateralis* (Melsheimer) were both observed to peak in AD from mid-July to mid-August (Fig. 27-28). *Drusilla canaliculata* was widely distributed and was frequently captured in both spring and fall hedgerows, while *Hoplandria lateralis* was only captured in soybean fields (Fig. 27-28) and was only locally common at the western sites in 2009.

With increasing distance from the field edge, more individuals were captured of *Apocellus sphaericollis* ($y = 0.16x+1.256$, $Z = 0.041$, $p < 0.001$), *Aleochara verna* ($y = 0.19x+0.26$, $Z = 0.079$, $p = 0.016$), *Dinaraea angustula* ($y = 0.31x-0.19$, $Z = 0.073$, $p < 0.001$) and *Strigota* sp. 1 ($y = 0.13x+1.48$, $Z = 0.024$, $p < 0.001$). With increasing distance from the field edge, fewer individuals were captured of *Anotylus tetracarinatus* ($y = -0.40x+1.24$, $Z = -3.04$, $p = 0.002$), *Drusilla canaliculata* ($y = -0.40x+1.43$, $Z = 0.060$, $p < 0.001$) and *Hoplandria lateralis* ($y = -0.24x+1.75$, $Z = 0.075$, $p = 0.002$). No differences were found in the remaining species.
Figure 19. Individuals of *Anotylus tetracarinatus* (Block) captured per trap on different sampling weeks by pitfall and canopy traps in southern Ontario soybean fields and their adjacent hedgerows at: A) 2009 east sites (SG, SC1, SC2); B) 2009 west sites (LA, LG, LB); C) 2010 east sites (E, RA1, RA2); and D) 2010 west sites (GD1, GD2, GD3).
Figure 20. Individuals of *Scopaeus minutus* Erichson captured per trap on different sampling weeks by pitfall and canopy traps in southern Ontario soybean fields and their adjacent hedgerows at: A) 2009 east sites (SG, SC1, SC2); B) 2009 west sites (LA, LG, LB); C) 2010 east sites (E, RA1, RA2); and D) 2010 west sites (GD1, GD2, GD3).
Figure 21. Individuals of Aleochara verna Say captured per trap on different sampling weeks by pitfall and canopy traps in southern Ontario soybean fields and their adjacent hedgerows at: A) 2009 east sites (SG, SC1, SC2); B) 2009 west sites (LA, LG, LB); C) 2010 east sites (E, RA1, RA2); and D) 2010 west sites (GD1, GD2, GD3).
Figure 22. Individuals of *Anotylus insecatus* (Gravenhorst) captured per trap on different sampling weeks by pitfall and canopy traps in southern Ontario soybean fields and their adjacent hedgerows at: A) 2009 east sites (SG, SC1, SC2); B) 2009 west sites (LA, LG, LB); C) 2010 east sites (E, RA1, RA2); and D) 2010 west sites (GD1, GD2, GD3).
Figure 23. Individuals of *Apocellus sphaericollis* (Say) captured per trap on different sampling weeks by pitfall and canopy traps in southern Ontario soybean fields and their adjacent hedgerows at: A) 2009 west sites (LA, LG, LB); B) 2010 west sites (GD1, GD2, GD3). No individuals were captured at the east sites in either year.
Figure 24. Individuals of *Dinaraea angustula* (Gyllenhal) captured per trap on different sampling weeks by pitfall and canopy traps in southern Ontario soybean fields and their adjacent hedgerows at: A) 2009 east sites (SG, SC1, SC2); B) 2009 west sites (LA, LG, LB); C) 2010 east sites (E, RA1, RA2); and D) 2010 west sites (GD1, GD2, GD3).
Figure 25. Individuals of *Strigota* sp. 1 captured per trap on different sampling weeks by pitfall and canopy traps in southern Ontario soybean fields and their adjacent hedgerows at: A) 2009 east sites (SG, SC1, SC2); B) 2009 west sites (LA, LG, LB); C) 2010 east sites (E, RA1, RA2); and D) 2010 west sites (GD1, GD2, GD3).
Figure 26. Individuals of *Amischa* spp. captured per trap on different sampling weeks by pitfall and canopy traps in southern Ontario soybean fields and their adjacent hedgerows at: A) 2009 east sites (SG, SC1, SC2); B) 2009 west sites (LA, LG, LB); C) 2010 east sites (E, RA1, RA2); and D) 2010 west sites (GD1, GD2, GD3).
Figure 27. Individuals of *Drusilla canaliculata* (Fabricius) captured per trap on different sampling weeks by pitfall and canopy traps in southern Ontario soybean fields and their adjacent hedgerows at: A) 2009 east sites (SG, SC1, SC2); B) 2009 west sites (LA, LG, LB); C) 2010 east sites (E, RA1, RA2); and D) 2010 west sites (GD1, GD2, GD3).
Figure 28. Individuals of *Hoplandria lateralis* (Melsheimer) captured per trap on different sampling weeks by pitfall and canopy traps in southern Ontario soybean fields and their adjacent hedgerows at: A) 2009 east sites (SG, SC1, SC2); B) 2009 west sites (LA, LG, LB); and C) 2010 west sites (GD1, GD2, GD3). No individuals were observed at the 2010 east sites.
3.5 Influence of hedgerow habitat type on common soybean species

In spring hedgerows, more individuals of *Apocellus sphaericollis* (Say) (*y* = 0.33x + 1.10, *Z* = 0.138, *p* = 0.016) were captured in field patches than in open woodland patches. In the same season, more individuals of *Anotylus tetracarinatus* (Block) were captured in open woodland patches than in field patches (*y* = -0.60x+1.44, *Z* = 0.11, *p* < 0.001). In fall hedgerows, more individuals of *Tachinus corticinus* Gravenhorst were captured in open woodland patches than field patches (*y* = -0.41x+2.05, *Z* = 0.074, *p* < 0.001). Although *Tachinus corticinus* was a common species in both seasons, no difference in AD was observed between open woodland and field patches in spring. Differences in other species were not observed.

4. Discussion

4.1 Assemblage richness and composition

The number of staphylinid species found by the present study in the soybean field-hedgerow landscape (154 spp.) was similar to a survey of apple (191 spp.) and pear (121 spp.) orchards in Hungary (Balog et al. 2008). Comparisons between agricultural assemblages of North American staphylinids are limited as the Aleocharinae are rarely identified to species due to the difficulty associated with their identification (Levesque and Levesque 1995, Brunke et al. 2009). However, the assemblage occurring in dairy pastures in the northeastern United States including aleocharines (Byers et al. 2000) was comparable in richness (79 spp.) to that of southern Ontario soybean fields in the present study (80 spp.). Although differences in sampling effort and methodology between the above studies and the present make comparisons problematic (Luff 1975, Schirmel et al. 2010), the similarities between agricultural landscape in richness suggest that the
soybean-hedgerow landscape is not drastically more species-rich or species-poor than other managed landscapes.

The staphylinid assemblage of hedgerows (Appendix 1) differed strongly in species composition between spring and fall. With respect to common species, the spring hedgerow assemblage was more similar to that of soybean fields (9 species shared) than the assemblage of fall hedgerows (6 species shared) (Table 3). This similarity implies that many common species in soybean have the potential to occur in fields before soybean pests, an important trait in generalist predators in soybean (Rutledge et al. 2004).

Available data on the habitat preferences of the common hedgerow species (Campbell 1973, 1979, Campbell and Tomlin 1983, Anderson 1991, Levesque and Levesque 1995, Assing 1999, 2001, Balog and Marko 2007, Klimaszewski et al. 2007, Brunke and Marshall 2011, Brunke et al. 2011) reveal that habitat generalists, typical of open or disturbed areas, dominate the assemblage. Only Omalium repandum can be considered typically forest-dwelling (Brunke and Marshall 2011). For the species Anotylus nanus, Apocellus sphaerocollis and Strigota sp. 1, published data were not available but collections in the University of Guelph Insect Collection suggest that they are also generalists and typical of open and/or disturbed areas. Indeed, only four of twenty-five common hedgerow species preferred either field or open woodland type patches of hedgerow in the present study. In general, hedgerows adjacent to soybean fields in southern Ontario, though heterogeneous in composition, appear to be similar in habitat value for most of the common staphylinid species in this study. Fournier and Loreau (2001) reached similar conclusions when comparing carabid species composition of
woodland fragments with that of hedgerows and found that heavily fragmented agricultural landscapes contained few habitat specialists.

The staphylinid assemblage in southern Ontario soybean fields (Appendix 2) was found to be a subset of the assemblage present in adjacent hedgerows, with only nine unique species, none of which were common. The annual nature of soybean agriculture presents challenges to species of the regional predator fauna and only those that are pre-adapted to tolerate these ephemeral and rather homogeneous environments can be expected to be successful (Wiedenmann and Smith 1997). Consequently, a variety of annual crops share several dominant and ubiquitous species that possess appropriate pre-adaptations (Wiedenmann and Smith 1997). In an extensive review of rove beetle species typically found in Norwegian agroecosystems, Anderson (1991) listed the thirty most widespread species based on their dominance in a variety of crop types; three of these species were also common in southern Ontario soybean fields: *Anotylus rugosus*, *Dinaraea angustula* and *Amischa analis* (Gravenhorst). Indeed, the four most abundant staphylinid species (*Dinaraea angustula, Strigota ambigua, Hoplandria lateralis, Anotylus spp.*) found in Pennsylvania vegetable crops (Leslie et al. 2007) were also found to be common in soybean fields. Only one of the four most abundant species (*Tachinus corticinus*) in less ephemeral raspberry plantations (Levesque and Levesque 1995) was common in soybean fields. In North American agroecosystems including those mentioned above and the present study, the most abundant rove beetle species were generally exotic, accidentally introduced by human activity. This pattern also occurs in ground beetle assemblages where the exotic *Pterostichus melanarius* was found to be an abundant species in soybean (Hajek et al. 2007), potato (Leslie et al. 2007), sweet potato
and carrot crop systems (Brunke et al. 2009) in northeastern North America. Clark et al. (1997) found this species to occur more often in managed than unmanaged habitats in Michigan. The widespread dominance of exotic species in agroecosystems assemblages suggests that traits that predispose generalist predators to accidental introduction from other continents also pre-adapt them to success in annual crop systems. Hedgerows in the present study represented a more permanent habitat and at many sites had a higher species richness and lower proportion of exotic staphylinid species compared to soybean fields, though an overall pattern across all sites was not apparent and other factors such as habitat heterogeneity (Duelli 1997) may be important.

4.2 Seasonal activity patterns in soybean fields

A seasonal progression of species was observed in southern Ontario soybean fields: four early season species (*Tachinus corticinus*, *Scopaeus minutus*, *Aleochara verna* and *Anotylus tetracarinatus*), were probably active in soybean before sampling began in mid-June and generally attained maximal AD in June to early-July; five species attained maximal AD in late June to July; and two late season species (*Drusilla canaliculata* and *Hoplandria lateralis*) reached maximal AD in late July to August. Very few staphylinids were captured at the end of soybean sampling in September.

Although temporal patterns of staphylinid activity in soybean are poorly known, Hajek et al. (2007) observed most Carabidae to also decline in AD over the growing season. *Tachinus corticinus* differed from the other early species in that individuals were generally absent after June. Maximum activity of *Tachinus corticinus* in Québec raspberry plantations occurred in June but high levels of activity were maintained until July (Levesque and Levesque 1996). The shaded microclimate provided by perennial
raspberry canes may be more favorable to this species than the relatively open conditions in early summer soybean. However, early seasonal AD of *Anotylus tetracarinatus* was similar in both raspberry and soybean fields (Levesque and Levesque 1996). *Scopaeus minutus* was only recently recorded in detail from North America (Brunke and Marshall 2011) and its seasonality was previously unknown although high spring activity has also been reported in Czechoslovakian populations (Bohac 1985). Seasonal activity of adult *Aleochara* species in agricultural fields is typically related to the availability of eggs and larvae of pestiferous *Delia* (Diptera: Anthomyiidae), the pupae of which serve as larval hosts (Hummel et al. 2010). As *Delia platura* Meigan is an early season pest of soybean seeds (OMAFRA 2011), the abundance of adult *Aleochara verna* during the early stages of soybean growth may be indicative of parasitism. A more detailed study involving rearing of *Delia platura* pupae to determine parasitoid identities and measure parasitism rates is recommended. *Hoplandria lateralis* has been collected broadly over the year (Genier 1989) and its seasonality in agroecosystems was not previously reported (Leslie et al. 2007). This species typically occurs in decaying organic matter or leaf litter (Genier 1989) and canopy closure of soybean in August may have provided a favorable level of moisture. Indeed it was more abundant towards the densely vegetated edge of soybean fields in the present study. Late season activity of *Drusilla canaliculata* was also observed in Hungarian apple orchards where it was more abundant in field edges or abandoned orchards compared to field interiors of operational orchards (Balog and Marko 2007). Its temporal occurrence in soybean may be due to a combination of life history and preferences for more perennial habitats. Congruently, higher AD was observed towards the edge of soybean fields (i.e. near hedgerows) in the present study.
Common staphylinid species with highly variable seasonal activity between fields and years were probably responding positively to specific microhabitat conditions only occasionally present in soybean fields. Of these, species of *Stethusa* Casey are typically found in high-moisture microhabitats such as rotting vegetation and dung (Gusarov 2003) and thus may not be ‘true’ inhabitants of soybean fields despite sporadically high AD.

**4.3 Habitat use of common soybean Staphylinidae**

Nine of 15 common soybean species were found in hedgerows outside of the soybean growing season. Adjacent hedgerows provide important habitat to predatory beetles outside the growing season in Europe (Holland et al. 2009). All staphylinid species sampled during the winter in a wheat and grass field landscape were more abundant in hedgerows compared to grass fields or ploughed winter wheat in Norway (Anderson 1997). While the current study did not sample simultaneously in both hedgerows and soybean fields, it confirms that most common soybean species do inhabit hedgerows and that those species (except *Tachinus corticinus* and *Anotylus tetracarinatus*) do not discriminate between field or open woodland patches. Further research comparing numbers of overwintering staphylinids between fields and hedgerows (as in Anderson 1997) or Pfiffner and Luka 2000) would assess the degree to which staphylinids benefit from this provision of habitat. European staphylinid species that utilize hedgerows for overwintering habitat were generally spring-active whereas those with summer activity generally overwintered in the fields themselves (Holland et al. 2009). This pattern was not observed in the current study and differences in hedgerow use by soybean staphylinids may be due to habitat or host requirements rather than phenology. *Scopaeus minutus* and *Strigota ambigua* are both reported as preferring
habitats with bare, highly disturbed ground (Bohac 1985, Leslie et al. 2007) and
*Aleochara verna, Hoplandria lateralis* and members of the genus *Stethusa* are most
typically found in highly productive rotting organic matter (Klimaszewski 1984, Genier
1989, Gusarov 2003), microhabitats that are uncommon in hedgerows. Additionally, the
hosts of *Aleochara verna* may not occur in hedgerows at levels adequate to sustain stable
populations. Holland et al. (2009) emphasized the importance of cultural practices such
as non-inversion tillage in the conservation of those species that overwintered in fields
rather than hedgerows. As *Oxypoda brachyptera* typically inhabits scrubby, forest edges
in its native Palaearctic range (Legowski et al. 1995), it is surprising that it only rarely
utilized hedgerows outside of the growing season in southern Ontario. Additional surveys
are needed to establish whether hedgerow use by the above species is stable across a
wider geographic area and range of annual crop systems.

The ability of a species to penetrate into the crop interior is important in the
evaluation of predator species for potential biocontrol services (Coombes and Sotherton
1986). Similar to carabids in New York soybean fields (Hajek et al. 2007), 12 of 15
common soybean staphylinids were distributed without an association with the edge.
Some carabid species that overwinter in hedgerows only occur in field interiors after a
time delay or remain in field edges (Coombes and Sotherton 1986). The only staphylinids
(*Tachyporus* spp.) observed in that study were able to quickly colonize field interiors. Of
the 9 species that overwintered in Ontario hedgerows, 7 were distributed in fields without
association with the edge and 3 of these even preferred to occur away from the edge.
Therefore, hedgerows outside of the growing season supported the majority of common
soybean staphylinids and most of these species were subsequently able to penetrate field interiors.

4.4 Potential biocontrol services and future directions

Due to high AD, an ability to penetrate field interiors and widespread occurrence in soybean fields, *Aleochara verna*, *Dinaraea angustula*, *Strigota* sp. 1 and *Strigota ambigua* have the highest potential for biocontrol services and warrant future investigation. Currently, little is known about the biology of *Strigota* species except that *Strigota ambigua* was an abundant species of vegetable crops in Pennsylvania (Leslie et al. 2007). *Strigota* sp. 1, which had the highest AD in soybean, is probably undescribed and widespread in range (J. Klimaszewski *pers. comm.*

1), and highlights the importance of detailed assemblage surveys for the study of staphylinid agroecology in North America. Although staphylinid assemblages in European agriculture appear to be generally constant in composition (Kross and Schaefer 1998), North American assemblages are dynamic with exotic species frequently establishing themselves (Majka and Klimaszewski 2008, Klimaszewski et al. 2010). *Dinaraea angustula* is an exotic species to North America, commonly encountered in North American (Klimaszewski et al. 2007, Leslie et al. 2007) and European agroecosystems (Anderson 1991, Balog et al. 2008) but little is known of its prey range. It was observed in the field to accept larval Diptera as prey (Balduf 1935). Finally, *Aleochara verna* may be an important natural enemy of seedcorn maggot in soybean, and so focused investigations of their parasitism rates and host synchronization similar to those of Andreassen et al. (2010) are recommended.

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1 Canadian Forest Service, Laurentian Forestry Centre, Ste. Foy, Québec.
4.5 Conclusion

This study identified the common species in soybean fields, enabling a description of their spatiotemporal distributions and use of the soybean-hedgerow landscape. The staphylinid assemblage in soybean was dominated by exotic species and its species were generally most active in July. Most species were able to penetrate field interiors and survived outside of the growing season in hedgerows. The baseline data acquired in this investigation provides a context for focused predation studies involving behavioural experiments under simulated field conditions (Kollat-Palenga and Basedow 2000, Hannam et al. 2008) and the verification of predation under natural conditions using molecular marking assays (Lundren et al. 2009a).

The current investigation represents the first species-level survey and study of Staphylinidae in soybean and in northeastern North American field crops. The use of hedgerows by agriculturally important staphylinids outside of the growing season has not been reported in annual North American agroecosystems. This survey also generated new records of exotic and native species for Ontario and Canada (Brunke and Majka 2010, Brunke and Marshall 2011, Brunke et al. 2011, Brunke and Klimaszewski in prep) and the most abundant species of staphylinid in soybean may be a new species of Strigota. Contrary to what was reported in most previous surveys of natural enemies in soybean, this study demonstrated that Staphylinidae is an abundant, diverse predator group in soybean with potential for biocontrol services and deserve further research attention.
Chapter IV

Rove beetles (Coleoptera: Staphylinidae) associated with Soybean Aphid (*Aphis glycines* Matsumura) and Bean Leaf Beetle (*Ceratoma trifurcata* (Forster)) populations in soybean-hedgerow landscapes

1 Introduction

In Ontario, Soybean Aphid and Bean Leaf Beetle are two of the most important insect pests of soybeans (OMAFRA 2011). Several recent surveys of soybean fields in northeastern North America uncovered a diverse, generalist predator assemblage (Fox et al. 2005, Hajek et al. 2007) that is capable of preventing pests from reaching their economic damage thresholds (Fox et al. 2004) or depressing pest population growth such that economic damage is delayed (Donaldson et al. 2007). Prior to the current study, the predaceous rove beetle assemblage of soybean fields had received little attention; however, a targeted survey found that several species were widespread and abundant, and may provide important biocontrol services (Chapter III).

Although accounts of rove beetle predation of Soybean Aphid are limited to one study in Indonesia (Van der Berg et al. 1997), these beetles are well known as biocontrol agents for cereal aphids in central Europe (Dennis and Wratten 1991). Beginning at dusk, species of *Tachyporus* Gravenhorst climb plants to consume aphids while other species prey upon aphids that have been displaced to the ground by weather or by other predators (Dennis and Sotherton 1994, Kollat-Palenga and Basedow 2000). The impact of predation by generalist staphylinids is greatest during the early growth phase of aphid populations (Dennis and Wratten 1991). While no *Tachyporus* species were considered to be common in Ontario soybean fields (Chapter III), the known biology of the genus suggests that the seven species captured probably provide important biocontrol services.
Soybean Aphids experience high mortality (~70%) while overwintering as eggs on exotic buckthorn shrubs (*Rhamnus* spp.) in Ontario hedgerows. Predation was proposed as a major contributing factor (Welsman et al. 2007). Several rove beetle species, including some *Tachyporus* were common in Ontario hedgerows (Chapter III) during the spring and fall, and those active on buckthorn shrubs may be important aphid predators.

In contrast, very little is known about insect predation of Bean Leaf Beetle (Toepfer et al. 2009) but, given its adult size (~5 mm) (OMAFRA 2011), adult beetles are too large to be preferred prey items for most rove beetles (which are mostly 3–4 mm in length). Species of the subtribe Staphylinina (large rove beetles: typically greater than 12 mm) are known to consume adults of pestiferous beetles comparable in size to Bean Leaf Beetle (Hawkins 1936). No species of this group were considered widespread and common in Ontario soybean fields except for *Tasgius ater* (Gravenhorst), which was recovered in relatively high numbers at several sites (Chapter III). However, several other species of Staphylinina were common and widespread in hedgerows adjacent to soybean fields (Chapter III) and may be important predators of Bean Leaf Beetles overwintering in leaf litter (Lam and Pedigo 2000).

Subterranean Bean Leaf Beetle larvae and eggs in soybean fields may be more susceptible to rove beetle predation than the larger, better protected and more mobile adults. ‘Small’ rove beetles (<5 mm) were among the most important predators of soil-inhabiting Western Corn Rootworm (*Diabrotica virgifera virgifera* LeConte) eggs and larvae (Lundgren et al. 2009a), and several Staphylinidae preyed upon turf-pest scarab (*Ataenius spretulus* (Haldeman)) larvae in lab assays (Jo and Smitley 2003).
To understand these potential predator-prey interactions, those components of the predator assemblage that co-occur with soybean pests at finer spatial scales and during critical times in their lifecycle need to be identified and characterized. In the present study Soybean Aphid and Bean Leaf Beetle populations in Ontario were surveyed to establish the seasonal occurrence of the early aphid growth phase and of immature stages, respectively. Soybean and buckthorn vegetation was surveyed for rove beetles to identify species with high levels of canopy activity. Diel patterns in this activity were observed in soybean fields over two days. Co-existing populations of large rove beetles and Bean Leaf Beetle were studied in the soybean-hedgerow landscape to evaluate potential predator-prey interactions. Relationships between field population levels of common soybean Staphylinidae, Soybean Aphid and Bean Leaf Beetle populations were examined.

2 Materials and Methods

2.1 Spatiotemporal distributions of rove beetles

Twelve soybean fields (six sites each year) and their adjacent hedgerows were sampled in 2009-2010 using the protocol described in Chapter III. For details of specimen preparation and identifications, the reader is referred to Chapter III. Voucher specimens were deposited in the University of Guelph Insect Collection, Guelph, Ontario, Canada. Species that comprised ≥1% of the total activity density (AD) in either spring hedgerows, soybean fields or fall hedgerows were considered common members in their respective habitat assemblages. Only common species were considered in the analyses described below, with the addition of Tachyporus species for those analyses examining potential predation of Soybean Aphid, and species of Staphylinina for analyses of adult
Bean Leaf Beetle occurrence. Seasonal patterns in AD of *Tachyporus* and Staphylinina species were determined using data acquired in another part of this study (summarized in Chapter III).

2.2 Population dynamics of soybean pests

Soybean Aphids were sampled by removing ten whole soybean plants, randomly selected from between existing sampling transects to prevent habitat disruption in vicinity of traps. Soybean was sampled weekly beginning at the R1 stage (mid-June) and continued until aphids were undetectable for two consecutive weeks. Dates with relatively low Soybean Aphid numbers preceded by a sharp population increase were considered to constitute the early growth phase. Soybean aphids were rarely encountered on buckthorn shrubs in hedgerows and thus were not regularly sampled in that habitat.

Bean Leaf Beetles were sampled in hedgerows and soybean fields using the same methodology used for rove beetles, described in Chapter III. Passive sampling (i.e. pitfall traps) in soybean was favored over active sampling (i.e. sweeping plants) to prevent disruption and damage to the vegetation in the experimental area of the field. The absence or a period of low AD of Bean Leaf Beetle after early summer activity and before late summer activity was considered to represent the presence of larvae and eggs.

2.3 Diel activity patterns in the soybean rove beetle assemblage

At site SG, rove beetles were collected from soybean foliage over 48 h, at 4 h intervals using a suction sampler built from a hand-held, gas powered commercial leaf blower/vacuum (Troy-Bilt, model tb320bv, Cleveland, Ohio). The device was fitted with 1m of dryer exhaust duct (12cm diam., ending in a 20cm diam. head) to provide flexibility in dense stands of soybean. Insect net bags (38.1cm diam., BioQuip, Rancho
 Dominguez, CA) were inserted into and clipped onto the end of the dryer duct and acted as removable sample bags. Samples were taken at 8am, 12pm, 4pm, 8pm, 12am and 4am. Each sampling replicate consisted of vacuuming ten randomly placed, 1m transects of planted soybean within a 5m x 30m plot as follows: plants were sampled using five upward sweeps on each side of the transect line, followed by five downward motions directly over the transect plants. After ten transects had been sampled within a plot, the net bag was removed, labeled, tied and replaced. The contents of net bags were hand sorted in the lab. Vouchers were deposited as above. Five plots were sampled per time interval. Plots were randomly assigned sampling times and were never used twice. One 48h experiment was conducted in flowering soybean (stage R2, July 16-18, 2009) and one in pod-forming soybean (R5, August 12-14, 2009). These experiments did not continue in 2010 as Soybean Aphids were not detected at any of the six sites.

2.4 Statistical analyses

All analyses were performed using R 2.12.1 (R Core Development Team 2010) and statistical significance was taken at $\alpha = 0.05$. The absence of Soybean Aphid in 2010 resulted in a low number of datapoints, a maximum of six for all analyses involving the co-occurrence of Soybean Aphid and rove beetle populations. Therefore, species absent from two or more sites were excluded from these analyses to avoid drawing conclusions based on insufficient data. The proportion of the total catch captured in canopy traps was considered an approximation of canopy activity and was measured for *Tachyporus* species and the common species discussed in Chapter III. These proportional data were arcsin transformed prior to analysis to satisfy the requirements of ANOVA but were presented untransformed in Table 5. Spring hedgerows, fall hedgerows, and soybean
fields were considered individually and canopy activity was calculated at the site level. With species as a main effect and sites as individual datapoints, an ANOVA was used to identify species with high levels of canopy activity and Tukey’s HSD was used for pairwise comparisons of species.

Diel activity over 48h in soybean was analyzed using an ANOVA with soybean stage (flowering/pod-forming) and sampling time as main effects. Tukey’s HSD was used for pairwise comparisons of sampling times to detect possible activity peaks. Diel activity was analyzed separately for each species that was present in both soybean growth stages and was represented by at least six individuals.

Linear regression analyses under a general linear model were used to examine how Soybean Aphid populations at each site varied with co-occurring rove beetle ADs during the early growth phase of Soybean Aphid (determined as mentioned above). Rove beetle ADs were standardized by the number of operational traps over the early growth phase at each site. Separate analyses were conducted for the total number of aphids captured over the early growth phase and the slope of population size over that time period. Linear regression was used instead of Poisson because the standardized, non-integer values for rove beetle AD were not appropriate for Poisson regression.

Spatiotemporal relationships between large rove beetle species and Bean Leaf Beetle were analyzed using a zero-inflated Poisson regression between rove beetle and Bean Leaf Beetle ADs at the trap level, with site as a predictor of excess zeros. For justification of this methodology, see Chapter III. Preferences of Bean Leaf Beetle for the edge or interior of soybean fields were examined using the above methodology, with distance from the field edge as a predictor of Bean Leaf Beetle AD. If spatial patterns
were detected in Bean Leaf Beetle AD, the same analysis was conducted with large rove beetle species occurring in soybean fields.

The total soybean ADs of common rove beetles were used as predictors of total site AD of Bean Leaf Beetle using a Poisson regression. Season totals for each site were used as individual datapoints in this analysis to ascertain whether fields with lower numbers of Bean Leaf Beetle adults were more likely to have higher populations of common rove beetle species. Species were included in this analysis if they co-occurred with Bean Leaf Beetle in at least 5 sites. Sites where Bean Leaf Beetles were never detected were excluded from analyses.

3 Results

3.1 Seasonal occurrence of Soybean Aphid and Bean Leaf Beetle

Soybean Aphid presence was first observed on July 14, 2009 in all fields (Fig. 29). A period of relatively low aphid populations was observed at all sites from July 14 to 27, with this period extending to August 4 at sites SG, LA and LB (Fig. 29). Therefore the period of early Soybean Aphid population growth in 2009 occurred from July 14 to July 27, though aphids may have been present at extremely low numbers prior to July 14. The first diel activity experiment occurred during this period. On the last date of trap collection, most soybean plants had senesced and Soybean Aphids were no longer detectable with our sampling methodology. No individuals of Soybean Aphid were detected in 2010.
Figure 29. Mean number of Soybean Aphid (*Aphis glycines* Matsumura) per plant (±SE, n = 5) selected randomly in A) east, and B) west groups of southern Ontario soybean fields over the growing season in 2009. Sampling occurred weekly and continued until fifty percent or more plants in the study area senesced. Aphids were first detected on July 14 in all fields.
Bean Leaf Beetles showed a low activity density in hedgerows during spring and fall and were sparsely distributed throughout this habitat compared to adjacent populations in soybean fields, with the exception of high AD on September 21, 2009 (Fig. 30). Activity in hedgerows during the spring was observed two weeks earlier in 2010 than in 2009. Two distinct peaks in adult Bean Leaf Beetle AD were observed in 2009 soybean fields while only a single peak was observed in 2010 (Fig. 30). In 2009, a period of low adult activity was observed for four weeks, from July 21 until August 18, and was considered to correspond with the presence of eggs and larvae. Overwintered adults were generally not detected in soybean fields before August in 2010 (Fig. 30). The four weeks previous to the observed late season AD in 2010 was considered to correspond to larval development (July 7-July 28). Between years, presumed larval development times overlapped by only one week.

3.2 Canopy activity of staphylinids in soybean fields and their adjacent hedgerows

In spring hedgerows, canopy activity differed significantly among species (d.f = 9, 95, $F = 6.31$, $p < 0.001$), but no differences were found among species in the fall. Of the six Tachyporus species found in Ontario hedgerows (Chapter III) only Tachyporus canadensis Campbell, Tachyporus dispar (Paykull) and Tachyporus nitidulus (Fabricius) were active in buckthorn canopies. Amischa spp. and Tachyporus dispar were significantly more active in spring canopies than Dinaraea angustula (Gyllenhal), Anotylus nanus (Erichson), Omalium rivulare (Paykull), Strigota sp. 1 and Tachinus corticinus Gravenhorst (Table 5). In spring, canopy activity of Mocyta fungi (Gravenhorst), Tachyporus nitidulus and Anotylus tetracarinatus (Block) was high but not statistically different than other species in post hoc comparisons (Table 5).
Figure 30. Activity density of Bean Leaf Beetle (*Ceratoma trifurcata* (Forster)) per trap on different sampling weeks, calculated from captures in pitfall and canopy traps placed in soybean fields or adjacent hedgerows in southern Ontario in A) 2009, and B) 2010.
Table 5. Presence of Staphylinidae in hedgerow canopy traps in 2009-2010 and mean percent (± SE) (untransformed) of total individuals captured in canopy traps (canopy activity). Means within a season followed by the same letter do not differ significantly, Tukey’s HSD, α = 0.05.

<table>
<thead>
<tr>
<th>Species</th>
<th>Canopy Activity (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Mean ± SE</td>
</tr>
<tr>
<td><strong>Spring</strong></td>
<td></td>
</tr>
<tr>
<td><em>Amischa spp.</em></td>
<td>57.6±10.9 a</td>
</tr>
<tr>
<td><em>Tachyporus dispar</em></td>
<td>57.0±15.1 a</td>
</tr>
<tr>
<td><em>Mocyta fungi</em></td>
<td>36.2±10.8 a,b</td>
</tr>
<tr>
<td><em>Tachyporus nitidulus</em></td>
<td>32.4±15.1 a,b</td>
</tr>
<tr>
<td><em>Anotylus tetracarinatus</em></td>
<td>29.9± 7.3 a,b</td>
</tr>
<tr>
<td><em>Dinaraea angustula</em></td>
<td>7.2± 2.2 b</td>
</tr>
<tr>
<td><em>Anotylus nanus</em></td>
<td>6.5± 3.3 b</td>
</tr>
<tr>
<td><em>Omalium rivulare</em></td>
<td>3.0± 1.1 b</td>
</tr>
<tr>
<td><em>Strigota</em> sp. 1</td>
<td>0.7± 0.7 b</td>
</tr>
<tr>
<td><em>Tachinus corticinus</em></td>
<td>0.5± 0.5 b</td>
</tr>
</tbody>
</table>

| **Fall**                 |                     |
| *Amischa spp.*           | 54.1±18.8a          |
| *Tachyporus dispar*      | 36.1±18.0a          |
| *Omalium rivulare*       | 25.6±16.3a          |
| *Stethusa spuriella*    | 22.1±18.8a          |
| *Olophrum obtectum*     | 16.7±16.6a          |
| *Tachyporus canadensis* | 16.7±18.0a          |
| *Tachinus corticinus*   | 11.3±16.6a          |
| *Xantholinus linearis*  | 1.7 ±16.3a          |
| *Omalium repandum*      | 1.6 ±17.4a          |
| *Strigota* sp. 1        | -1                  |
| *Tachyporus nitidulus*  | -1                  |

1Species excluded from analysis due to insufficient data, means not calculated.
Tachyporus canadensis was not active in hedgerow canopies during the spring and was only active in fall. Early in the spring sampling period, the canopy-active staphylinid assemblage was predominantly composed of *Amischa* spp. (see Chapter III), *Anotylus tetracarinatus* (see Chapter III), *Mocyta fungi* (Fig. 31), and *Tachyporus dispar* (Fig. 32), while later in the spring the assemblage was dominated by *Anotylus tetracarinatus* and *Tachyporus nitidulus* (Fig. 33). In the fall sampling period, temporal patterns in the canopy staphylinid assemblage were unclear, as species did not differ significantly in their mean activity.

The soybean canopy-active species *Hoplandria lateralis* (Melsheimer), *Oxypoda brachyptera* (Stephens) and *Scopaeus minutus* Erichson were excluded from analysis because of insufficient data (see Methods). Of the seven *Tachyporus* species found in Ontario soybean fields (Chapter III), only *Tachyporus dispar* and *Tachyporus nitidulus* were active in soybean vegetation. Mean canopy activity was found to differ among species in soybean (d.f. = 6, 28, $F = 3.94$, $p = 0.005$) (ANOVA), but post hoc means comparisons (Tukey’s HSD) failed to recognize differences. *Tachyporus nitidulus* and *Amischa* spp. had the highest mean canopy activity although only the former was found to be significantly different and only from the two least active species, *Strigota ambigua* and *Strigota* sp. 1 (Table 6). *Stethusa spuriella* (Casey), *Anotylus tetracarinatus* and *Tachyporus dispar* also had high mean canopy activity relative to other species (Table 6). Canopy activity in soybean, as determined by passive traps, was observed during the early aphid growth period for all canopy active species except *Scopaeus minutus*, *Strigota ambigua* and *Tachyporus dispar* (Table 6).
Figure 31. Individuals of *Mocyta fungi* (Gravenhorst) captured per trap on different sampling weeks by pitfall and canopy traps in southern Ontario soybean fields and their adjacent hedgerows at: A) 2009 east sites (SG, SC1, SC2); B) 2009 west sites (LA, LG, LB); C) 2010 east sites (E, RA1, RA2); and D) 2010 west sites (GD1, GD2, GD3). This species did not occur in fall hedgerows and was uncommon in soybean fields.
Figure 32. Individuals of *Tachyporus dispar* (Paykull) captured per trap on different sampling weeks by pitfall and canopy traps in southern Ontario soybean fields and their adjacent hedgerows at: A) 2009 east sites (SG, SC1, SC2); B) 2009 west sites (LA, LG, LB); C) 2010 east sites (E, RA1, RA2); and D) 2010 west sites (GD1, GD2, GD3).
Figure 33. Individuals of *Tachyporus nitidulus* (Fabricius) captured per trap on different sampling weeks by pitfall and canopy traps in southern Ontario soybean fields and their adjacent hedgerows at: A) 2009 east sites (SG, SC1, SC2); B) 2009 west sites (LA, LG, LB); C) 2010 east sites (E, RA1, RA2); and D) 2010 west sites (GD1, GD2, GD3).
Table 6. Presence of Staphylinidae in canopy traps over the 2009 soybean growing season and mean percent of total individuals (± SE) captured in canopy traps (canopy activity). The period of early Soybean Aphid population growth (July 13-July 27) is delimited by the black rectangle; presence of a species is indicated by grey squares.

<table>
<thead>
<tr>
<th>Species</th>
<th>Jun 22</th>
<th>Jun 29</th>
<th>Jul 7</th>
<th>Jul 14</th>
<th>Jul 21</th>
<th>Jul 28</th>
<th>Aug 4</th>
<th>Aug 11</th>
<th>Aug 18</th>
<th>Aug 25</th>
<th>Sep 1</th>
<th>Sep 9</th>
<th>Sep 15</th>
<th>Sep 21</th>
<th>Mean (± SE) Canopy Activity (%)</th>
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<tbody>
<tr>
<td>Tachyporus nitidulus</td>
<td></td>
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<td></td>
<td></td>
<td></td>
<td>52.4±23.8 a¹</td>
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<td>52.4±23.8 a¹</td>
</tr>
<tr>
<td>Amischa spp.</td>
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<td></td>
<td></td>
<td></td>
<td>48.6±22.7 ab</td>
<td></td>
<td></td>
<td></td>
<td>48.6±22.7 ab</td>
</tr>
<tr>
<td>Stethusa spuriella</td>
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<td></td>
<td></td>
<td></td>
<td>33.1±23.8 ab</td>
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<td></td>
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¹Different letters denote statistically different (p < 0.05) means in post hoc comparisons (Tukey’s HSD).
²Species excluded from analysis due to insufficient data, means not calculated.
3.3 Rove beetle and co-occurring early season Soybean Aphid populations

The soybean species *Anotylus insecatus*, *Hoplandria lateralis*, *Oxypoda brachyptera* and *Scopaeus minutus* were excluded from the analyses because of insufficient data. No relationships were found between the slope of early aphid population increase and activity density of co-occurring common rove beetle species. However, a positive relationship was found between aphid numbers and populations of *Anotylus tetracarinatus* ($y = 352.3x + 81.16$, $t = 8.46$, $p = 0.001$).

3.4 Seasonality of large rove beetles

In the soybean assemblage, nearly all large rove beetles were *Tasgius ater* (Gravenhorst), most of which occurred at sites LA and LB in 2009. Activity density of *Tasgius ater* peaked in August (Fig. 34), coinciding with the presence of new Bean Leaf Beetle adults. Other large rove beetles were rarely collected in soybean and generally occurred very early or late in the growing season (Fig. 35-37).

The spring hedgerow assemblage of large rove beetles consisted of *Dinothenarus badipes* (LeConte), *Tasgius melanarius* (Heer) and *Tasgius winkleri* (Bernhauer) (Fig. 35-37). In the fall, only the latter two species were frequently collected (Fig. 36-37). *Tasgius ater* was rarely collected in hedgerows; however, it was collected in relatively high numbers at site SG immediately following adjacent soybean senescence.

3.5 Spatial co-occurrence of large rove beetles with adult Bean Leaf Beetles

More individuals of Bean Leaf Beetle were captured towards the interior of soybean fields compared to the edge ($y = 0.84 - 2.42$, $Z = 5.61$, $p < 0.001$). No significant association was found between distance from the edge and activity density of *Tasgius ater*. Other large beetles occurring in soybean were collected in numbers too low for
Figure 34. Individuals of *Tasgius ater* (Gravenhorst) captured per trap on different sampling weeks by pitfall and canopy traps in southern Ontario soybean fields and their adjacent hedgerows at: A) 2009 east sites (SG, SC1, SC2); B) 2009 west sites (LA, LG, LB); and C) 2010 west sites (GD1, GD2, GD3). This species was not present at the 2010 east sites.
Figure 35. Individuals of *Dinothenarus badipes* (LeConte) captured per trap on different sampling weeks by pitfall and canopy traps in southern Ontario soybean fields and their adjacent hedgerows at: A) 2009 east sites (SG, SC1, SC2); B) 2009 west sites (LA, LG, LB); C) 2010 east sites (E, RA1, RA2); and D) 2010 west sites (GD1, GD2, GD3).
Figure 36. Individuals of *Tasgius melanarius* (Heer) captured per trap on different sampling weeks by pitfall and canopy traps in southern Ontario soybean fields and their adjacent hedgerows at: A) 2009 east sites (SG, SC1, SC2); B) 2009 west sites (LA, LG, LB); and C) 2010 east sites (E, RA1, RA2).
Figure 37. Individuals of *Tasgius winkleri* (Bernhauer) captured per trap on different sampling weeks by pitfall and canopy traps in southern Ontario soybean fields and their adjacent hedgerows at: A) 2009 east sites (SG, SC1, SC2); B) 2009 west sites (LA, LG, LB); C) 2010 east sites (E, RA1, RA2); and D) 2010 west sites (GD1, GD2, GD3).
analysis. *Tasgius winkleri* was found to co-occur spatially with Bean Leaf Beetle in hedgerows during the fall \( (y = 0.72x -0.54, Z = 2.48, p = 0.01) \). No patterns were found with other large rove beetles or with *Tasgius winkleri* in the spring.

### 3.6 Common rove beetle and Bean Leaf Beetle populations in soybean

A negative relationship was observed in soybean fields between activity density of Bean Leaf Beetle and activity density of *Anotylus rugosus* (Fabricius) \( (y = -0.02x + 2.92, Z = -2.95, p = 0.003) \), *Strigota ambiguа* (Erichson) \( (y = -0.03x + 3.24, Z = -5.49, p < 0.001) \), *Strigota* sp. 1 \( (y = -0.002x + 3.11, Z = 4.38, p < 0.001) \), and rove beetles as a group \( (y = -0.003x + 4.47, Z = -6.91, p < 0.001) \). However, positive relationships were found between adult Bean Leaf Beetle in soybean fields and *Dinaraea angustula* \( (y = 0.01x + 2.15, Z = 6.34, p < 0.001) \) and *Stethusa spuriella* \( (y = 0.03x + 2.15, Z = 8.39, p < 0.001) \). Of the significant negative correlations between rove beetle and Bean Leaf Beetle populations, total number of rove beetles was the best predictor of Bean Leaf Beetle populations \( (AIC = 92 \text{ vs. } AIC = 103-135) \). The species *Oxypoda brachyptera*, *Scopaeus minutus* and *Tachinus corticinus* were excluded from the analyses on the basis of insufficient data (see Methods).

### 3.7 Diel activity patterns in the soybean rove beetle assemblage

Most staphylinids were active in soybean canopies at dusk or after sunset (Fig. 38). None were captured by suction sampling between 8am-12pm and only two individuals were captured at 4pm. *Anotylus tetracarinatus* and *Tachyporus dispar* were the only frequently collected species (20 and 7 total individuals, respectively) and their activity differed significantly with time of day \( (d.f = 5, 95, F = 9.63, p < 0.001; d.f = 5, 95, F = 2.54, p = 0.03, \text{ respectively}) \). The summed activity of the other collected species
Figure 38. Mean number (± SE, n=20) of individuals of: A) *Anotylus tetracarinatus* (Block), B) *Tachyporus dispar* (Paykull), C) other Staphylinidae, captured by suction sampling every 4 hours in 2009 soybean over two 48 hour periods. Captures in flowering soybean and pod-forming soybean were pooled. Different letters denote statistically different (p < 0.05) means in post hoc comparisons (Tukey’s HSD).
was also found to differ significantly with time of day (d.f = 5, 95, $F = 6.43$, $p = 0.03$). *Anotylus tetracarinatus* was most active at 8pm, *Tachyporus dispar* was most active at 12am and as a group, staphylinids other than *Tachyporus dispar* and *Anotylus tetracarinatus* were most active from 8pm-12am (Fig. 38). However, activity peaks were not statistically significant for *Tachyporus dispar* and ‘other Staphylinidae’ in post hoc comparisons. While *Tachyporus dispar* was most active in the canopy of pod-forming soybean (d.f = 1, 95, $F = 4.12$, $p = 0.04$), *Anotylus tetracarinatus* was most active in the canopy of flowering soybean (d.f = 1, 95, $F = 11.20$, $p = 0.001$) (Fig. 39). No differences in canopy activity were found among soybean stages for the other species as a group (Fig. 39). A list of all species collected by suction sampling is provided in Appendix 3.

4 Discussion

4.1 Seasonality of soybean pests

Since its arrival to Ontario in 2001, populations of Soybean Aphid have fluctuated on a biennial cycle with economically damaging levels occurring broadly in odd years and only very localized large populations occurring in even years (Bahlai 2007, Bahlai and Sears 2009, *unpublished data*). Soybean Aphid populations observed in the present study (2009) generally peaked in August, corresponding to a ‘high aphid year’ in the population scenario of Bahlai and Sears (2009). An early Soybean Aphid growth phase was identified and occurred in mid to late July, despite high variability in Soybean Aphid population dynamics between some sites in 2009. However, the markedly earlier early growth phase found in 2005 (beginning in late June) by Bahlai and Sears (2009) relative to that of the present study suggests that the timing of this phase is variable in Ontario.
Figure 39. Mean number (± SE, n=40) of individuals of Staphylinidae captured by suction sampling in 2009 soybean over 48 h in flowering and pod-forming stages. Within a species, different letters denote statistically different ($p < 0.05$) means by ANOVA.
and emphasizes the importance of simultaneous surveys of aphids and potential predators to associate them accurately. Soybean Aphids were detected in both ‘low years’ (2004, 2006) by Bahlai et al. (2009) and our failure to detect even one individual in 2010 is difficult to explain. Furthermore, aphid colonization at the 2010 sites would be expected in low aphid years due to the presence and high density of buckthorn in adjacent hedgerows (Bahlai et al. 2010). Higher than normal predation and/or inadequate sampling effort at the study sites during 2010 may be responsible for these discrepancies and further research is needed to determine why some fields apparently escape Soybean Aphid colonization.

In both years a single peak in adult Bean Leaf Beetle AD was observed after a period of midseason low AD, consistent with populations observed in Minnesota and Nebraska where one generation occurs per year (Loughran and Ragsdale 1986, Witkowski and Echtenkamp 1996). However, unlike most studies, early adult activity in soybean was not observed in 2010, making it difficult to define a period of larval development. The estimated larval development period for 2010 and observed late season AD peak were substantially earlier than in 2009 and earlier spring activity of Bean Leaf Beetle in overwintering sites in 2010 may be responsible for both low early season AD and backward shifts in life history events. Bean Leaf Beetle abundance in soybean may be lower in years with earlier emergence due to poor synchronization with young soybean (Jeffords et al. 1983). Soybean fields planted earlier are generally favored by Bean Leaf Beetle over those planted later (Witkowski and Echtenkamp 1996) and it is likely that only the earliest planted sites in southern Ontario were colonized by overwintered adults in 2010. The relatively low and intermittent AD of Bean Leaf Beetle
in hedgerows compared to soybean fields may be due to the tendency of Bean Leaf Beetle to cluster at overwintering sites, which may occur up to 520m deep into woodlots (Boiteau et al. 1980). Therefore, placement of pitfall traps in the present study may have missed preferred microhabitats and active sampling of ground debris may be preferable for quantitative studies.

4.2 Canopy activity in Staphylinidae

Of the several staphylinids active on buckthorn foliage, *Amischa* spp. and *Tachyporus dispar* were the most likely to encounter overwintering colonies of Soybean Aphid and their eggs. These staphylinids were active in both spring and fall, well before the earliest Ontario soybean fields are planted, and were among those with the highest percentage of total individuals captured in canopy traps. The diets of both species are poorly understood. *Tachyporus dispar* has only recently been considered a valid species separate from the closely related *Tachyporus chrysomelinus* (L.) (Booth 1988), a known aphid predator in the Palaearctic region (Sunderland et al. 1987). Aphid predation is widespread in this genus and although studies confirming aphid predation by *Tachyporus chrysomelinus* were conducted before the recognition of *Tachyporus dispar*, the latter species probably accepts aphid prey. In the only known account of *Amischa* feeding behaviour, adults always rejected freshly killed pieces of *Tribolium* MacLeay (Coleoptera) larvae (Good 1995). However, Clough et al. (2007) considered *Amischa analis* as a predator and molecular assays similar to those of Lundgren et al. (2009a) may be necessary to ascertain if these small beetles consume aphids or their eggs.

Several staphylinid species were observed to have relatively high AD in soybean foliage during the early growth phase of Soybean Aphid in 2009. As with the hedgerow
assemblage, *Amischa* spp. was among the taxa with the highest proportion of canopy activity. Passive canopy traps failed to detect individuals of *Tachyporus dispar* during this period but this species was recovered using suction sampling. Species of *Stenus* were also rarely collected by passive traps in the present study but several individuals were captured in the soybean canopy using suction sampling. No species of either genus were considered common soybean species in Chapter III and their proportional abundances may have been underestimated due to sampling bias. Species of both *Stenus* and *Tachyporus* were effectively sampled in crop vegetation using vacuum samplers in European cereal fields (Good and Giller 1991a, Holland et al. 2004) and were found to consume aphids present there (Sunderland et al. 1987). Given their reputation as aphid predators and their under-representation by some methods, suction sampling is recommended for the study of these genera in agroecosystems.

Predominantly nocturnal activity in staphylinids was also observed in cereal fields (Vickerman and Sunderland 1975). Congruent with the present study, species of *Tachyporus* were frequently collected in British (Vickerman and Sunderland 1975) and Danish (Pederson et al. 1990) cereal fields and the highest AD occurred around midnight. This activity peak corresponded to an increase in relative humidity (Pederson et al. 1990) and increased proportions of *Tachyporus* containing aphid cuticle or proteins in their gut (Vickerman and Sunderland 1975). However, *Anotylus* species were never (Holland et al. 2004) or rarely (Vickerman and Sunderland 1975) collected in crop vegetation in cereal fields, and only in the late afternoon. *Anotylus tetracarinatus* was the most frequently collected species by suction sampling in the present study and was most active at sunset (~8pm). Researchers seeking to quantify Soybean Aphid predation by Staphylinidae
should make observations or collect samples for DNA analyses after sunset when these species are active.

Although relatively high canopy activity during the early aphid growth phase was observed for *Anotylus tetracarinatus*, this species prefers field edges (Chapter III) and its biocontrol services may be limited. The observed positive correlation between high early populations of Soybean Aphid and high numbers of *Anotylus tetracarinatus* may be due to covariation with another environmental or ecological variable, though staphylinids have been previously observed to aggregate in patches of high aphid abundance (Bryan and Wratten 1984). The diet of *Anotylus tetracarinatus* is unknown but some *Anotylus* accept low numbers of aphid prey (Kollar-Palenga and Basedow 2000) whereas other species of the genus are considered to be saprophagous (Hammond 1976) or omnivorous (Good and Giller 1991b).

4.3 Rove beetles associated with Bean Leaf Beetle populations in the soybean-hedgerow landscape

Large rove beetles were absent from most soybean fields in the present study and adult Bean Leaf Beetles probably escape staphylinid predation during the growing season. However, *Tasgius ater* was present at relatively high numbers at two sites and was able to penetrate field interiors, which were preferred by adult Bean Leaf Beetle. This exotic staphylinid accepts large, sclerotized prey, such as European Earwig (Crumb et al. 1941). *Tasgius ater* inhabits a broad range of human-altered and natural habitats (Brunke et al. 2011) and it is difficult to explain why only some soybean fields were favored by this species. Large rove beetles are rarely reported from annual crop systems in Europe and do not appear on a list of the 30 most frequently collected species in
Norwegian agroecosystems (Andersen 1991). However, *Ocypus nitens* (Schrank) (as *Ocypus similis* (Fabricius)) was dominant in German winter wheat fields (Krooss and Schaefer 1998a) and accepted adult beetles as prey (Krooss and Schaefer 1998b). The range of this exotic species in North America is largely confined to the New England states, but it was recently found in New York and it is likely to spread to Ontario in the future (Brunke et al. 2011).

In contrast, three abundant species of large rove beetles inhabit hedgerows and may provide important biocontrol services by predating upon overwintering Bean Leaf Beetles, though only *T. winkleri* was significantly associated spatiotemporally at a smaller spatial scale. All three species are active in both spring and fall (Brunke et al. 2011) but *Dinothenarus badipes* was captured most frequently in the hedgerows sampled in spring and *Tasgius winkleri* was most frequently captured in fall. The diet of the native *Dinothenarus badipes* is known to include millipedes (Snider 1984) and adults of Wheat Wireworm (*Elateridae: Agriotes mancus* (Say)) (Hawkins 1936). While prey records for the two exotic *Tasgius* species remain obscure, individuals of both species have accepted various isopods as prey (A. Brunke, *unpublished data*). All three species are conspicuous and easily collected for future assessments of their impact on adult Bean Leaf Beetle.

High populations of three rove beetle species were associated with low Bean Leaf Beetle abundance, and two of these (*Strigota* sp. 1 and *Strigota ambigua*) were consistently collected in high numbers (see Chapter III) when Bean Leaf Beetle eggs and larvae were present in soybean fields. While some individuals of *Anotylus rugosus* were also captured during this time, this species was most abundant in hedgerows. Its sporadic presence in soybean (see Chapter III) may limit its potential as a predator of immature
Bean Leaf Beetles. A large proportion of the staphylinid assemblage in soybean has peak AD in July (see Chapter III) and species other than those above may be important predators. Immature stages of the congeneric Western Corn Rootworm experienced 99% mortality in South Dakota cornfields, a large proportion of which was attributed to predation by ‘small staphylinids’ (<5mm), especially during the egg stage (Lundgren et al. 2009a,b). However, our analysis must be considered preliminary as environmental factors favorable to the above staphylinids and unfavorable to Bean Leaf Beetle may be driving these patterns, and no observations of predation were made. Despite this, the entire staphylinid assemblage was a far better predictor of low Bean Leaf Beetle populations than any individual species in the analysis and future investigations of these potential interactions are warranted.

4.4 Conclusion

Several staphylinid species were found to be active on both soybean and buckthorn vegetation and are likely to encounter Soybean Aphid colonies throughout the year and during early aphid population growth on soybean. In addition to the Tachyporus species with canopy activity, several other rove beetles were prevalent in canopies and warrant future study for their role in aphid predation. To prevent underestimation of several foliar active species’ AD, including Tachyporus and Stenus, suction sampling or sweeping should be incorporated into sampling protocols to augment passive trapping whenever practical. Nearly all staphylinid foliar activity was observed on or after 8pm and although nocturnal field observations at this time may be difficult, microcosm experiments such as those of Dennis and Sotherton (1994) and Hanam et al. (2008) are recommended. Predation of adult Bean Leaf Beetles by large rove beetles is most likely
to occur in hedgerows while the former are overwintering in leaf litter. Simple feeding assays with *Tasgius* and *Dinothenarus badipes* including alternative prey items are recommended for future research. Soybean fields with higher rove beetle populations were more likely to have lower Bean Leaf Beetle populations. However, models incorporating environmental parameters and populations of other predator groups need to be tested before any further conclusions can be made about potential rove beetle impact on Bean Leaf Beetle.

This research provides the first insights into the potential biological control services of select staphylinid species for integrated management of North American Soybean Aphid and Bean Leaf Beetle populations. This is also the first North American study we are aware that considers the potential biocontrol services of predatory beetles in the overwintering habitat of major pest insects. While direct observations of predation were outside the scope of the present study, our results (including those of Chapter III) allow future researchers to focus on common, widespread species within this highly diverse family that co-occur with soybean pests when they might have their greatest impact.
5.1 Summary of results

In recent years, researchers have moved from a narrow focus on specialist predators of soybean pests to a more inclusive view of the natural enemy complex by considering a diverse assemblage of generalist predators. Although descriptions of soybean-associated ground beetle and spider assemblages are relatively complete, our baseline knowledge of rove beetles in this agroecosystem remained fragmentary until this thesis. My research demonstrates that a variety of staphylinid species predictably occur in soybean agroecosystems, often in high abundance and co-occurring with major soybean pests. These predators are typically exotic, habitat generalists and are capable of dispersal by flight. This is the first complete, species-level survey of Staphylinidae in Canadian agroecosystems and is one of few (along with Byers et al. 2000 and Leslie et al. 2007) in North America. *Tachyporus nitidulus*, *Tachyporus dispar*, and the genus *Amischa spp.* were recognized as potential predators of Soybean Aphid and *Strigota* sp. 1 and *Strigota ambigua* were recognized as predators of Bean Leaf Beetle immature stages. *Tasgius melanarius*, *Tasgius winkleri* and *Dinothenarus badipes* may be potential predators of adult Bean Leaf Beetles in hedgerows. Unmanaged areas serving as field hedgerows support populations of common soybean staphylinids outside of the growing season and may positively contribute to the landscape level abundance of these species. Further research is required to experimentally demonstrate this potential and to understand which aspects of hedgerows maximize the support of biological control.
services. This thesis also explores the potential predation of overwintering Bean Leaf Beetle and Soybean Aphid populations by rove beetles. Several staphylinids co-occur in buckthorn canopies with Soybean Aphid and three large staphylinids (Staphylininae: Staphylinini: Staphylinina) co-occur with adult Bean Leaf Beetles overwintering in leaf litter. As far as I am aware, this is the first discussion of the dual role of hedgerows in supporting predaceous beetle populations that impact both direct and indirect biocontrol services.

5.2 Future research directions

The results of this thesis greatly advance the understanding of rove beetle agroecology in North America but many basic questions remain unaddressed for even the most common species of this assemblage. *Amischa* spp. is one of the most abundant staphylinid taxa in Ontario soybean-hedgerow landscapes yet it is unknown whether the species of this genus are predaceous, mycophagous or omnivorous. To further complicate this question, a modern revision is lacking for this genus in North America and identification of native species is impossible, though species introduced from central Europe are identifiable. Dietary studies should integrate laboratory assays, which assess dietary proportions (e.g., fungivory:carnivory) and preferences (Dennis and Sotherton 1994), with molecular gut content analyses using field collections to assess prey diversity and temporal patterns (Sunderland et al. 1987, Lundgren et al. 2009b).

Several species are widespread and common in soybean-hedgerow landscapes in southern Ontario and many of these are expected to occur in similar habitats across northeastern North America. However, future surveys should include sites in central Ontario and Quebec to better identify the most consistent faunal elements of this
assemblage. Some species with otherwise broad distributions in North America (e.g., *Tasgius ater*) could be more dominant in soybean fields further north or south while some common species may disappear entirely in these areas. The identification and exclusion of transient/accidental faunal elements in an assemblage is a difficult but important task for accurate faunistic studies (Mossakowski and Dormann 2011). Soybean fields may be normally unsuitable for several sporadically abundant species and additional surveys could help identify whether these high activity densities are due to dispersal events, specialized microhabitat elements or an ephemeral adult stage.

Although rove beetles are relatively easy to survey in agroecosystems using standardized passive traps, they are rarely encountered during the active, diurnal sampling used by IPM scouts for other predators in soybean fields. However, select staphylinid groups may be sampled for using the following techniques. Sweeping soybean foliage during dusk or later will capture species of *Tachyporus* that are easy to identify based on their teardrop shaped body and light coloration. Other predators in soybean fields, including coccinellid larvae, spiders, parasitic wasps and true bugs, also increase their activity during and after dusk (A. Brunke, unpublished data) and shifting predator scouting from afternoon to evening may provide growers with a more accurate assessment of predator abundance. Additionally, potential adult Bean Leaf Beetle predators could be surveyed in hedgerows using cover boards as in Davalos and Blossey (2004) and the large rove and ground beetles attracted using this method may be easily counted in the field.
5.3 Synergism between faunistic surveys, identification tools and ecology

In the past, rove beetles have received relatively little research attention compared to other beetle families. This is likely due to their small size, inconspicuous nature and the fact that most universities lack adequately curated reference collections or access to insect collections at all. However, this situation is improving due to a synergistic interaction between faunistics, taxonomy and digital identification tools. Surveying the soybean-hedgerow landscape in southern Ontario resulted in the collection of 14,039 rove beetle specimens and the characterization of the assemblages in these two habitats. Common and widespread species were recognized (Chapter III) and further observations were made about their potential role in the biological control of soybean pests (Chapter IV). Over the course of this survey, nine exotic species and four native species were newly recognized in Ontario or Canada (Brunke and Majka 2010, Brunke and Marshall 2011, Brunke et al. 2011), including one species never before reported from North America. Over 20 additional records of Aleocharinae remain to be published. One of the most abundant species in soybean fields may even be new to science. Several exotic species previously reported from Canada but lacking specimen-based locality data have now been verified and vouchered specimens collected. Some of these new distributional data were incorporated in a recent faunistic review (see Chapter II or Brunke et al. 2011) and were critical in providing an identification tool that accurately reflected the fauna of eastern Canada and the adjacent United States. Non-experts may now separate the three species of Staphylinina with potential as natural enemies of adult Bean Leaf Beetles (Chapter IV) using this publication. With additional staphylinid reviews and keys, the effort and resources required by future survey projects or more focused ecological
investigations will decrease (Marshall 2003). Survey-based studies focusing on or incorporating rove beetles may no longer be prohibitively difficult without significant involvement of a taxonomist. An increase in survey-generated specimens would result in earlier recognition of new introductions and improve the efficacy of identification keys via updates that could be made to the online versions. Positive interactions between faunistic research, identification tools and ecology were demonstrated herein to accelerate research on Staphylinidae.

An overall objective of this thesis was to provide the scientific community with detailed, accurate baseline data of a poorly known predator group in soybean agroecosystems and to facilitate their identification for future research. I hope that the foundation provided herein will encourage future workers to incorporate rove beetles in applied ecological studies and eventually into integrated pest management programs, and emphasize that even in seemingly familiar and simple environments much remains to be discovered.
References


Balduf, W.V. 1935. The Bionomics of Entomophagous Coleoptera. E.W. Classey Ltd.,
England.


Fox, C.J.S. and MacLellan, C.R. 1956. Some Carabidae and Staphylinidae shown to feed on a wireworm, Agriotes sputator (L.), by the precipitin test. The Canadian Entomologist 88: 228-231.


Ganglbauer (Coleoptera: Staphylinidae: Staphylininae). Occasional Papers of the

Oligota minuta (Coleoptera: Staphylinidae), a Predator of Mites. The Florida
Entomologist 75: 376-380.


Genier, F. 1989. A revision of the genus Hoplandra Kraatz of America north of Mexico
(Coleoptera: Staphylinidae: Aleocharinae). Memoirs of the Entomological Society
of Canada 150: 1-59.

Good, J.A. 1995. Habitat records of Amischa C.G. Thomson (Staphylinidae:
Aleocharinae) from Ireland. Coleopterist 3: 77-79.

Good, J.A. and Giller, P.S. 1991a. The effect of cereal and grass management on
staphylinid (Coleoptera) assemblages in south-west Ireland. Journal of Applied

Good, J.A. and Giller, P.S. 1991b. The diet of predatory staphylinid beetles – a review of


Grebennikov, K.A. and Newton, A. 2009. Good-bye Scydmaenidae, or why the ant-like
stone beetles should become megadiverse Staphylinidae sensu latissimo

Gusarov, V.I. 2003. A revision of the Nearctic species of the genus Stethusa Casey, 1910


(currently *Platydracus maculosus* and *P. violaceus*; Insecta, Coleoptera): usage of

Experimental Station 248: 1-20.

Colonization of Soybean by the Bean Leaf Beetle (Coleoptera: Chrysomelidae) in

Jennings, V.H. and Tallamy, D.W. 2006. Composition and Abundance of Ground-
Dwelling Coleoptera in a Fragmented and Continuous Forest. Environmental
Entomology 35: 1550-1560.

Jo, Y.-K. and Smitley, D.R. 2003. Predation of *Ataenius spretulus* (Coleoptera:
Scarabaeidae) Eggs and Grubs by Species of Carabidae and Staphylinidae on Golf

Kellner, R.L.L. 2001. Horizontal transmission of biosynthetic capabilities for pederin in

Kellner, R.L.L. and Dettner, K. 1995. Allocation of Pederin during lifetime of *Paederus*
rove beetles (Coleoptera: Staphylinidae): evidence for polymorphism of

Kirk, V.M. 1972. Seed-Caching by Larvae of Two Ground Beetles, *Harpalus*
pensylvanicus and *H. erraticus*. Annals of the Entomological Society of America
65: 1426-1428.

Kishimoto, H. and Adachi, I. 2008. Predation and oviposition by predatory *Stethorus*
japonicus, *Oligota kashmirica benefica*, and *Scolothrips takahashii* in egg patches.


adventive species of Coleoptera (Insecta) recorded from eastern Canada. Pensoft, Sofia, Moscow.


Levesque, C. and Levesque, G.-Y. 1995. Abundance, diversity and dispersal power of rove beetles (Coleoptera: Staphylinidae) in a raspberry plantation and adjacent


Makranczy, G. 2006. Systematics and phylogenetic relationships of the genera in the
_Carpelimus_ group (Coleoptera: Staphylinidae: Oxytelinae). Annales Historico-
Naturales Musei Nationalis Hungarici _98_: 29-120.


Survey of Canada _22_: 1. Available online:
2011

Mannerheim, C. G. 1830. Précis d'un nouvel arrangement de la famille des brachélytres,
de l'ordre des insectes coléoptères. St. Petersburg.

Mazur, A. 1995. Kusakowate (Coleoptera, Staphylinidae) towarzyszace zerowiskom
ksylöfagow i wystepujace pod kora drzew [Rove beetles (Coleoptera,
Staphylinidae) accompanying saproxylic insects under tree bark]. _In_ Mat Konf
Nauk, Puszczykowo, 220495 Szkodniki wtörne, ich rola oraz znaczenie w lesie
[Secondary pests, their role and significance in forests]. _Edited by_ A. Mazur.
Wydawnictwo Acarus, Poznan, Poland. pp. 71-79.

Mignault, M.-P., Roy, M. and Brodeur, J. 2006. Soybean Aphid Predators in Québec and
the Suitability of _Aphis glycines_ as Prey for Three Coccinellidae. BioControl _51_: 89-106.

Miyazaki, M. 1987. Forms and Morphs of Aphids. _In_ World Crop Pests: Aphids - their
biology natural enemies and control. Minks, A.K. and Harrewijn, P, Eds. Elsevier,
Amsterdam. 2A: 27-55.


Samsoe-Peterson, L. 1985. Laboratory tests to investigate the effects of pesticides on two beneficial arthropods: a predatory mite (Phytoseilulus persimilis) and a rove beetle (Aleochara bilineata). Pesticide Science 16: 321-331.


Schirmel, J., Lenze, S., Katzmann, D. and Buchholz, S. 2010. Capture efficiency of pitfall traps is highly affected by sampling interval. Entomologia Experimentalis


Smetana, A. 1971b. Revision of the tribe Quediini of America North of Mexico (Coleoptera: Staphylinidae). Supplementum 1. The Canadian Entomologist 103:


Solodovnikov, A. and Schomann, A. 2009. Revised systematics and biogeography of 'Quediina' of sub-Saharan Africa: new phylogenetic insights into the rove beetle


Witkowski, J.F. and Echtenkamp, G.W. 1996. Influence of Planting Date and Insecticide on the Bean Leaf Beetle (Coleoptera: Chrysomelidae) Abundance and Damage in


Appendix 1. List of Staphylinidae sampled at each site, by pitfall and canopy traps (pooled) in hedgerows adjacent to soybean fields in southern Ontario. Sampling occurred from Apr 29-Jun 22 and Sep 15-Nov 24 in 2009, and Apr 28-Jun 9 and Sep 8-Nov 10 in 2010. S = Spring, F=Fall, + = adventive in North America.

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262
Appendix 1 continued. List of Staphylinidae sampled at each site, by pitfall and canopy traps (pooled) in hedgerows adjacent to soybean fields in southern Ontario. Sampling occurred from Apr 29-Jun 22 and Sep 15-Nov 24 in 2009, and Apr 28-Jun 9 and Sep 8-Nov 10 in 2010. S = Spring, F=Fall, + = adventive in North America.

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<td>Klimaszewski and Majka</td>
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| *Oxypoda opaca* (Gravenhost) + | -   | -   | -   | -   | X   | -   | -   | -   | -   | -   | X   | X   | **X** X
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Appendix 1 continued. List of Staphylinidae sampled at each site, by pitfall and canopy traps (pooled) in hedgerows adjacent to soybean fields in southern Ontario. Sampling occurred from Apr 29-Jun 22 and Sep 15-Nov 24 in 2009, and Apr 28-Jun 9 and Sep 8-Nov 10 in 2010. S = Spring, F=Fall, + = adventive in North America.

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275
Appendix 1 continued. List of Staphylinidae sampled at each site, by pitfall and canopy traps (pooled) in hedgerows adjacent to soybean fields in southern Ontario. Sampling occurred from Apr 29-Jun 22 and Sep 15-Nov 24 in 2009, and Apr 28-Jun 9 and Sep 8-Nov 10 in 2010. S = Spring, F=Fall, + = adventive in North America.

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276
Appendix 1 continued. List of Staphylinidae sampled at each site, by pitfall and canopy traps (pooled) in hedgerows adjacent to soybean fields in southern Ontario. Sampling occurred from Apr 29-Jun 22 and Sep 15-Nov 24 in 2009, and Apr 28-Jun 9 and Sep 8-Nov 10 in 2010. S = Spring, F=Fall, + = adventive in North America.

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Appendix 2. List of Staphylinidae sampled at each site, by pitfall and canopy traps (pooled) in southern Ontario soybean fields. Sampling occurred from Jun 22-Sep 21 in 2009 and Jun 15-Sep 7 in 2010. + = adventive in North America.

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278
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<th>RA2</th>
<th>GD1</th>
<th>GD2</th>
<th>GD3</th>
</tr>
</thead>
</table>
| *Dinaraea angustula*  
(Gyllenhal) + | X  | X   | X   | X  | X  | X  | X  | X   | X   | X   | X   | X   |
| *Drusilla canaliculata*  
(Fabricius) + | X  | X   | X   | X  | X  | X  | X  | X   | X   | X   | X   | X   |
| *Hoplandria lateralis*  
(Melsheimer) | X  | -   | -   | X  | X  | X  | -  | -   | -   | X   | X   | X   |
| *Ilyobates bennetti*  
Donisthorpe + | X  | -   | -   | -  | -  | -  | X  | X   | -   | -   | -   | -   |
| *Leptusa jucunda*  
Klimaszewski and Majka | -  | -   | -   | -  | -  | -  | -  | -   | -   | -   | X   | X   |
| *Mocyta fungi*  
(Gravenhorst) + | -  | X   | X   | -  | -  | X  | X  | -   | X   | -   | X   | X   |
| *Nehemitropia luridipennis*  
(Mannerheim) + | X  | X   | X   | -  | -  | X  | X  | -   | -   | -   | -   | X   |
| *Oxypoda brachyptera*  
(Stephens) + | X  | X   | X   | X  | X  | X  | X  | -   | -   | X   | -   | -   |
| *Oxypoda opaca*  
(Gravenhorst) + | -  | -   | -   | -  | -  | -  | -  | -   | -   | X   | -   | -   |
| *Oxypoda perexilis*  
Casey | -  | -   | -   | -  | -  | -  | -  | -   | -   | X   | -   | -   |
| *Philhygra clemens*  
(Casey) | -  | -   | -   | -  | -  | -  | -  | X   | -   | X   | -   | -   |
| *Stethusa spuriella*  
(Casey) | X  | X   | X   | X  | X  | X  | X  | X   | X   | X   | X   | X   |
| *Strigota ambigua*  
(Erichson) | X  | X   | X   | X  | -  | X  | X  | X   | X   | X   | X   | X   |
Appendix 2 continued. List of Staphylinidae sampled at each site, by pitfall and canopy traps (pooled) in southern Ontario soybean fields. Sampling occurred from Jun 22-Sep 21 in 2009 and Jun 15-Sep 7 in 2010. + = adventive in North America.

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| Omaliinae                |    |     |     |    |    |    |     |     |     |     |     |     |
| *Omalium rivulare*       |    |     |     |    |    |    |     |     |     |     |     |     |
| (Paykull) +              | -  | -   | -   | -  | X  | -  | -   | -   | X   | -   | X   | X   |

| Oxytelinae               |    |     |     |    |    |    |     |     |     |     |     |     |
| *Anotylus inescatus*     |    |     |     |    |    |    |     |     |     |     |     |     |
| (Gravenhorst) +          | X  | -   | -   | X  | X  | X  | X   | X   | X   | X   | -   | X   |
| *Anotylus insignitus*    |    |     |     |    |    |    |     |     |     |     |     |     |
| (Gravenhorst) +          | X  | -   | -   | X  | X  | X  | -   | -   | -   | X   | -   | X   |
| *Anotylus nanus*         |    |     |     |    |    |    |     |     |     |     |     |     |
| (Erichson)               | X   | X   | X   | X   | -  | X   | -   | -   | X   | X   | -   | -   |
| *Anotylus rugosus*       |    |     |     |    |    |    |     |     |     |     |     |     |
| (Fabricius) +            | X  | -   | -   | X   | X   | X   | -   | -   | X   | X   | X   | X   |
| *Anotylus tetracarinatus*|    |     |     |    |    |    |     |     |     |     |     |     |
| (Block) +                | X  | -   | -   | -   | -   | -   | X   | -   | X   | X   | X   | X   |
| *Apocellus sphaericollis*|    |     |     |    |    |    |     |     |     |     |     |     |
| (Say)                    | -  | -   | -   | X   | -   | -   | -   | -   | X   | X   | X   | X   |

| Paederinae               |    |     |     |    |    |    |     |     |     |     |     |     |
| *Lathrobium sp 1*        | X  | X   | X   | X   | X   | -  | X   | -   | -   | X   | X   | X   | X   |

280
Appendix 2 continued. List of Staphylinidae sampled at each site, by pitfall and canopy traps (pooled) in southern Ontario soybean fields. Sampling occurred from Jun 22-Sep 21 in 2009 and Jun 15-Sep 7 in 2010. + = adventive in North America.

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<th>RA2</th>
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**Staphylininae**

*Dinothenarus*

*badipes* (LeConte)

*Gabrius appendiculatus*

Sharp +

*Gyrohypnus angustatus*

Stephens +

*Gyrohypnus fracticornis*

(Müller) +

*Neobisnius sobrinus* (Erichson)

*Neohypnus obscurus* (Erichson) -

*Neohypnus melanops* (Casey) -

*Philonthus carbonarius* (Gravenhorst) +

*Philonthus cognatus* Stephens +

*Philonthus concinnus* (Gravenhorst) +

*Philonthus debilis* (Gravenhorst) +
Appendix 2 continued. List of Staphylinidae sampled at each site, by pitfall and canopy traps (pooled) in southern Ontario soybean fields. Sampling occurred from Jun 22-Sep 21 in 2009 and Jun 15-Sep 7 in 2010. + = adventive in North America.

<table>
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<th>RA2</th>
<th>GD1</th>
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<tr>
<td>Philonthus palliatus (Gravenhorst)</td>
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</tr>
<tr>
<td>Philonthus varians (Paykull) + Stenistoderus rubripennis (LeConte)</td>
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282
Appendix 2 continued. List of Staphylinidae sampled at each site, by pitfall and canopy traps (pooled) in southern Ontario soybean fields. Sampling occurred from Jun 22-Sep 21 in 2009 and Jun 15-Sep 7 in 2010. + = adventive in North America.

<table>
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</table>
Appendix 2 continued. List of Staphylinidae sampled at each site, by pitfall and canopy traps (pooled) in southern Ontario soybean fields. Sampling occurred from Jun 22-Sep 21 in 2009 and Jun 15-Sep 7 in 2010. + = adventive in North America.

<table>
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<th>RA2</th>
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Appendix 3. Species collected by suction sampling of soybean foliage in flowering (R2 July 16-18) and pod-forming (R5, August 12-14) soybean, at site SG in 2009 (Guelph, Ontario, Canada).

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<td><em>Oxypoda brachyptera</em> (Stephens)</td>
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<td><em>Oxypoda convergens</em> Casey</td>
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<td><em>Philhygra clemens</em> Casey</td>
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