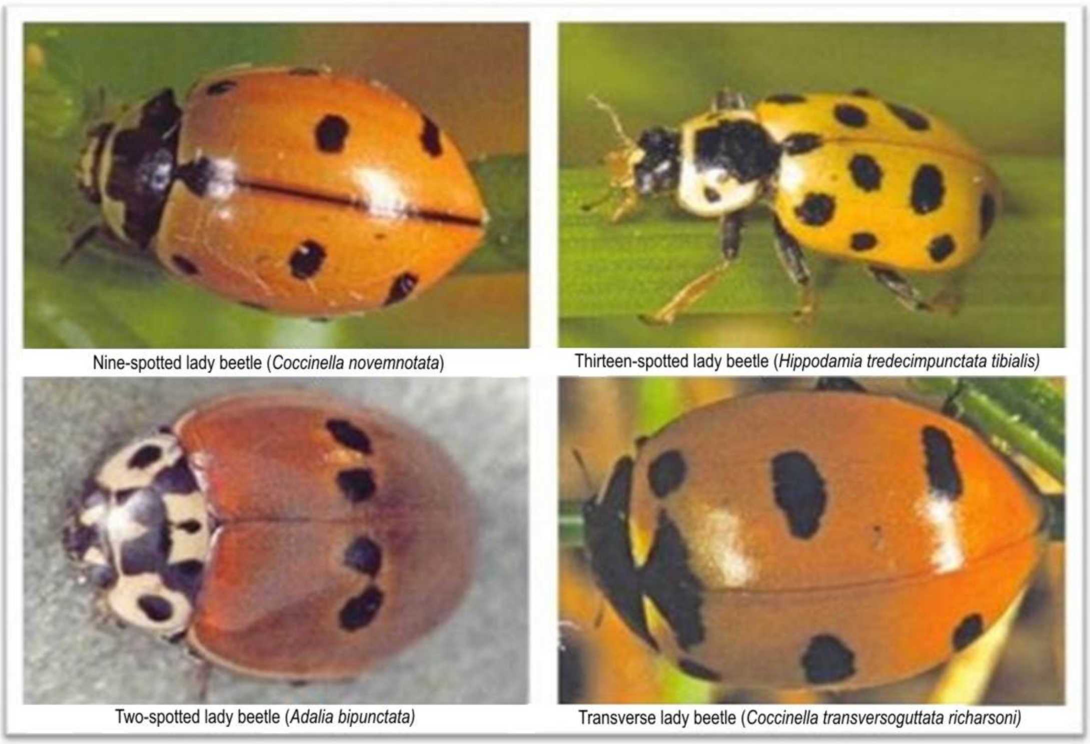
COSEWIC Special Report

on the

List of Prioritized Coccinelidae and Related Groups at Risk in Canada



Nine-spotted lady beetle (*Coccinella novemnotata*)

Thirteen-spotted lady beetle (*Hippodamia tredecimpunctata tibialis*)

Two-spotted lady beetle (*Adalia bipunctata*)

Transverse lady beetle (*Coccinella transversoguttata richarsoni*)

2012

Funding provided by Environment Canada

COSEWIC
Committee on the Status
of Endangered Wildlife
in Canada

COSEPAC
Comité sur la situation
des espèces en péril
au Canada

This report may be cited as follows:

COSEWIC. 2012. COSEWIC Special Report on the Changes in the Status and Geographic ranges on the Canadian Lady Beetles Coleoptera: Coccinellidae: Coccinellinae and the selection of Candidate Species for Risk, in Canada. Committee on the Status of Endangered Wildlife in Canada. Ottawa. 60 pp. (http://www.cosewic.gc.ca)

Production note:
COSEWIC would like to acknowledge Dr. David B. McCorquodale, Dr. Donna J. Giberson and Meghan Marriott for writing the Special Report on Canadian Lady Beetles, Coleoptera: Coccinellidae: Coccinellinae, in Canada, prepared under contract with Environment Canada. This report was overseen and edited by Dr. Paul Catling and Jennifer Heron, Co-chair of the COSEWIC Arthropods Specialist Subcommittee.

For additional copies contact:

COSEWIC Secretariat
c/o Canadian Wildlife Service
Environment Canada
Ottawa, ON
K1A 0H3

Tel.: 819-938-4125
Fax: 819-938-3984
E-mail: COSEWIC/COSEPAC@ec.gc.ca
http://www.cosewic.gc.ca

Également disponible en français sous le titre Évolution de la situation et de la répartition géographique des coccinelles canadiennes (Coleoptères : Coccinellidés : Coccinellinés) et sélection d'espèces candidates à une évaluation détaillée de situation au Canada.

Cover illustration/photo:
Canadian Lady Beetles — Photo Credit: Acorn 2007.

©Her Majesty the Queen in Right of Canada, 2014.

Recycled paper

PREAMBLE

This report was commissioned to document changes in geographic ranges of potentially vulnerable native lady beetles (*Coccinella novemnotata*, *C. transversoguttata*, *Hippodamia hieroglyphica*, *H. parenthesis*, *H. tredecimpunctata*, *Adalia bipunctata* and *Anatis mali*) ; the five most common and widespread non-native lady beetles (*C. septempuncata*, *C. undecimpunctata*, *H. variegata*, *Propylaea quatuordecimpunctata, Harmonia axyridis*) and other species. The purpose of this report was to document geographic declines, the rates of decline, the time and period when the decline occurred, the extent of suspected declines, and the reasons for and correlations with the decline. It was also to note all threats in approximate order of priority and any changes in quality of habitat for each taxon. This report serves as the primary basis for prioritising species for future COSEWIC assessments.

TABLE OF CONTENTS

ABSTRACT....6
DEDICATION....6
INTRODUCTION....7
Lady beetles (Coccinellinae) in Canada....7
Insect collections and changes in lady beetle distribution and abundance....11
METHODS....12
RESULTS AND DISCUSSION....13
Shrinkage of geographic range and decline in relative abundance....13
Nine-spotted lady beetle, *Coccinella novemnotata*....24
Transverse lady beetle, *Coccinella transversoguttata richardsoni*....27
Other Coccinellinae of Potential Conservation Concern....32
Threats to native lady beetle species....34
Status of Coccinellinae database for Canada....38
Archiving the database....40
Data gaps and ongoing monitoring....42
CONCLUSIONS....46
LITERATURE CITED....46
EDITORIAL NOTES....54
Contact information....54

List of Figures

Figure 1. Changes in the number of specimens collected for five common native species of lady beetles in Southern Ontario and Quebec during three time periods, pre-1960, 1960-1979, 1980-2009....14
Figure 2. Distribution of *Coccinella novemnotata* (nine-spotted lady beetle) in central and eastern Canada from 1895 to 1960, and by decade from 1960 to 2010. The recent Quebec record is from Mont St-Hilaire (Skinner and Domaine 2010). The most recent Ontario record is from 1983. Each point represents the total collected on a given day for a given locality (note that points may overlap)....15
Figure 3. Distribution of *Coccinella transversoguttata richardsoni* (transverse lady beetle) in central and eastern Canada from 1895 to 1960, and by decade from 1960 to 2010. Each point represents the total collected on a given day for a given locality (note that points may overlap)....16
Figure 4. Distribution of *Coleomegilla maculata lengi*(twelve-spotted lady beetle) in central and eastern Canada from 1895 to 1960, and by decade from 1960 to 2010. Each point represents the total collected on a given day for a given locality (note that points may overlap)....17

Figure 5. Distribution of *Adalia bipunctata* (two-spotted lady beetle) in central and eastern Canada from 1895 to 1960, and by decade from 1960 to 2010. Each point represents the total collected on a given day for a given locality (note that points may overlap). 18

Figure 6. Distribution of *Hippodamia tredecimpunctata tibialis* (thirteen-spotted lady beetle) in central and eastern Canada from 1895 to 1960, and by decade from 1960 to 2010. Each point represents the total collected on a given day for a given locality (note that points may overlap). 19

Figure 7. Distribution of *Coccinella septempunctata* (seven-spotted lady beetle) in central and eastern Canada from 1895 to 1960, and by decade from 1960 to 2010. Each point represents the total collected on a given day for a given locality (note that points may overlap). 20

Figure 8. Distribution of *Harmonia axyridis* (multicoloured Asian lady beetle) in central and eastern Canada from 1895 to to 1960, and by decade from 1960 to 2010. Each point represents the total collected on a given day for a given locality (note that points may overlap). 21

Figure 9. Distribution of *Hippodamia variegata* (variegated lady beetle) in central and eastern Canada from 1895 to 1960, and by decade from 1960 to 2010. Each point represents the total collected on a given day for a given locality (note that points may overlap). 22

Figure 10. Distribution of *Propylaea quatuordecimpunctata* (fourteen-spotted lady beetle) in central and eastern Canada from1895 to 1960, and by decade from 1960 to 2010. Each point represents the total collected on a given day for a given locality (note that points may overlap). 23

Figure 11. Distribution of *Coccinella undecimpunctata undecimpunctata* (eleven-spotted lady beetle) in central and eastern Canada from 1895 to 1960, and by decade from 1960 to 2010. Each point represents the total collected on a given day for a given locality (note that points may overlap). 24

Figure 12. The historic geographic range of *Coccinella novemnotata,* gray shading, from Gordon (1985). 25

Figure 13. Changes in area of occupancy for *Coccinella novemnotata* in Ontario and Quebec based on museum collections for three time periods, before 1960, 1960-1979 and 1980-2009. 26

Figure 14. The historic geographic range of *Coccinella transversoguttata richardsoni*, from Gordon (1985). This species also occurs on the island of Newfoundland. 28

Figure 15. Records of *Coccinella transversoguttata richardsoni* (red bars) and *C. septempunctata* (blue bars) from the west end of Montreal in the Lyman Entomological Museum. 30

Figure 16. The relative abundances of the native lady beetles, *Coccinella transversoguttata richardsoni* (green dashed line) and *Hippodamia parenthesis* (blue line) and the non-native *C. septempunctata* (red dotted line) in agricultural areas of southern Manitoba from 1982 through 2002. No data were available for 1986, 1997, 1999, and 2001. Adapted from Turnock *et al.* (2003). 31

List of Tables

Table 1. Summary of non-native coccinellines in Canada including first record in Canada, and current distribution. Sources: Brown 1940; Gordon 1985; Gordon and Vandenberg 1991; Coderre *et al.* 1995; Marshall 1999; Hicks *et al.* 2010; Canadian Coccinellinae database, this report......9

Table 2. Native species and localities for which declines have been reported in Canada and the northern United States. 10

Table 3. Changes in relative abundance (proportion of total for the time period) of 5 native and 5 non-native species of lady beetles from collections in Ontario and Quebec, from three time periods: pre-1960, 1960-1979, 1980-2009. 13

List of Appendices

Appendix I: Insect collections in Canada, Coccinellinae databased 55

Appendix II: Insect collections in Canada Coccinellinae still to be databased 58

Appendix III: People with significant expertise on Coccinellinae in Canada 59

ABSTRACT

Historic and current information on the geographic ranges and abundance of lady beetles in the subfamily Coccinellinae are reviewed for Canada. The focus is on two native taxa, *Coccinella novemnotata* Herbst, nine-spotted lady beetle, and *C. transversoguttata richardsoni* Brown, transverse lady beetle, and the evidence that could be used to list them as species at risk in Canada. Evidence of a reduced geographic range of these two taxa is most obvious in southern Ontario, southern Quebec, New Brunswick, Nova Scotia and Prince Edward Island. Evidence comes largely from reviewing specimen label data in collections across Canada. Changes in geographic range and relative abundance are interpreted in light of ideas on why native lady beetles have declined, i.e. threats in the context of Committee on the Status of Endangered Wildlife in Canada (COSEWIC). The declines occurred in the late 1970s, at approximately the same time as the arrival of the non-native *C. septempunctata* Linnaeus, and were best documented after the arrival and spread of three other non-native coccinellines in the 1980s. The decline of native lady beetles has been attributed to competition with non-native coccinellines, intraguild predation by non-native species, interactions with parasites and parasitoids to which native species are more susceptible, and changes in land use and pesticide use. However there is no strong evidence linking any particular threat to the declines.

A summary of collections databased, ongoing work in collections, and potential archiving of the database are included. Gaps in understanding the natural history of lady beetles are identified, other species that deserve attention are noted, and some guidelines for monitoring are outlined.

DEDICATION

This report is dedicated to the late Dr. Rob Roughley. Rob’s vision was instrumental in sparking our interest in lady beetle conservation. His expertise, enthusiasm and personal interest in our progress started DBMcC working through the collections at CNC, grew through work on the Biological Survey of Canada with DJG and DBMcC and included advice and encouragement to SMM as she started her M.Sc. His role in this project is typical of Rob’s influence on studies of insect biodiversity in Canada.

INTRODUCTION

Lady beetles (Coccinellinae) in Canada

The bright red, black spotted beetles most people recognize as lady beetles (known as ladybugs in North America, ladybirds in Great Britain, les coccinelles in Quebec) are in the beetle family Coccinellidae. The family contains about 6,000 species worldwide in about 360 genera (Vandenberg 2002; Giorgi and Vandenberg 2009). In North America there are 481 species in 60 genera; in Canada there are 166 species, including 54 species in the subfamily Coccinellinae.

Classification of this subfamily (Vandenberg 2002):

Phylum Arthropoda
- Class Insecta
  - Subclass Pterygota
    - Order Coleoptera
      - Suborder Polyphaga
        - SuperfamilyCucujoidea
          - Family Coccinellidae
            - Subfamily Coccinellinae

There is a solid knowledge base for taxonomy, identifications and geographic distributions of this subfamily in Canada and details continue to be added to this base. Gordon (1985; "The Coccinellidae (Coleoptera) in America north of Mexico") provides the basis for alpha level taxonomy and identification of all species of Coccinellinae in Canada. Most species can be identified with external morphological features, but a few western *Hippodamia* require dissections of male genitalia to distinguish species. Vandenberg (2002) updated higher level classification and argued that some genera within the Coccinellinae are very narrowly defined (e.g. *Ceratomegilla* and *Naemia*) while others are broadly defined and paraphyletic (e.g. *Hippodamia* and *Coleomegilla*). Therefore, refinement of generic classification is needed. Gordon (1985) drew upon important regional studies from Canada such as Dobzhansky (1935) for British Columbia, Belicek (1976) for western Canada, Larochelle (1979) for Quebec and the general work on coccinelline systematics and distributions by Watson and Brown and their co-workers (e.g. Watson 1956, 1976; Brown 1962; Brown and de Ruette 1962). McNamara (1991) updated provincial lists using data from Gordon (1985) and the Canadian National Collection. Recent regional works have fine tuned the details of geographic distributions in the Maritimes (Majka and McCorquodale 2006, 2010) and Alberta (Acorn 2007). These works provided the basis for the review of geographic distribution of 49 native and 5 non-native coccinellines in Marriott *et al.* (2009) and for the yet unreleased 2010 General Status Assessment of Coccinellidae in Canada by Environment Canada.

Basic life history and behavior, including food use, is relatively well known for Canadian coccinellines. Coccinellinae, as adults and larvae, feed primarily on aphids, prompting interest in their use in biological control (Obrycki and Kring 1998; Obrycki *et al.* 2009). Most species also feed opportunistically on other soft-bodied herbivorous arthropods (e.g. scale insects, psyllids, beetle larvae, mites) and pollen (Gordon 1985; Giorgi *et al.* 2009). Members of one tribe, Halyziini (which includes *Psyllobora*) feed on fungi, specifically powdery mildews (Vandenberg 2002; Giorgi *et al.* 2009). In Canada, most species overwinter as mated females and become active when temperatures warm in the spring (Acorn 2007). These females lay fertile eggs on plants that are likely to support populations of aphids. Many females also lay trophic eggs, along with the fertile eggs, as another food source for young larvae. Development from egg to adult takes from 2 weeks to 2 months, depending on temperature. In many species the adults that result from these eggs mate and lay eggs and the adults from this second generation overwinter. Most species are generalists in food and habitat use, often tracking changes in aphid abundance across many types of open habitats (Hagen 1962; Hodek and Honek 1996; Majerus 1994; Sloggett and Majerus 2000), such as coastal dunes and open prairies to field edges and suburban gardens. Some species, however, are more restricted in their range of habitats. For example, *Naemia striata* (Melsheimer) prefers saltmarsh dominated by cordgrass (*Spartina spp.)* and *Anisoticta bitriangularis* (Say) prefers marshes with sedges (*Carex spp.)* (Majka and McCorquodale 2010; Acorn 2007). Despite generally good information on basic life history for coccinellines in Canada, our understanding of habitat use and changes in microhabitat use through the seasons lags far behind that for lady beetles in Europe (Majerus 1994). Acorn's (2007) overview of Alberta lady beetles is an exception, and provides a useful template for future work.

There are five non-native species of coccinellines in Canada as of 2010 (Table 1). The first to become established in Canada was *Coccinella u. undecimpunctata* (Linnaeus). It was discovered in North America in 1912 (Schaeffer 1912). In Canada it was first recorded near Rimouski, Quebec in the 1930s and in 1939 in New Brunswick and Prince Edward Island (Brown 1940). In the 1950s and 1960s it was reasonably common in Maritimes, southern Quebec and southern Ontario (Watson 1979). Another population became established on the west coast, including the Vancouver area (Belicek 1976). Records since 1980 in southern Quebec and Ontario are infrequent and by 2000 the only populations were in southern British Columbia and coastal Nova Scotia (Wheeler and Hoebeke 2008; Majka and McCorquodale 2010). In the late 1960s and the 1970s three more species became established (Table 1). By the late 1980s these three species, *Propylaea quatuordecimpunctata* (Linnaeus) *C. septempunctata* Linnaeus and *Hippodamia variegata* (Goeze) had expanded their ranges to include eastern Canada from southern Ontario to the Maritimes (Gordon 1985; Marshall 2008; McCorquodale 1998; Majka and McCorquodale 2010). One of these, *C. septempunctata*, expanded its range west through Manitoba to Alberta and British Columbia (Matheson 1989; Acorn 2007) and now occurs across southern Canada and north into the Yukon and the Northwest Territories. A fifth non-native species, *Harmonia axyridis* (Pallas), first became established in North America in 1988 (Chapin and Brou 1991). It was first recorded in Canada in 1994 (Coderre *et al.* 1995; Marshall 1999), and is now often the most frequently encountered lady beetle in the Maritimes, southern Quebec, southern Ontario, southern Manitoba and urban and agricultural regions of southern British Columbia (Majka and McCorquodale 2010; Marshall 2008; Wise *et al.* 2001).

Table 1. Summary of non-native coccinellines in Canada including first record in Canada, and current distribution. Sources: Brown 1940; Gordon 1985; Gordon and Vandenberg 1991; Coderre *et al.* 1995; Marshall 1999; Hicks *et al.* 2010; Canadian Coccinellinae database, this report.

Species	First record (Year, Province)	Current distribution
Coccinella u. undecimpunctata	1939, PE,NB 1930s, QC	BC, NS
Propylaea quatuordecimpunctata	1968, QC	ON, QC, NB, PE, NS
Coccinella septempunctata	1973, QC	All provinces, NWT, YT
Hippodamia variegata	1984, QC	ON, QC, NB, PE, NS
Harmonia axyridis	1994, QC, ON	BC, MB, ON, QC, NB, PE, NL

There has been considerable speculation that the spread of these non-native coccinellines across Canada is related to a concurrent decline in some native species of lady beetle (e.g. Harmon et al. 2007). In the mid-1990s (shortly after the newly arrived non-native species became more numerous and widely distributed in eastern Canada), entomologists noticed that formerly common native species became increasingly difficult to find (Wheeler and Hoebeke 1995, Marshall 1999, Turnock *et al.* 2003). Wheeler and Hoebeke (1995) documented a coincidental decline in the geographic range and relative abundance of *Coccinella novemnotata* Herbst with the arrival and spread of *C. septempunctata* in northeastern North America. In Canada, Marshall (1999) noted that, after 1982, there were no specimens of *C. novemnotata* in the University of Guelph collection. Instead, the lady beetle collected from previous *C. novemnotata* locations was *C. septempunctata*. The decline in *C. novemnotata* was so pronounced in central Canada that a report of this species at Mont St-Hilaire (near Montreal) in 2006 (the first record in the province since 1980) prompted a review of the status of this species in Quebec (Skinner and Domaine 2010). In western Canada, *C. septempunctata* may have affected other lady beetle species. For example, in an intensive study of lady beetle abundance and distribution in southern Manitoba, Turnock *et al.* (2003) found that C. t. richardsoni Brown, *Hippodamia convergens* Guerin-Meneville, *H. parenthesis* (Say) and *C. trifasciata* Mulsant declined coincidentally with the arrival of *C. septempunctata*. In addition, there are reports of presumed declines in native species such as *Adalia bipunctata* (Linnaeus) in Nova Scotia (Cormier *et al.* 2000) and *C. novemnotata* and *C. transversoguttata richardsoni* in Alberta (Acorn 2007). Table 2 summarizes studies that have commented on the influence of non-native lady beetles on native species.

Significant declines in geographic range and abundance of insects are frequently due to changes in habitat or interactions with non-native species (New 1995). The coincidence of species declines with the recent arrival of non-native species has led to a widespread assumption that non-natives have caused the observed declines. Most explanations focus on interactions with the recently arrived non-native species through competition, intraguild predation or indirect effects of parasites (Evans 2004; Lucas 2005; Lucas *et al.*2007a,b; Snyder and Evans 2006; Kenis *et al.* 2008; Riddick *et al.* 2009).

Despite documented declines in populations of native species of lady beetles in Canada (e.g. Turnock *et al.* 2003) and the arrival and range expansion of non-native lady beetles in North America (e.g. Wheeler and Stoops 1996; Lucas *et al.* 2007a,b), the links between the non-native species and causes of the declines are not clear. For example, Harmon *et al.* (2007) and Acorn (2007) argued that there is little direct evidence that competition or other interactions with recently arrived non-native species has caused the declines in native species. Acorn (2007) reported that the distribution and abundance of *C. t. richardsoni* declined in Alberta since the 1970s, but suggested that a focus on human-disturbed habitats may have distorted our understanding of the overall pattern. For example, *C. t. richardsoni* likely increased its abundance in new habitat types such as gardens, city parks and agricultural fields (and therefore may have been very obvious to collectors), as these habitats became more widespread in Alberta during the mid-1900s. In contrast, there was relatively low collecting effort in natural habitats at the time, so patterns in the natural habitats are not known. Subsequent declines in the non-natural (human created) habitats were very noticeable because they are habitats frequented by collectors, but there is no comparable evidence to assess whether the same declines occurred in natural habitats.

Table 2. Native species and localities for which declines have been reported in Canada and the northern United States.

Native species	Province / State	Sources
Adalia bipunctata	New Brunswick, Nova Scotia, South Dakota, Michigan, Missouri	Elliott *et al.* 1996; Obrycki *et al.* 2000, Colunga-Garcia and Gage 1998; Boiteau *et al.* 1999; Cormier *et al.* 2000; Hesler *et al.* 2004; Hesler and Kieckhefer 2008; Fothergill and Tindall 2010
Coccinella novemnotata	Alberta, Ontario, Quebec, South Dakota, Missouri	Wheeler and Hoebeke 1995; Marshall 1999; Harmon *et al.* 2007; Skinner and Domaine 2010; Hesler and Kieckhefer 2008; Acorn 2007; Fothergill and Tindall 2010
Coccinella transversoguttata richardsoni	Alberta, Manitoba, New Brunswick, Maine, South Dakota	Elliott *et al.* 1996; Acorn 2007; Hesler et al. 2004; Turnock *et al.* 2003; Hesler and Kieckhefer 2008; Boiteau *et al.* 1999; Boiteau 1983; Alyokhin and Sewell 2004; Finlayson *et al.* 2008
Coccinella trifasciata perplexa	Manitoba	Turnock *et al.* 2003

Native species	Province / State	Sources
Cycloneda munda	Michigan	Colunga-Garcia and Gage 1998
Hippodamia convergens	Alberta, Manitoba, Michigan, Connecticut, Pennsylvania, Virginia	Wheeler and Stoops 1996; Colunga-Garcia and Gage 1998; Ellis *et al.* 1999; Turnock *et al.* 2003; Acorn 2007
Hippodamia parenthesis	Manitoba	Turnock *et al.* 2003
Hippodamia tredecimpunctata tibialis	Quebec, New Brunswick, Midwestern United States, Maine, South Dakota	Boiteau 1983; Elliott *et al.* 1996; Boiteau *et al.* 1999; Obrycki *et al.* 2000; Alyokhin and Sewell 2004; Lucas *et al.* 2007b; Finlayson *et al.* 2008

Here we review evidence from recent literature and coccinelline specimen label data gathered from across Canada for shrinkage of the geographic ranges of native species of lady beetles in Canada. Our emphasis is on species and regions for which data are of high quality and complete over the time period when non-natives arrived in Canada, so there is a focus on eastern Canada and on a subset of 10 species of coccinellines. We assess whether the data support a conclusion that declines of native species coincide with the arrival of non-natives, and review potential threats to native lady beetles, with an emphasis on Canada and the northern United States. We identify gaps in natural history information and discuss the need for monitoring, especially in non-agricultural habitats. Finally, we provide a summary of Canadian collections that include Coccinellinae specimens and the status of databasing specimen label data for Canadian Coccinellinae within those collections, and comment on long-term archiving of this database.

Insect collections and changes in lady beetle distribution and abundance

Insect collections are important sources for information on geographic distribution of species (Wiggins *et al.* 1991). Specimens collected by systematists and during biodiversity inventories, general collections, ecological studies and applied studies on crop and forest pests form the bulk of specimens in Canadian collections. Data from collections have helped delineate geographic ranges of lady beetles (e.g. Brown 1962; Gordon 1985; McNamara 1991) and can be used to assess temporal changes in distribution and abundance if the strengths and weaknesses of collection data are understood and considered. For example, specimens in a specialist's collection are not likely to reflect the true abundance of a species, because experts would not continue to collect specimens of a common lady beetle once there were several in the collection. Such collections result in a time series biased by the collector's expertise. Conversely, because of its novelty, a newly introduced and invasive species could be collected out of proportion to the actual relative abundance of the species. In contrast, naïve students adding many specimens annually to a university general collection, or collections based on regular large scale agricultural and forestry surveys, may better reflect true abundance patterns. Therefore, any assessment of temporal and distribution patterns based on insect collection data should include a wide variety of collections. Accurate identifications are also critical. For example, a widely publicized Canadian Nature

Federation project in the 1990s to document lady beetles across Canada encouraged non-experts to submit records based on identification of beetles by counting elytral spots. This led to many misidentifications and the failure of the project (see Acorn 2007; Marshall 2008).

METHODS

Specimen label data from a variety of museum collections were combined to assess overall patterns of change in geographic distribution and relative abundance of Canadian lady beetles (Appendix I). Most museums listed in Appendix I were visited and coccinelline specimens were identified or verified as necessary, then specimen label information was databased. In many collections, specimen label data for all Coccinellinae were recorded, but in all cases, at least 10 species were assessed: the five non-native species (Table 1) and five native species representing a range of abundance patterns. The natives included two that were thought to be declining (*Coccinella novemnotata* and *C. t. richardsoni*), two that are widely distributed with equivocal evidence of declines (*Adalia bipunctata* (Linnaeus) and *Hippodamia tredecimpunctata tibialis*(Say)) and one thought to be abundant in agricultural areas of southern Ontario and Quebec (*Coleomegilla maculata lengi* Timberlake).

Databases for each species were combined and localities were georeferenced so that species could be mapped using GIS software. Latitude and longitude were taken from labels when available, but only about 10% of specimens had these data. For others, the locality written on the label was searched in the online database of geographical names in Canada maintained by Natural Resources Canada (http://geonames.nrcan.gc.ca/). For cities and towns the latitude and longitude of the town centre was used unless a more specific locality could be determined. For some localities with more detail than just a place name, for example 10 miles north, Google Earth or MAPINFO were used to ascertain latitude and longitude. All latitudes and longitudes were stored in decimal degree format for mapping with GIS software. Records with ambiguous names or with multiple possible locations (e.g. Salmon River, Sand Lake, Trout Lake) were not included in the mapping analysis.

For some analyses, records were sorted by date into three time periods: Pre-1960, 1960-1979, 1980-2009. These three periods represented the pre-introduction, arrival, and establishment of the now common non-native species. Each time period had more than 1000 specimens in total of the 10 lady beetles chosen for intensive study. Geographic patterns were evaluated by plotting each record on a map of eastern Canada for each time period for each species. A “record” consisted of all specimens collected from one locality on one date, therefore some records represent multiple specimens. Relative abundance was determined by counting the total number of specimens of each species for each time period, then expressing each as proportion of the total for the 10 species for that time period.

These data were then used to assess changes in geographic range and relative abundance of the 10 species of lady beetles. We focused on the three Maritime Provinces and southern Ontario and Quebec partly because these areas were best represented in the collections studied. A primary interest was the reduced geographic range and relative abundance of *C. novemnotata* in southern Ontario and Quebec and *C. t. richardsoni* from Ontario east to the Maritimes. In addition to data from collections, we relied on Acorn (2007) and Turnock *et al.* (2003) for data from western Canada.

RESULTS AND DISCUSSION

Shrinkage of geographic range and decline in relative abundance

The relative abundance of native species of lady beetles in collections from southern Ontario and southern Quebec has declined since 1960, concurrent with an increase in collection of non-native species (Table 3). In the most recent period (since 1980), non-native species made up more than 50% of the specimens (Table 3). Many of these collections were made by naïve (rather than expert) collectors (i.e. from university student collections and broad surveys), and should therefore be a reasonable reflection of local relative abundance, although some museums may have focused efforts on novel, recently arrived, non-native species. These non-native species, *C. septempunctata, P. quatuorodecimpunctata, H. variegata and Harmonia axyridis*, did not occur in Canada prior to 1970 and therefore an increase in relative abundance was expected as they moved into new localities.

Table 3. Changes in relative abundance (proportion of total for the time period) of 5 native and 5 non-native species of lady beetles from collections in Ontario and Quebec, from three time periods: pre-1960, 1960-1979, 1980-2009.

	Relative Abundance		
Species	**<1960**	**1960-1979**	**1980-2009**
Natives			
Adalia bipunctata	0.253	0.152	0.100
Coccinella novemnotata	0.180	0.060	0.003
Coccinella transversoguttata richardsoni	0.258	0.274	0.072
Coleomegilla maculata lengi	0.097	0.131	0.177
Hippodamia tredecimpunctata tibialis	0.211	0.257	0.094
Non-natives			
Coccinella septempunctata	0	0.043	0.314
Coccinella u. undecimpunctata	0.001	0.040	0.001
Harmonia axyridis	0	0	0.091
Hippodamia variegata	0	0	0.038
Propylaea quatuordecimpunctata	0	0.043	0.112

Despite the overall increase in proportion of non-native species, some native species increased in relative abundance after the arrival of non-native species. For example *Coleomegilla maculata lengi* made up about 10% of the specimens prior to 1960 and almost 18% after 1980 (Table 3, Fig. 1). In contrast *C. novemnotata* declined from about 18% prior to 1960 to <0.05% after 1980, and the previously common *C. t. richardsoni* also declined. This contrast in trends in relative abundance of the native species suggests that declines in these two native species, *C. novemnotata* and *C. t. richardsoni*, are not explained by collecting bias.

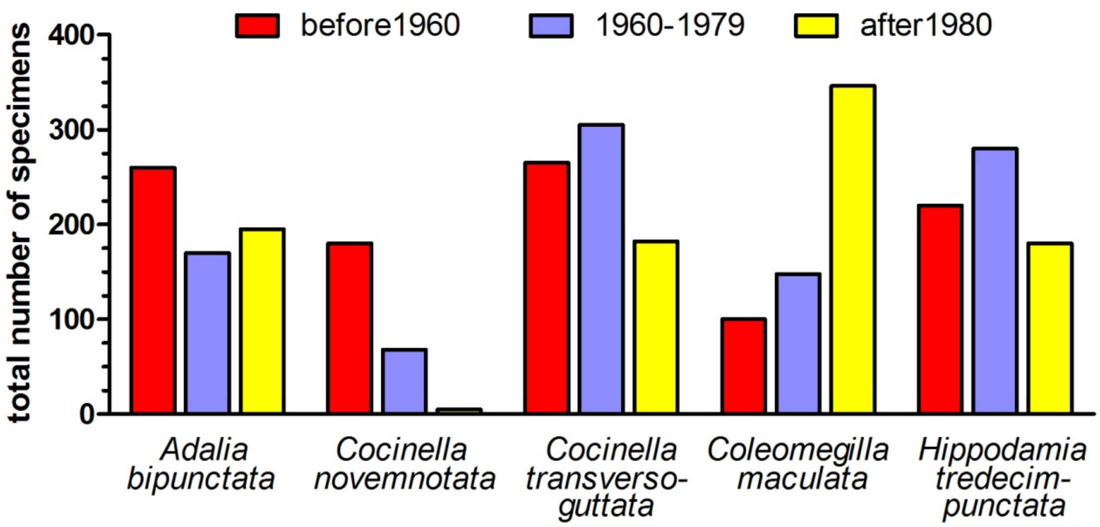


Figure 1. Changes in the number of specimens collected for five common native species of lady beetles in Southern Ontario and Quebec during three time periods, pre-1960, 1960-1979, 1980-2009.

Changes in geographic ranges of the native and non-native species after 1960 paralleled changes in relative abundance (Figs. 2-11, Table 2). The two native species with the sharpest declines in relative abundance in eastern Canada, *C. novemnotata* and *C. t. richardsoni*, also showed the most obvious decreases in geographic range (Figs. 2, 3). *Coleomegilla maculata lengi*, the native taxon that increased in relative abundance, showed a modest increase in geographic range (Fig. 4). Four non-native species, *C. septempunctata*, *Hippodamia variegata*, *P. quatuordecimpunctata*, *Harmonia axyridis*, showed expanding geographic ranges in eastern Canada after their arrival (Figs. 7-10). The geographic range of *C. undecimpunctata undecimpunctata* (the other non-native species) expanded initially, but has been decreasing since 1980 (Fig. 11).

Documenting accurately the geographic distribution of a species is a difficult task (Fortin *et al.* 2005; Elith *et al.* 2006), and adding the extra complexity of documenting changes in range increases the difficulty (Koch and Strange 2009). Maps of geographic distribution may show a decrease in geographic range when in fact, they reflect a decrease in population size, because with a reduced population there is a decrease in probability of collection. For this report we infer changes in geographic range based on inspection of maps and consideration of the number of lady beetles collected in locations and habitats in which the declining native species occurred historically. Ideally the large dataset of label information can eventually be used with the presence-only algorithms developed by Elith *et al.* (2006).

Combined, the data on changes in relative abundance and maps of changes in geographic range in eastern Canada suggest that collecting effort has been comprehensive enough to observe lady beetle patterns in eastern Canada since 1960. We conclude that declines observed for *C. novemnotata* and *C. t. richardsoni* are real, and are not artifacts of inadequate sampling.

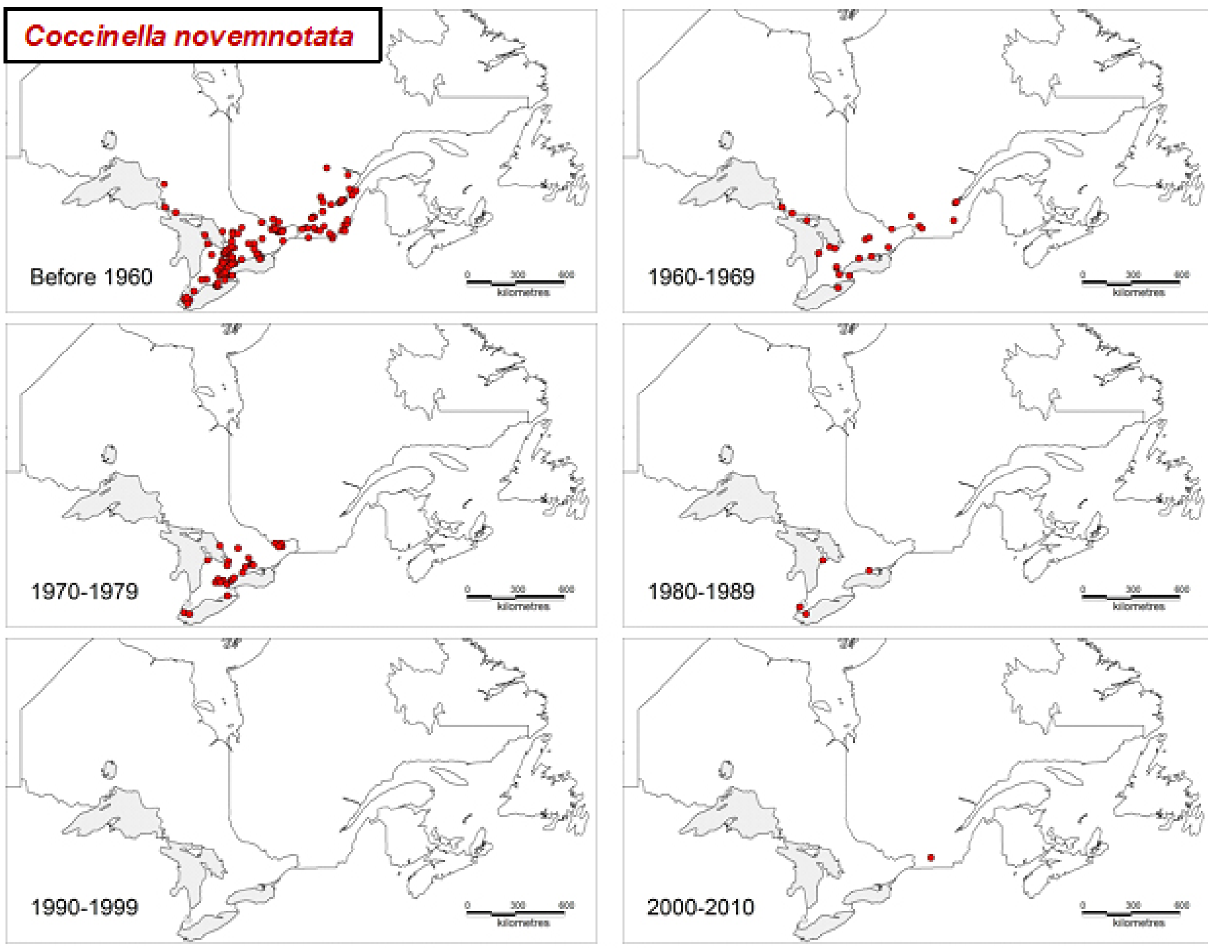


Figure 2. Distribution of *Coccinella novemnotata* (nine-spotted lady beetle) in central and eastern Canada from 1895 to 1960, and by decade from 1960 to 2010. The recent Quebec record is from Mont St-Hilaire (Skinner and Domaine 2010). The most recent Ontario record is from 1983. Each point represents the total collected on a given day for a given locality (note that points may overlap)

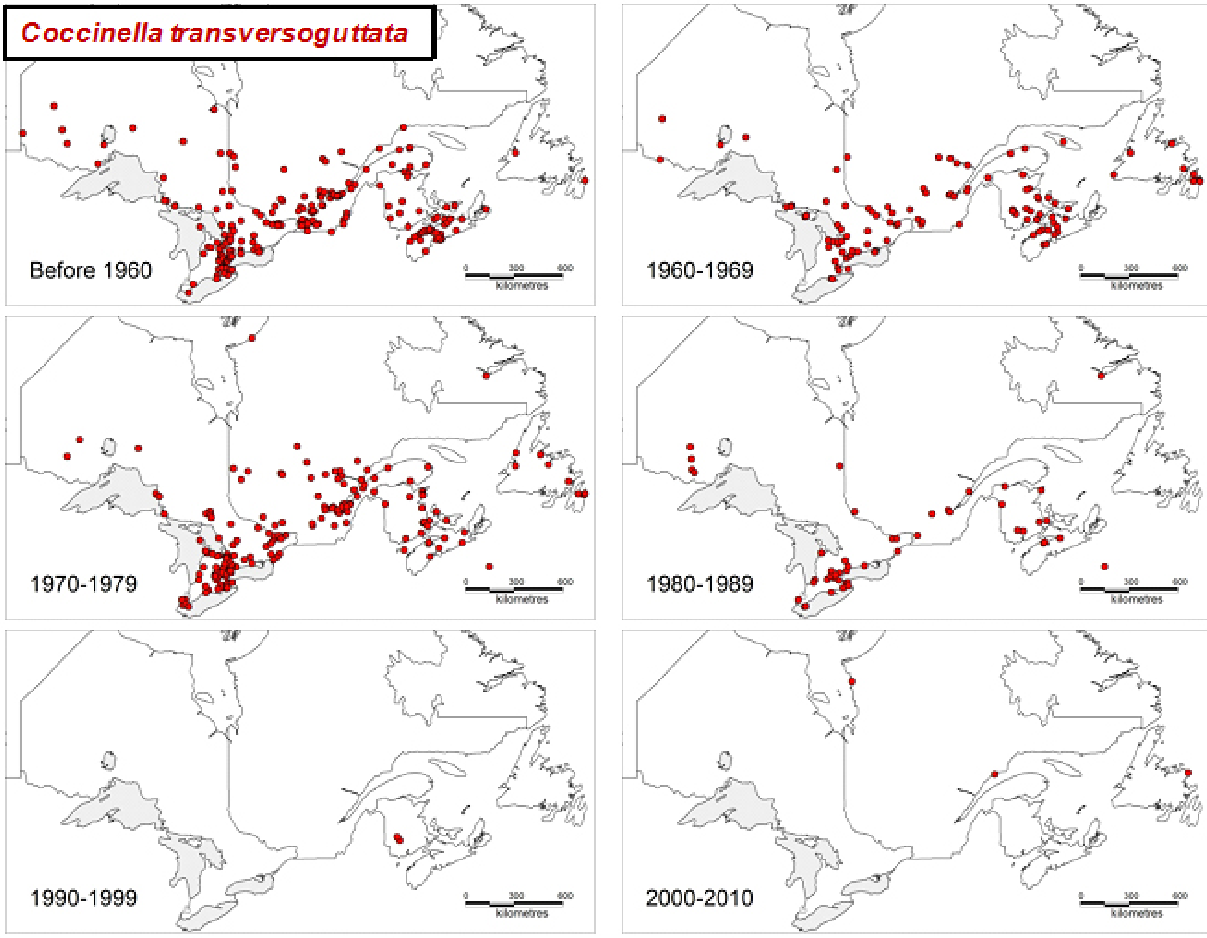


Figure 3. Distribution of *Coccinella transversoguttata richardsoni* (transverse lady beetle) in central and eastern Canada from 1895 to 1960, and by decade from 1960 to 2010. Each point represents the total collected on a given day for a given locality (note that points may overlap).

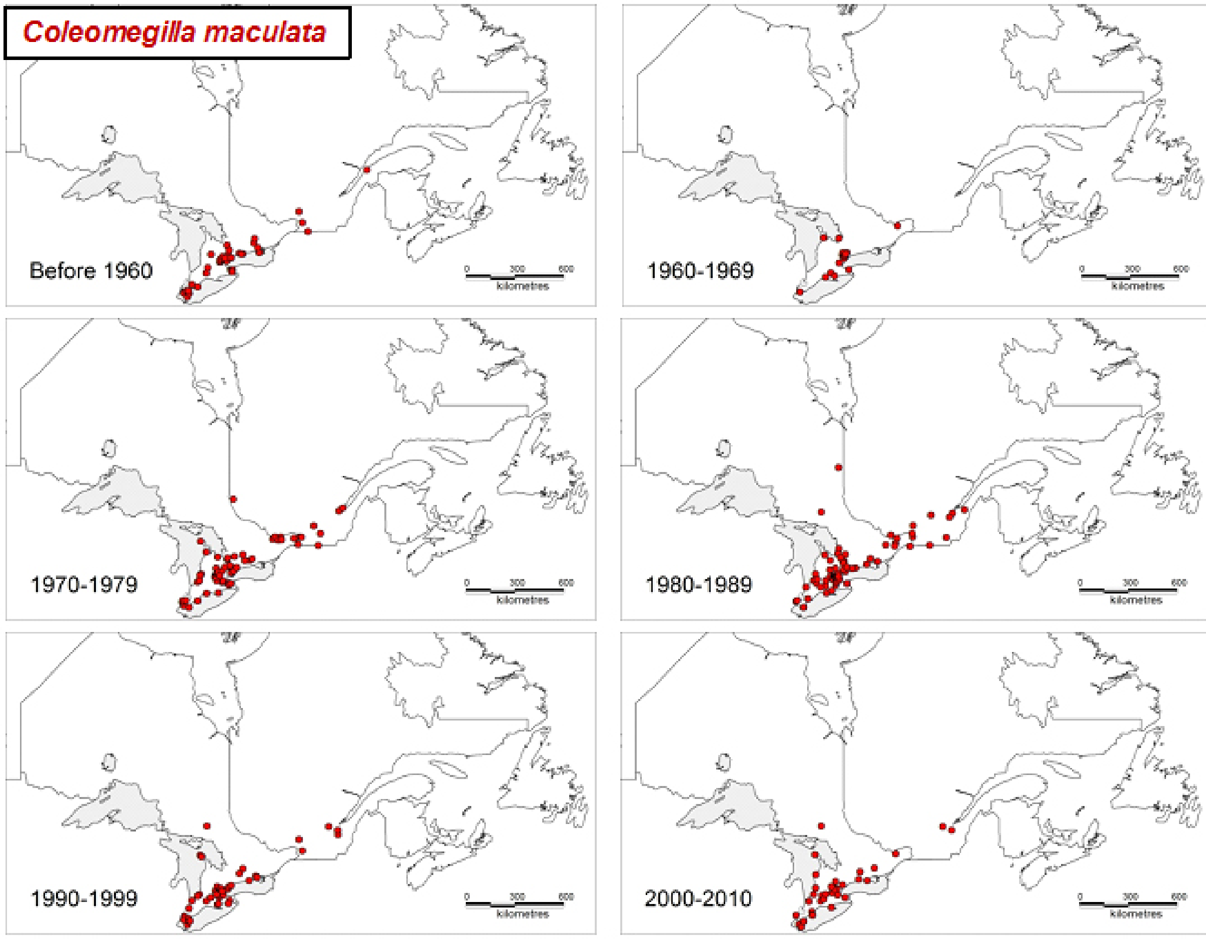


Figure 4. Distribution of *Coleomegilla maculata lengi*(twelve-spotted lady beetle) in central and eastern Canada from 1895 to 1960, and by decade from 1960 to 2010. Each point represents the total collected on a given day for a given locality (note that points may overlap).

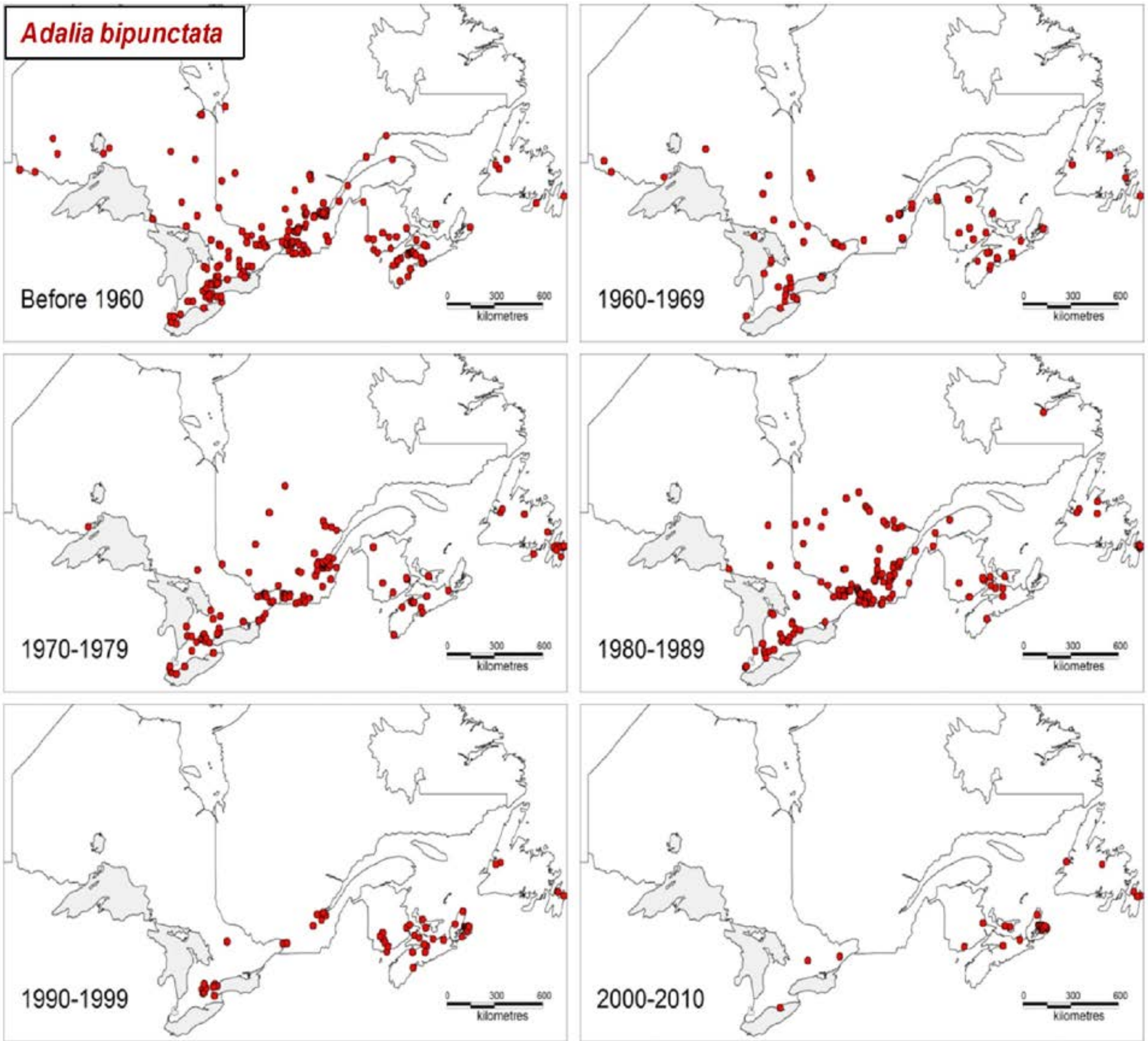


Figure 5. Distribution of *Adalia bipunctata* (two-spotted lady beetle) in central and eastern Canada from 1895 to 1960, and by decade from 1960 to 2010. Each point represents the total collected on a given day for a given locality (note that points may overlap).

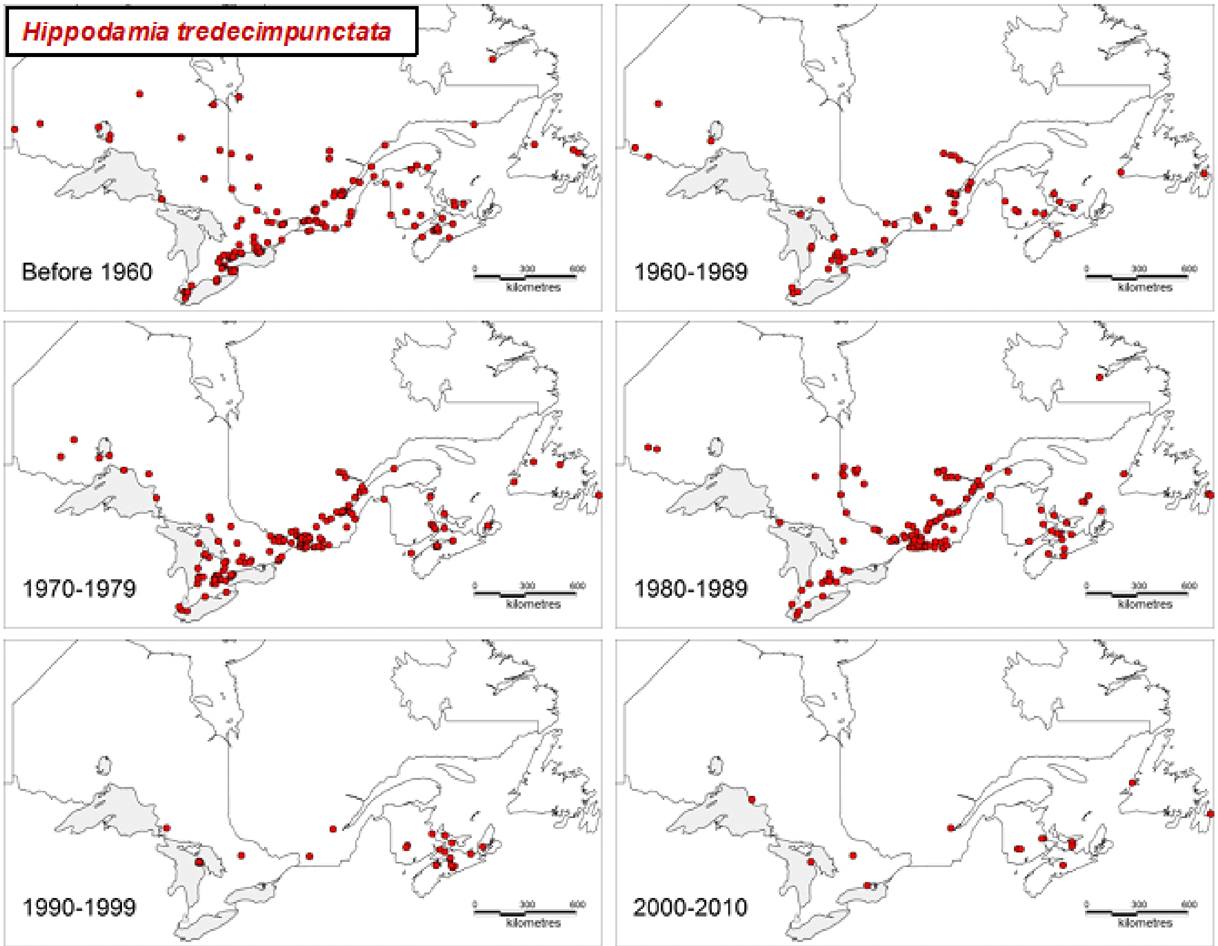


Figure 6. Distribution of *Hippodamia tredecimpunctata tibialis* (thirteen-spotted lady beetle) in central and eastern Canada from 1895 to 1960, and by decade from 1960 to 2010. Each point represents the total collected on a given day for a given locality (note that points may overlap).

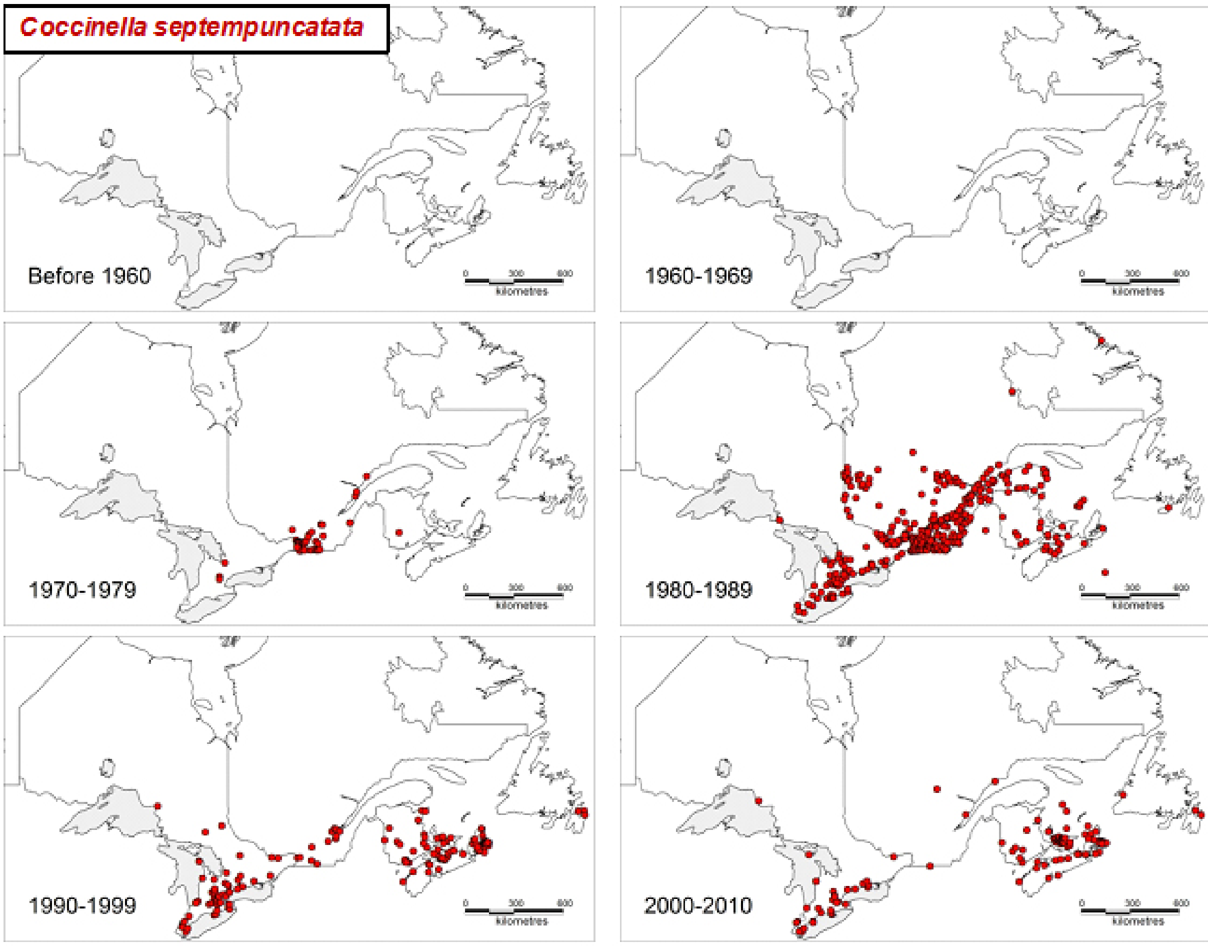


Figure 7. Distribution of *Coccinella septempunctata* (seven-spotted lady beetle) in central and eastern Canada from 1895 to 1960, and by decade from 1960 to 2010. Each point represents the total collected on a given day for a given locality (note that points may overlap).

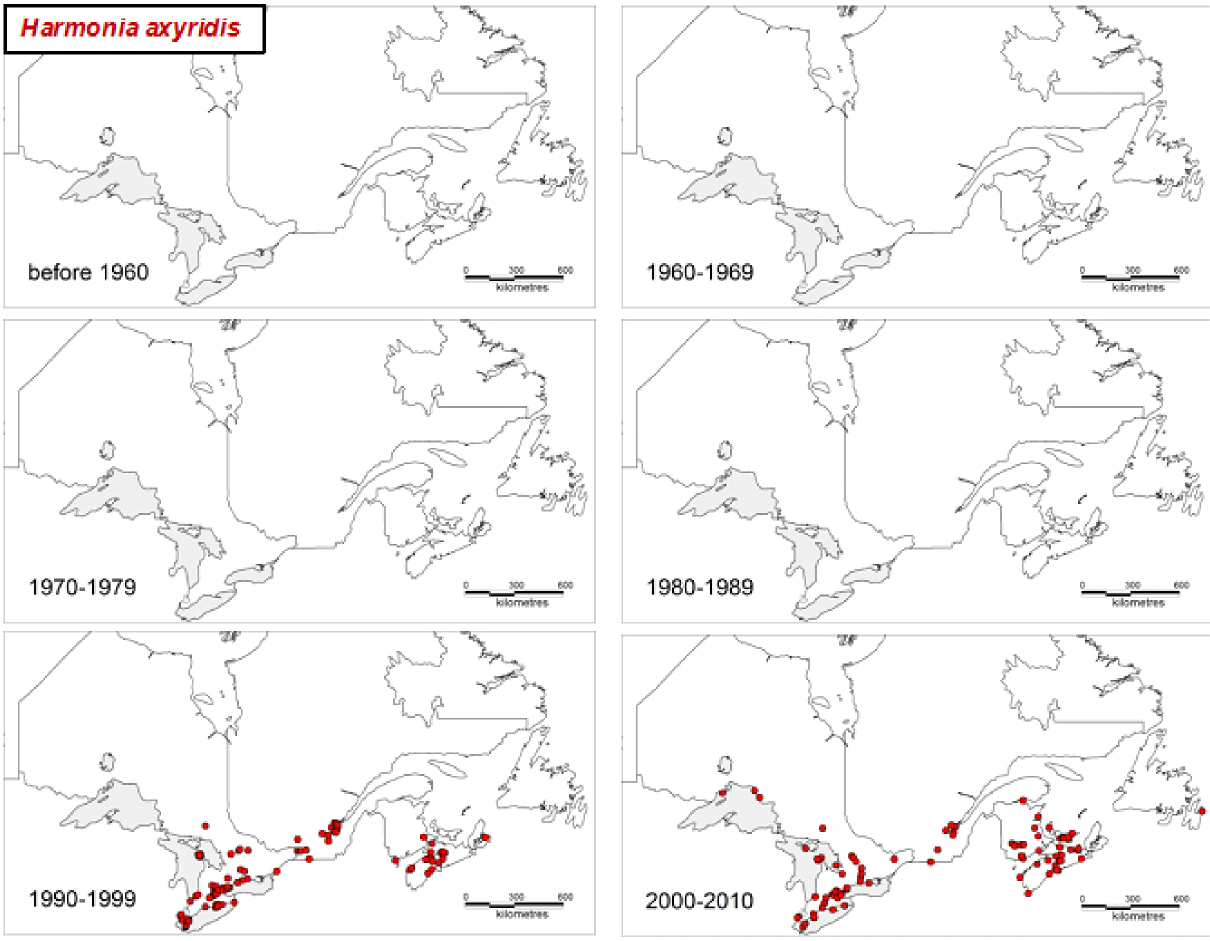


Figure 8. Distribution of *Harmonia axyridis* (multicoloured Asian lady beetle) in central and eastern Canada from 1895 to to 1960, and by decade from 1960 to 2010. Each point represents the total collected on a given day for a given locality (note that points may overlap).

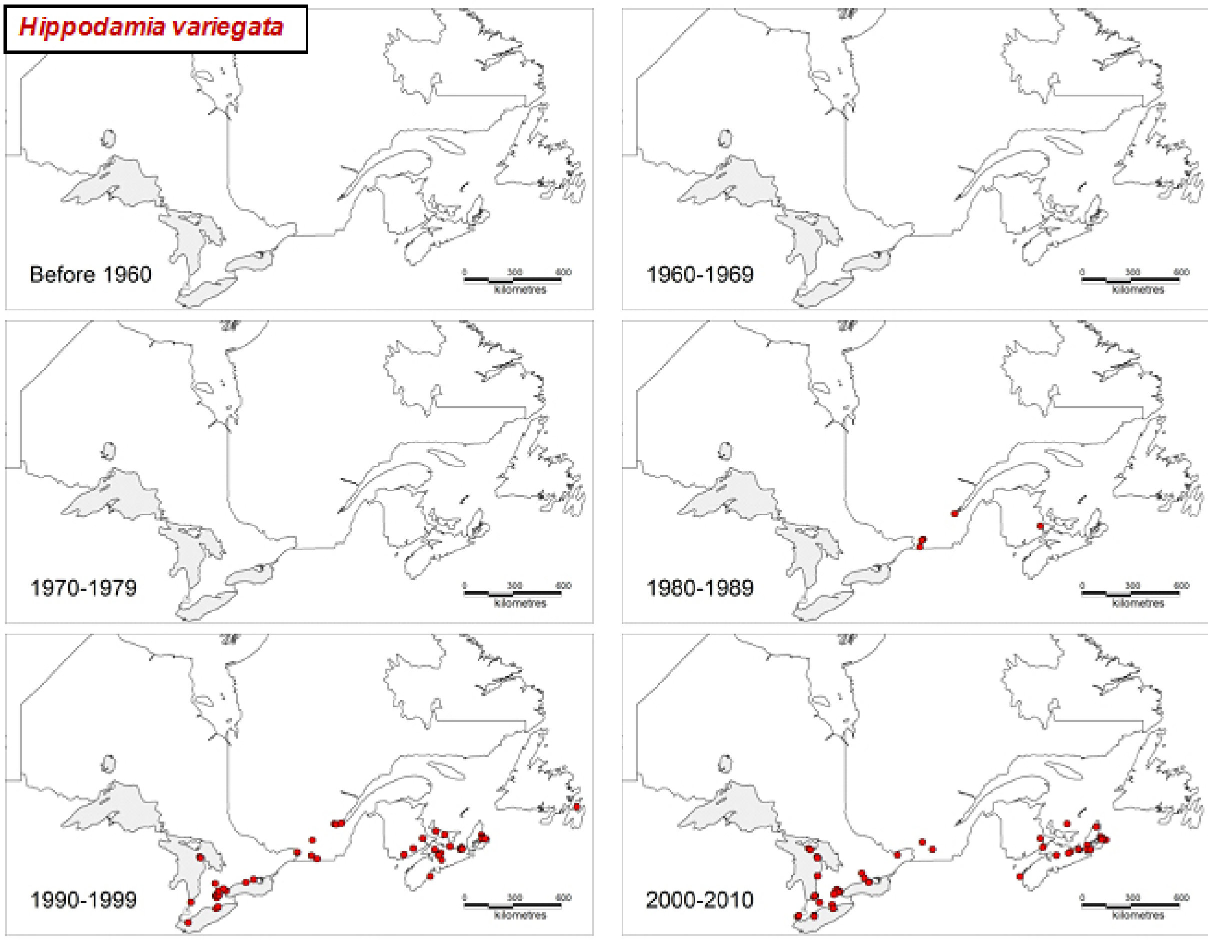


Figure 9. Distribution of *Hippodamia variegata* (variegated lady beetle) in central and eastern Canada from 1895 to 1960, and by decade from 1960 to 2010. Each point represents the total collected on a given day for a given locality (note that points may overlap).

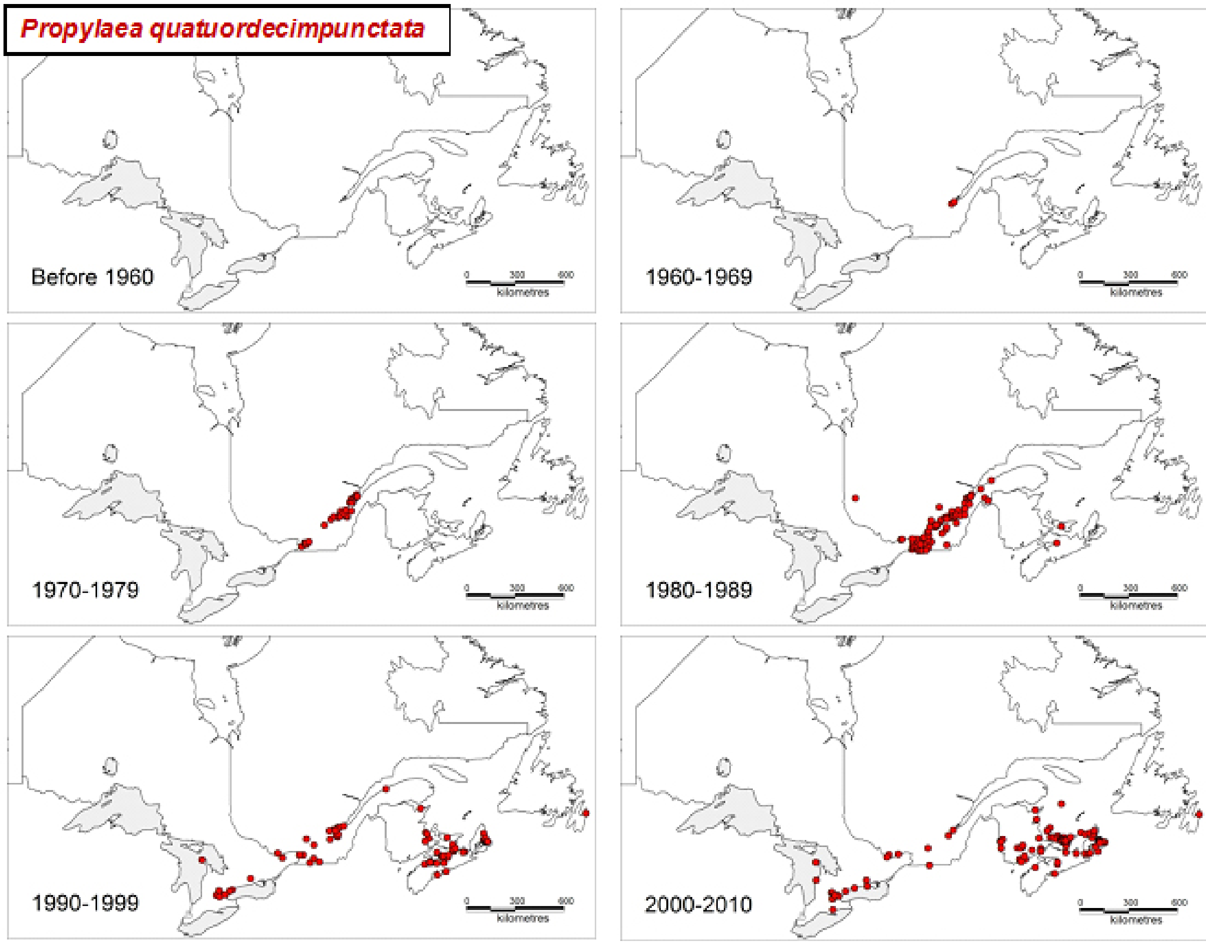


Figure 10. Distribution of *Propylaea quatuordecimpunctata* (fourteen-spotted lady beetle) in central and eastern Canada from1895 to 1960, and by decade from 1960 to 2010. Each point represents the total collected on a given day for a given locality (note that points may overlap).

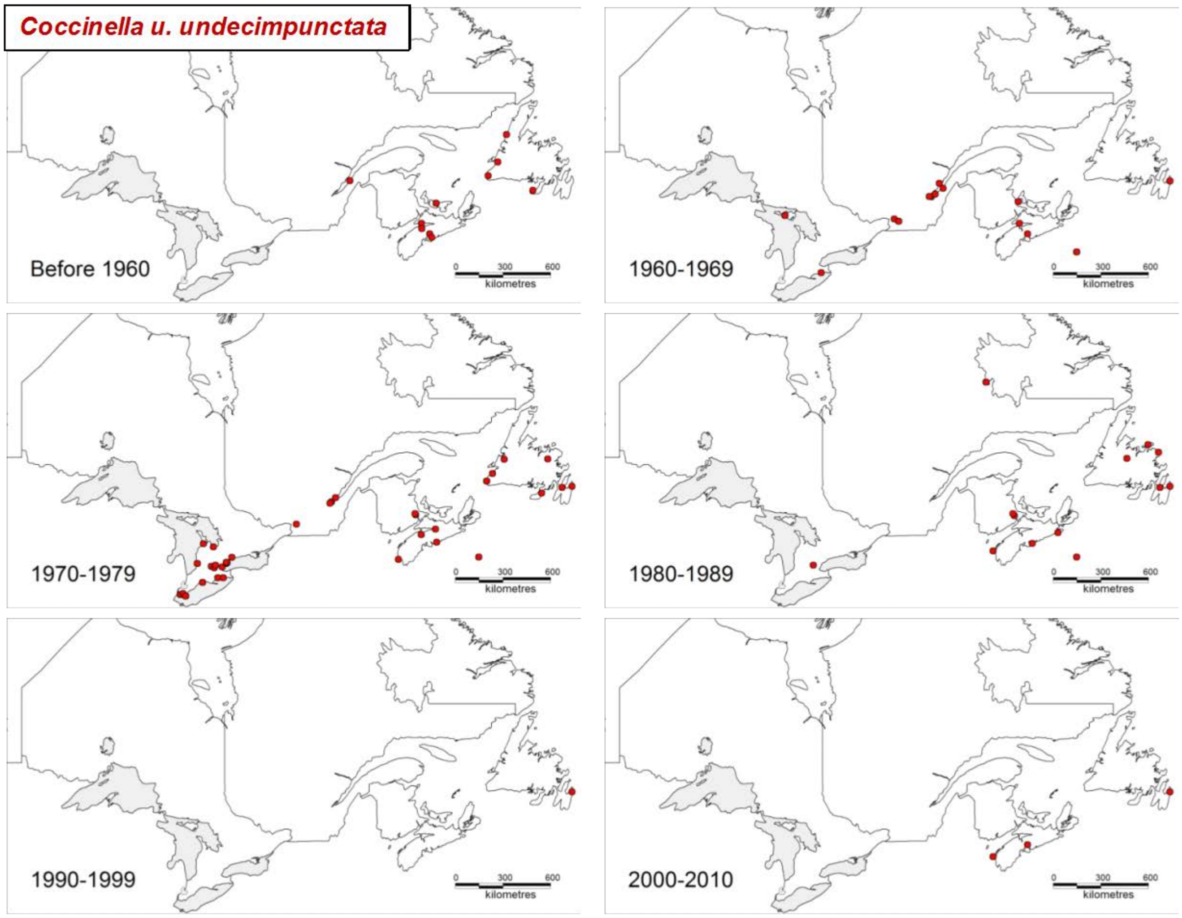


Figure 11. Distribution of *Coccinella undecimpunctata undecimpunctata* (eleven-spotted lady beetle) in central and eastern Canada from 1895 to 1960, and by decade from 1960 to 2010. Each point represents the total collected on a given day for a given locality (note that points may overlap).

Nine-spotted lady beetle, *Coccinella novemnotata*

Coccinella novemnotata, the nine-spotted lady beetle, was widely distributed in southern Canada before 1980 (Fig. 12) but was rarely collected between 1980 and 2010, and its geographic distribution became much narrower in that period (Figs. 1, 2, 13). Historically *C. novemnotata* occurred from southern Quebec to Vancouver Island in southern Canada (Brown 1962; Gordon 1985). Historic range maps, such as those reported in Gordon (1985) can be misleading, since they tend to “connect the dots” between localities and assume range occupancy between known collection points. Based on collection data, the northern limits of the range were in Salmon Arm, BC, Gros Cap on Great Slave Lake, NWT, Saskatoon, SK, Carberry, MB, Arnprior, ON, and Fort Coulonge, QC. In the US it occurred across the contiguous states south to southern California, central Arizona, New Mexico, northeastern Texas, and southwestern Georgia (Brown 1962; Gordon 1985).

Figure 12. The historic geographic range of *Coccinella novemnotata,* gray shading, from Gordon (1985).

The species declined dramatically in collections from central Canada from 1980-2010 (Figs. 1, 2). There are no specimens in collections from southern Ontario after1983, despite targeted searches during this period (e.g. S. Marshall, U of Guelph, personal communication). The only records for southern Quebec after 1980 are from Mont St-Hilaire, from targeted searches between 2006 and 2010. We conclude that that this species has declined in abundance (Fig.1) as well as in geographic range (Figs. 2, 12, 13) in Ontario and Quebec.

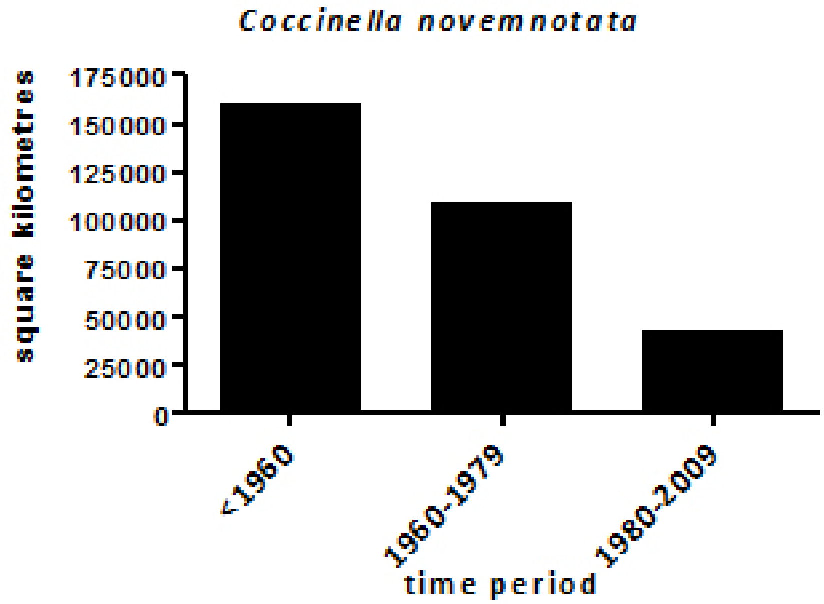


Figure 13. Changes in area of occupancy for *Coccinella novemnotata* in Ontario and Quebec based on museum collections for three time periods, before 1960, 1960-1979 and 1980-2009.

Coccinella novemnotata appears to have declined in other parts of Canada as well. Historically this species had a small range in southern Manitoba, south and west of Carberry and Brandon (Gordon 1985). Current distribution is not clear, partly because data from the University of Manitoba (J.B. Wallis Museum) and the Manitoba Provincial Museum have not been incorporated into this analysis due to delays in acquiring the data. The species was also reported from southern Saskatchewan, south of Saskatoon (Gordon 1985). Few recently collected Saskatchewan coccinellines were available for this project to assess current patterns.

Acorn (2007) summarized the status of *C. novemnotata* in Alberta. After reviewing insect collections and carrying out extensive fieldwork for more than 10 years, Acorn (2007) concluded that "...the nine-spot appears to be persisting in low numbers, especially on the prairies...". Their low numbers since 1990 contrasts with those from the early 1980s when *C. novemnotata* was one of the common species on the southern prairies, especially in sandy areas. Acorn (2007) noted they were common at wash-ups at Barrier Lake and Ghost Dam. He also noted that he collected them at Opal (just north of Edmonton) about 1000 km south of the northern limit of the range (Gros Cap, NWT; Gordon 1985). There are few records between Edmonton and the southern NWT and historically the vast majority of Alberta records are from south of the Trans-Canada Highway between Calgary and Medicine Hat. The most recent record from Alberta was a specimen photographed by Tim Loh on 12 June 2009 near Calgary and reported to the Lost Ladybug Project.

In British Columbia, *C. novemnotata* was most common in the southern valleys and also occurred in the Vancouver area and on southern Vancouver Island. Only two specimens collected since 1990 were found, one in the Spencer Museum (UBC) and one in the Royal British Columbia Museum (RBCM). Both were from the southern Okanagan, the most recent from Mount Kobua near Osoyoos in 1991 and the other from Oliver in 1994.

In the northeastern United States, the decline of *C. novemnotata* was documented by Wheeler and Hoebeke (1995). They highlighted studies that showed it was a common species in many areas of the northeast from the 1950s through 1970s. However, they could find only 5 records of *C. novemnotata* in the northeast after 1985. Since 1995, only one specimen (dead when found) has been reported from Virginia (Losey *et al.* 2007). Iowa is typical of most northern states. Intensive surveys of lady beetles in Iowa show that *C. novemnotata* was common and widespread prior to 1980, but is now very rare or extirpated (Hesler 2009). The Lost Ladybug Project has created a significant amount of publicity about lady beetles, increasing the probability that people will notice lady beetles and locate remnant populations of *C. novemnotata* in the northeast United States. For example, this project has documented the occurrence of *C. novemnotata* in Wisconsin, Nebraska, Colorado and Washington from 2007-2009, but none east of Wisconsin.

In summary, in Ontario and Quebec, this once common lady beetle is now rare and has a restricted range, and Acorn (2007) reported similar (though not as dramatic) declines in abundance in Alberta. In British Columbia it was less frequently collected between 1990 and 2010 than in previous decades. On the basis of area of occupancy in the east, and changes in range and changes in relative abundance, the conservation status of this species should be reviewed by COSEWIC. Threats to this and other native species are dealt with in the section on 'Threats to native lady beetle species'.

Transverse lady beetle, *Coccinella transversoguttata richardsoni*

Historically *C. transversoguttata richardsoni*, the transverse lady beetle, occurred in Canada from Newfoundland west to Yukon and Alaska, south of the treeline (Fig. 14, Brown 1962; Gordon 1985). Brown (1962) considered it "very abundant and generally distributed in southern Canada from Newfoundland to the coast ranges". This taxon had a much wider distribution than *C. novemnotata* and was more common in many settled areas where both occurred. In the US, the range extended south to Virginia, Texas, New Mexico, Arizona and northern California. Other subspecies occur in Greenland (*C. t. ephippiatta* Zetterstedt), and in Siberia (*C. t. transversoguttata* Faldermann).

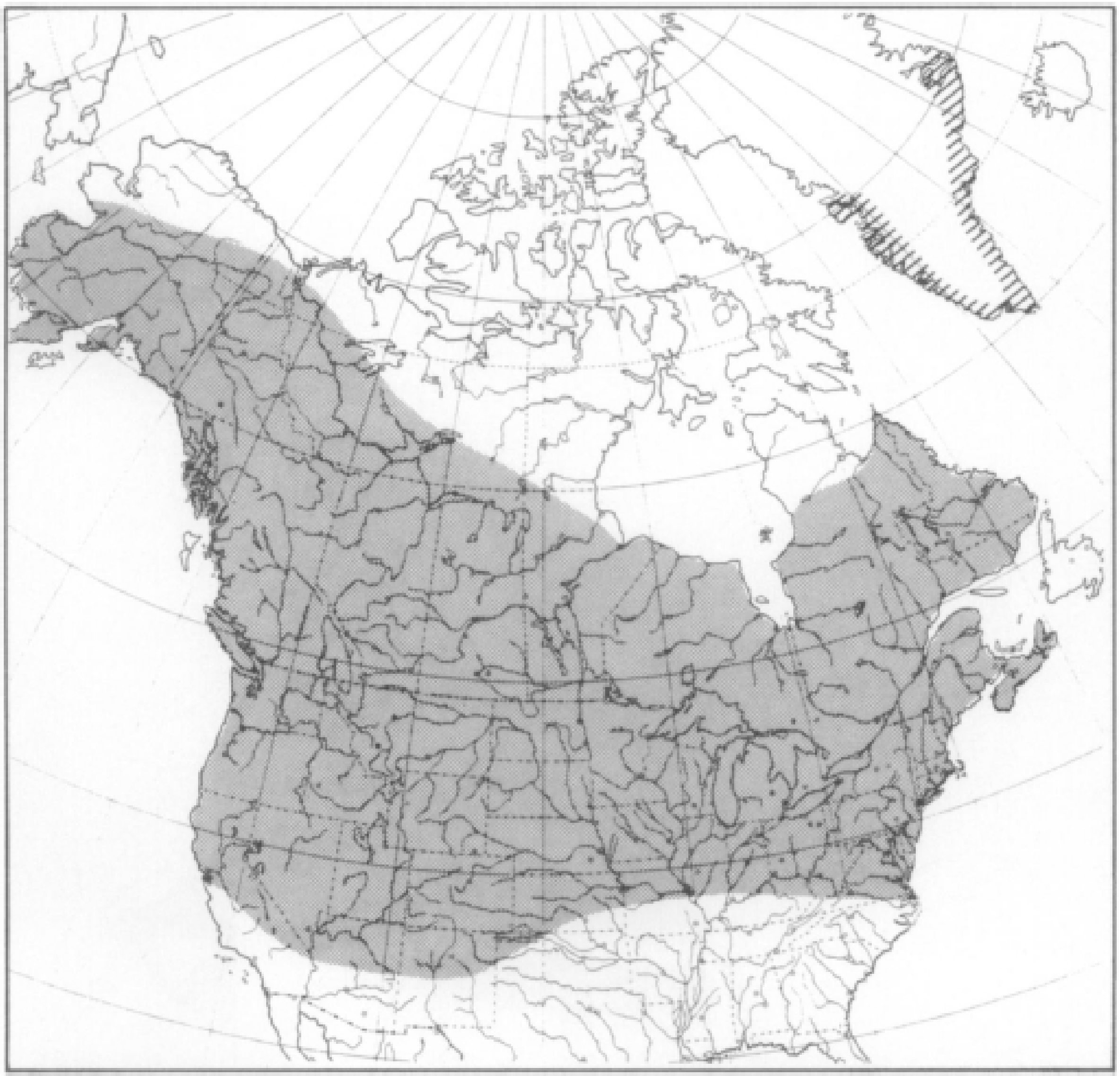


Figure 14. The historic geographic range of *Coccinella transversoguttata richardsoni*, from Gordon (1985). This species also occurs on the island of Newfoundland.

In the three Maritime Provinces *C. t. richardsoni* was common and widespread up until the 1980s (Fig. 3 and see Boiteau 1983). Collection records from the 1950s through the 2000s document a decline in area of occupancy (Fig. 3). The most recently collected specimens in the Maritimes were from near Fredericton, NB in 1994. Between 1995 and 2010, considerable collection effort has improved understanding of the lady beetle fauna of the Maritimes region. During this period, the non-native species, *C. septempunctata*, *Harmonia axyridis* and *P. quatuordecimpunctata* were frequently collected (Figs. 6, 8, 10). Many of the specimens came from the same locations and habitats where *C. t. richardsoni* was found earlier and were accessed from small collections where most specimens were not identified prior to this study. This indicates that collecting effort remained high and the dominance of non-native species is unlikely to be collector bias for novel species.

In southern Ontario and southern Quebec *C. t. richardsoni* declined in relative abundance, from about 25% of all coccinellines prior to 1980 to less than 10% between 1980 and 2010 (Table 3). This decline is significant, though not as striking as that for *C. novemnotata*. Collection records mapped by decade (Fig. 3) show a shrinking area of occupancy that coincides with the decline in relative abundance. Based on museum records for southern Ontario and Quebec, this beetle has not been collected since the mid-1980s and it has apparently disappeared from the settled areas of southern Ontario and Quebec. However, there are records since 2000 from James Bay and Baie Comeau. It has a broad range across the boreal forests of Canada and inadequate sampling in northern Quebec and Ontario means that its status there is unclear.

Change in the status of *C. t. richardsoni* is also striking on a local scale, as can be seen from records (Fig. 15) from the west end of Montreal (Ste Anne de Bellevue and neighbouring suburbs). The Lyman Entomological Museum, (McDonald College of McGill University) has numerous lady beetles from this part of Montreal with collection dates spanning the 20^{th}century. *Coccinella septempunctata* was first collected in the west end of Montreal in 1976 and no *C. t. richardsoni* were collected after 1982. Through the 1980s the number of *C. septempunctata* collected approximately equaled the number of *C. t. richardsoni* collected in the 1960s. These data suggest a decline in *C. t. richardsoni* coincidental with the arrival of *C. septempunctata*. However few *C. t. richardsoni* were collected in the early 1970s, which was prior to the arrival of *C. septempunctata* (Fig. 15). Therefore, these data do not confirm a causative relationship between the arrival of the non-native species and the decline of the native.

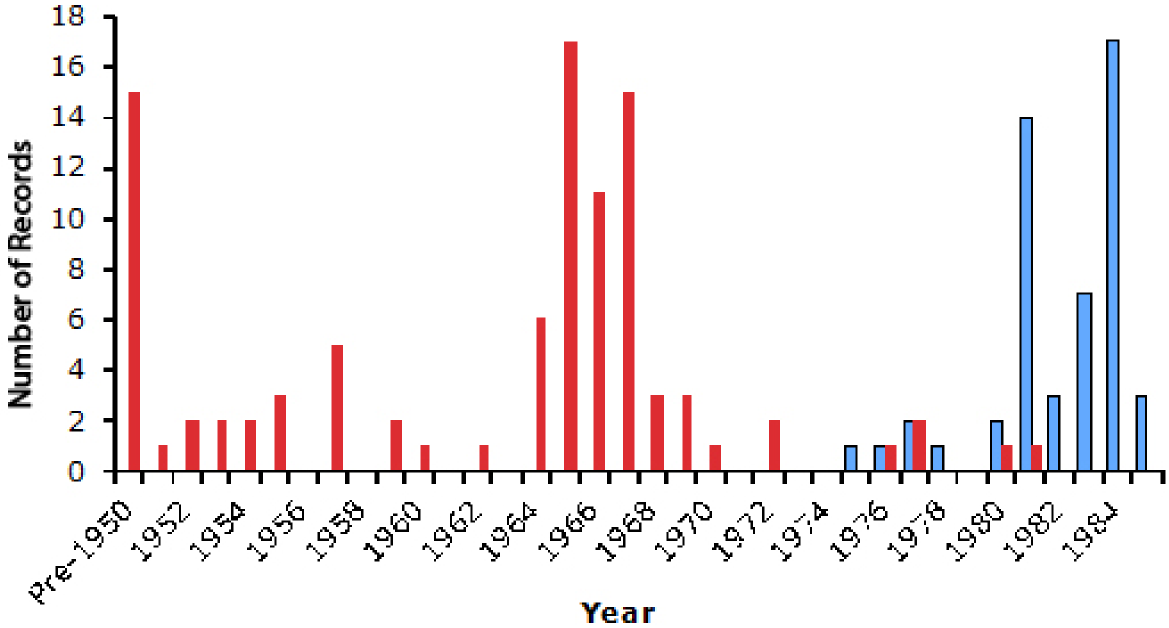


Figure 15. Records of *Coccinella transversoguttata richardsoni* (red bars) and *C. septempunctata* (blue bars) from the west end of Montreal in the Lyman Entomological Museum.

Historically *C. t. richardsoni* was also common in the agricultural areas of southern Manitoba. Turnock *et al.* (2003) sampled lady beetles in crops (sweep nets and visually) and at wash-ups along lakeshores in southern Manitoba from 1982 until 2001 (Fig. 16), providing the only field data that clearly document the arrival of a non-native species and coincident changes in the relative abundance of native species in Canada. The non-native *C. septempunctata* was first recorded in Manitoba in 1988, and *C. t. richardsoni* and *H. parenthesis* both declined following its appearance. In contrast, another native, *Hippodamia tredecimpunctata tibialis*, varied considerably from year to year with no discernible trend (Turnock *et al.* 2003).

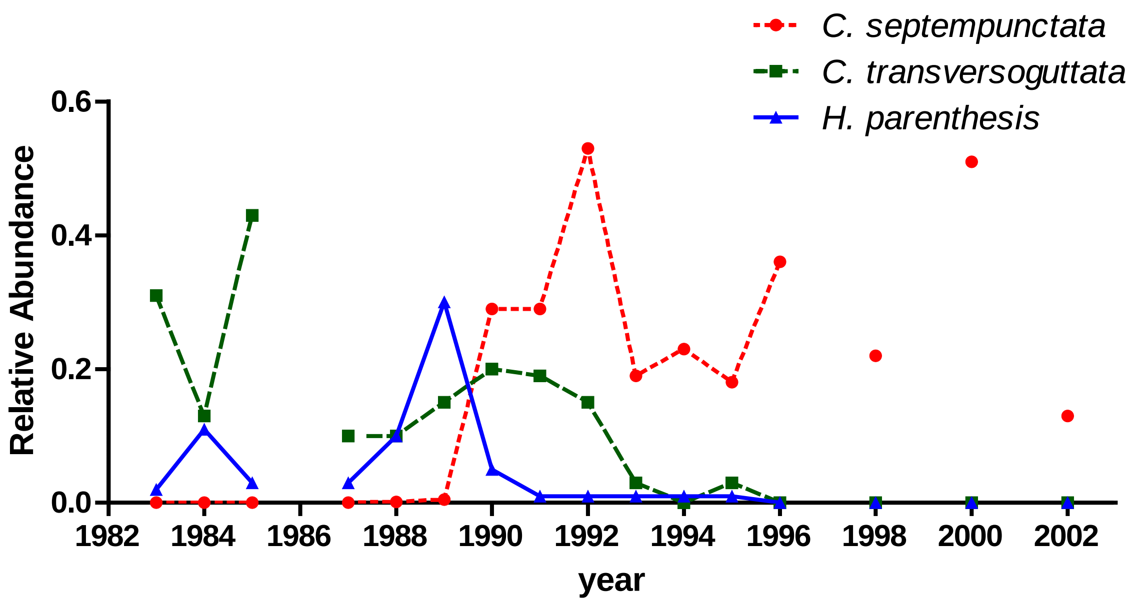


Figure 16. The relative abundances of the native lady beetles, *Coccinella transversoguttata richardsoni* (green dashed line) and *Hippodamia parenthesis* (blue line) and the non-native *C. septempunctata* (red dotted line) in agricultural areas of southern Manitoba from 1982 through 2002. No data were available for 1986, 1997, 1999, and 2001. Adapted from Turnock *et al.* (2003).

Acorn's (2007) summary of the status of *C. t. richardsoni* in Alberta was based on extensive field work as well as review of regional insect collections. In the 1980s, *C. t. richardsoni* was a habitat generalist, found in many open habitats including many human disturbed sites such as agricultural fields and housing developments. This species became less common in the 1990s, and Acorn (2007) suggested that it became a habitat specialist, restricted to areas such as sparsely vegetated sand dunes and slopes in badlands. Acorn (2007) also found some specimens on deciduous seedlings in a recently burned black spruce bog. After its arrival in the mid-1980s, *C. septempunctata* apparently became the common habitat generalist lady beetle in Alberta.

In British Columbia, *C. t. richardsoni* was historically widespread in the interior, sparsely distributed on the lower mainland and absent from Vancouver Island (Brown 1962; Gordon 1985). Several specimens were collected in the southern Okanagan Valley during the 1980s and early 1990s. Based on UBC and the RBCM collections, only a single specimen was collected between 2000 and 2010 (from Creston in 2002). Interestingly, a small, new collection at the University of Northern British Columbia includes several *C. septempunctata* but no specimens of *C. t. richardsoni*.

Elsewhere in Canada, recent records for the transverse lady beetle are sporadic, leading to difficulties in assessing current status. Historically it occurred throughout Saskatchewan, from the northern boreal forest to the southern prairies, through Yukon and the forested portions of the Northwest Territories (Brown 1962; Fig. 14). No collections in Saskatchewan with coccinelline specimens were databased so current patterns have not been assessed for the province. For the north, we have examined records from 2008 for Whitehorse, Yukon, and Henri Goulet (Pers. comm.) collected numerous individuals in Yukon and Alaska in 2009, but the status over all the territories is unclear.

In the northern United States there has been a similar decline in *C. t. richardsoni* as in southern Canada. However this species has not attracted nearly as much attention as *C. novemnotata*. The decline has been best documented in Maine (Alyokhin and Sewell 2004; Finlayson *et al.* 2008) where *C. t. richardsoni* was one of two common lady beetles in agroecosystems in the 1970s. In 2004 and 2005 it was rarely collected, despite intensive sampling of both agricultural and more natural habitats and a sample of more than 2500 lady beetles in both years (Finlayson *et al.* 2008). Hesler (2009) documented a similar decline in Iowa. The Lost Ladybug Project documents records from 2007-2009 of *C. t. richardsoni* in several of the same general locations as *C. novemnotata*, for example Ferry Co. Washington, Nebraska, Colorado and South Dakota.

It is clear that there has been a decrease in geographic range and a decline in relative abundance for *C. t. richardsoni* in the Maritimes, Quebec, Ontario and Alberta, the areas with the most complete data on lady beetle distributions. Common and widely distributed in southern Canada prior to the 1980s, this lady beetle had a restricted range there by the 2000s. However, this species is broadly distributed through the boreal forest from Newfoundland to Yukon and there has been little to no collecting or monitoring in significant portions of this less accessible portion of the historic range. Even so, based on changes in area of occupancy in the east, and changes in range and relative abundance, the conservation status of this species should be reviewed by COSEWIC.

Other Coccinellinae of Potential Conservation Concern

Coccinella novemnotata and *C. t. richardsoni* were chosen for detailed consideration in this report because data from several regions across their wide geographic ranges demonstrated reduction in area of occurrence and decline in relative abundance of both species. There are several other species that may be declining, but supporting data are limited. Most are habitat generalists and would likely be sampled in surveys targeting *C. novemnotata or C. t. richardsoni.* If monitoring programs for *C. novemnotata or C. t. richardsoni* are established, a further six species should also be assessed.

Adalia bipunctata.

The distribution maps and relative abundance by time period (Fig. 5, Table 2) indicate both a declining relative abundance and many fewer localities in southern Ontario and Quebec. Henri Goulet (pers. comm.) has not seen it in eastern Ontario and neighbouring Quebec since before 2000. In Cape Breton, Cormier *et al.* (2000) noted a decline through the 1990s. It is collected annually, but in reduced numbers in most years since 2005. John Acorn (pers. comm.) indicates it has not declined in Alberta.

Hippodamia tredecimpunctata tibialis.

Turnock *et al.* (2003) documented a decline in southern Manitoba. The distribution maps by time period (Fig. 6) indicate both reduced number of locations and shrinking geographic range in eastern Canada.

Hippodamia parenthesis (Say).

Turnock *et al.* (2003) documented a decline in southern Manitoba. It was never a very common species in the Maritimes, but specimens since 2000 are less frequent than expected. This was not one of the target species for the database of this project and therefore data for southern Ontario and Quebec are lacking.

Coccinella monticola.

This is a widespread species from the west coast to the Maritimes, associated with coniferous forests. It was most common in the west whereas in the east it was never common and had a very patchy distribution (Gordon 1985; Acorn 2007; Majka and McCorquodale 2010). John Acorn (pers. comm.) suggested it was another species worthy of monitoring.

Coccinella johnsoni and Coccinella californica.

These two very similar species occur on the southwest mainland and Vancouver Island and can be confused with *C. novemnotata* based on colour patterns on the head, pronotum, and elytra. The similarities among the three, coupled with the overlap in range, cause some confusion with identifications. All three species have been recorded at the same localities on southern Vancouver Island. There are about 400 specimens of the three species in the collections of UBC and RBCM from the 1930s through 1980s. However, since 1990, there are only two specimens of the three species combined: one *C. johnsoni* from 1991 from Bamfield and one *C. californica* from Swishswash Island in 1999. The lack of specimens of large, obvious *Coccinella* for the past two decades indicates a reason to monitor their status.

Threats to native lady beetle species

Because of the coincidence of reported declines in native species with the arrival of non-natives, many workers have emphasized the threats posed by non-native lady beetles (Evans 2004; Snyder and Evans 2006; Kenis *et al.* 2008; Finlayson *et al.* 2008). Others have argued that the role of non-native species in declines of native species may be overstated. For example, changes in land use and pesticides have also been implicated (e.g. Wheeler and Hoebeke 1995; Harmon *et al.* 2007) and other researchers have suggested that the perceived declines may be collecting artifacts. Marshall (2008) argued that the decline in abundance of native species may have been overemphasized because the non-native species are common and therefore easy to collect, drawing attention away from less common native species. Acorn (2007) pointed out that native lady beetle species are still present in Alberta, although there has been a change in the predominant (numerically dominant) species. Acorn also suggested that interpretation of long term patterns might have been obscured by human activities that occurred during lady beetle collection periods, and cites the conservation status of *H. tredecimpunctata tibialis* as an example. As humans altered landscapes during urban and agricultural expansion, *H. tredecimpunctata tibialis* likely used the altered habitats in addition to its “historical” habitat. Since 1935, the species has been found living on lawns, some agricultural crops, and in gardens, where it has been easy to collect. Apparent declines in abundance could have been inferred if recent non-native arrivals replaced *H. tredecimpunctata tibialis* in (well collected) human-altered habitats, even if its distribution and abundance were not altered in its native habitat. Evans (2004) indicated that non-native species such as *C. septempunctata* reduce aphid densities in human-altered habitats and therefore native species do not aggregate in such habitats. If collecting tends to focus on easily accessible human-altered habitats, the perception of native species decline could be accentuated.

Despite these caveats, it is clear from the wide variety of museum and collector types considered in this review that some lady beetle species have declined in abundance and geographical range in Canada. It is also clear that some of the regional declines are coincident with the arrival of non-native species. Two recent reviews on the ecological effects of non-native, generalist arthropod predators (Snyder and Evans 2006; Kenis *et al.* 2008) summarized the mechanisms for threats from non-natives into three categories: direct competition, intraguild predation, and indirect effects through introduction of pathogens.

Competition

The arguments linking the decline of *C. novemnotata* with competition from *C. septempunctata* are based mainly on the coincidence of one species declining as the other is increasing, and there is little or no evidence for direct interactions. For example, the decline of *C. novemnotata* in northeastern North America was not widely recognized until the mid-1990s, almost 20 years after the arrival of *C. septempunctata* (Wheeler and Hoebeke 1995). At that time the most recent records for *C. novemnotata* were from 1980 in Quebec (Skinner and Domaine 2010), 1982 from Ontario (Marshall 1999) and

1990 in Michigan (Maredia *et al.* 1992). It is difficult to conduct field studies on competitive interactions between native and non-native lady beetles, however, when susceptible native species have already declined. Therefore current work comparing competitiveness of non-native versus native species, under varying conditions of food availability, temperature, susceptibility to pathogens and other factors, regularly use native species that have not experienced shrinkage in range or declines in populations (e.g. *Coleomegilla maculata*) (e.g. Lucas *et al.* 2002; Michaud 2002; Cottrell and Shapriro-Ilan 2003; Yasuda *et al.* 2004).

Hodek and Michaud (2008) argued that *C. septempunctata* is a good competitor under a wide variety of conditions. Its plasticity, ability to compete for food, mate, and lay eggs under a variety of conditions, result in it doing well overall, rather than its being the best under a particular set of conditions. However, competition studies between native and non-native lady beetles have produced mixed results. Evans (2000) tested body size as an indication of competition, and found no decrease in adult body size in a number of native species (including *C. t. richardsoni)* after testing with *C. septempunctata*. He reasoned that this could have been the outcome of scramble competition with the non-native species for food, and declines in aphid density have in fact been documented after the arrival of non-native lady beetles (Evans 2004; Alyokhin and Sewell 2004). In the field, these reduced aphid densities could reduce populations of native lady beetle species through competition for limited food, either through direct mortality or migration of the native species from these areas. In a follow-up study in Maine, Finlayson *et al.* (2008) found very few of the once common native lady beetle *C. t. richardsoni*, and numerous non-native lady beetles, no matter what kind of habitat was sampled.

Aphid densities could also be reduced by other aphid predators, parasitoids or parasites, so relationships with lady beetles may be difficult to observe directly. Considerable effort has been invested to find effective biological control agents for pest aphids (e.g. Brewer and Elliott 2004). As an example, soybean aphid, *Aphis glycines* Matsumara, is a pest in North America yet in its native range populations are largely kept in check by a variety of natural enemies and is less frequently a pest (Ragsdale *et al.* 2004, 2007). At least three non-native parasitoid wasps, *Aphelinus albipodus* Hayat and Fatima (Hymenoptera: Aphelinidae), *Lipolexis gracilis* Forster and *Binodoxys communis* (Gahan) (Hymenoptera: Braconidae) have been assessed for effectiveness and potential risks and released in North America (Heimpel *et al.* 2004; Wyckhuys *et al.* 2009). The goal of biological control is to have a suite of predators, so in this example, it would include these non-native wasps, and generalist predators such as the lady beetle *Harmonia axyridis*, and the hemipteran *Orius insidiosus* (Say) (Rutledge *et al.* 2004). It is not clear whether suppressing aphid populations in crops, a recent addition to the food supply of native lady beetles, will influence competitive interactions with non-native lady beetles.

Direct competition may be mediated by landscape level effects. Gardiner *et al.* (2009) surveyed lady beetles in soybean fields from Michigan, Wisconsin, Minnesota and Iowa. The specific habitat was held constant. However the surrounding habitats, the landscape, changed through the study area. They found more native species in soybean fields surrounded by open habitats than in fields surrounded by forested habitats. This meant that in Iowa they found more native species than in Michigan. This work suggests that a better understanding of how habitats are used through a year are important in understanding competitive interactions.

Intraguild predation

Intraguild predation refers to predation on one member of a feeding guild by other members of the same guild. In this situation, the term refers to feeding by non-native lady beetles on the larvae of native lady beetles. The potential of this interaction received more attention with the arrival and spread of the multicoloured Asian lady beetle, *Harmonia axyridis* (Snyder *et al.* 2004; Lucas *et al.* 2007b; Pell *et al.* 2008). *Harmonia axyridis* readily feeds on larvae of herbivorous beetles and lady beetles as well as on aphids. Its success as an aphid predator is linked to its ability to prey on competitors for the aphids as well as the aphids themselves. However, intraguild predation is unlikely to have been a major cause of the declines of native lady beetles in Canada, because in many locations the native species were already scarce by the time this species arrived. For example, the most recent records of *C. novemnotata* and *C. t. richardsoni* in southern Ontario are more than 10 years prior to the arrival of *H. axyridis* in 1994. However, intraguild predation could play a major role in preventing recolonization by native lady beetles. When populations of *H. axyridis* are high, as they are in many agricultural areas of eastern Canada and southern British Columbia, intraguild predation may constrain population increase in native species.

The negative impacts of intraguild predation to native lady beetles and their ability to recolonize habitats have been confirmed in laboratory studies with the non-native lady beetles, *H. axyridis* and *C. septempunctata*. In paired trials, *C. septempunctata* and *H. axyridis* both preyed more on two native species, *Hippodamia convergens* and *C. t. richardsoni*, than the reverse (Snyder *et al.* 2004). In contrast, when the two native species were paired with each other, there was no clear advantage for one species over the other. *Harmonia axyridis* also feeds on larvae of the native *Coleomegilla maculata* in the laboratory (Lucas *et al.* 2007b).

Parasites, parasitoids, pathogens and fungi

Non-native species may also affect native lady beetles indirectly through the introduction of new natural enemies such as parasites and pathogens. Lady beetles are hosts to a variety of parasitoids (e.g. *Dinocampus (Perilitus) coccinellae*, Hymenoptera: Braconidae), fungi (e.g. *Beauveria bassania,* Ascomycota), bacteria (e.g. *Rickettsia* spp.), protozoans (*Tubulinosema hippodamiae*, Microsporidia), and nematodes (*Steinernema* spp.) (Ceryngier and Hodek 1996; Riddick *et al.* 2009; Bjornson *et al.* 2011). Bjornson (2008) demonstrated that *H. convergens* (collected at overwintering sites in California and shipped throughout North America for sale as biological control agents) transfer several natural enemies. Prevalence of microsporidians, eugregarines, a braconid, and the fungus *Verticillium* in the lady beetles ranged from 1-8% of individuals. Since *H. convergens* are sold by the pound (comprising thousands of individuals), it is likely that these natural enemies are released with every release of the lady beetle for biological control. Similarly, the arrival of non-native lady beetle species in North America has probably introduced non-native species of parasites and pathogens, though direct evidence for impacts from these pathogens does not exist. Although the effect of these natural enemies on native lady beetle species is uncertain, it is likely to be detrimental for some. Limited work has been done on the susceptibility of native species of lady beetles to the microsporidians, fungi and male killing bacteria that have arrived in North America. This is partly because there has been little basic work on how the various organisms that live in close association with lady beetles influence different species (Riddick *et al.* 2009).

Habitat change

Harmon *et al.* (2007) pointed out that there is no clear evidence for a cause and effect relationship between the arrival of non-native species and the decline of native species. They argued that other factors, such as habitat change, have also occurred coincidentally with declines in native species and the arrival of non-natives. Most species of lady beetles are associated with plants (and their herbivores) that are found in open areas such as meadows, forest edges, and farmland. After an initial increase in open habitat associated with European settlement in eastern North America in the 1800s (allowing lady beetles to spread and increase in numbers), much marginal farmland was abandoned and reverted to forest, or planted in other types of crops. In southern Quebec and Ontario and in the Maritimes, the conversion of marginally productive farmland to forest began about 1900 and has continued (e.g. Fox and Macenko 1985; Bucknell and Pearson 2007). The changes in land use in Cape Breton are typical of the Maritimes. In 2000 forested land comprised about two thirds of the island, compared to only one third in 1900. The increase in forested land was largely due to abandoned farmland reverting to forest (Browne and Davis 1996; Loo and Ives 2003). The connection to lady beetle populations is that early in the succession from field to forest, abandoned farms would have been good habitat for lady beetles, particularly *C. novemnotata* and *C. t. richardsoni* (see Martin 1966). As the land reverted to forest, there would have been less suitable open habitat for these species. It is possible that populations of *C. novemnotata* and *C. t. richardsoni* were unnaturally high 60-100 years ago because of open areas created by agriculture on marginal farmland. As these farms were abandoned, concurrent population declines would have been noticed by collectors and attributed to other factors.

Summary of threats and interactions

There is a broad coincidence between shrinkage of geographic range and population decline for *C. novemnotata* and *C. t. richardsoni* and the arrival of non-native species such as C. *septempunctata.* A direct causal link is not obvious, though potential mechanisms include direct competition for food, intraguild predation, spread of new parasitoids or pathogens and changing land use resulting in unsuitable habitat. For some factors there is circumstantial evidence of a detrimental effect. For example *Harmonia axyridis* and *C. septempunctata* preyed upon native lady beetles in the laboratory, leading to the inference that intraguild predation in the field could hinder recolonization of a site. New parasitoids and pathogens that could reduce populations of native lady beetles have been shown to be transported with shipments of lady beetles, but more study is needed to determine whether these are affecting native lady beetle populations.

Changes in land use clearly affect populations of native lady beetles, and this factor needs more study to assess potential linkages between land use and species declines, especially in concert with the arrival of non-native lady beetles. The impact of these threats and how they may interact is not clear.

Status of Coccinellinae database for Canada

Collections included

One goal of this project was to archive label data for specimens of Coccinellinae that have been reliably identified in insect collections, to aid in assessing the historical status of Coccinellinae in Canada. Many collections (Appendix I) were visited to identify specimens, or to verify existing identifications and label data (date and location). A database of about 10,000 specimens focused on Ontario and Quebec and the three Maritime provinces was submitted with an interim report to COSEWIC in October 2009. More than 90% of these specimens had a georeference (latitude, longitude in decimal degrees). The remaining specimens, particularly older specimens, lacked collecting locality information that could be georeferenced. Where possible, all specimens of Coccinellinae were databased, but in all collections, the 10 species highlighted earlier in this report were databased (Non-natives: *C. u. undecimpunctata*, *C. septempunctata*, *Propylaea quatuordecimpunctata*, *Hippodamia variegata* and *Harmonia axyridis*; Natives: *Adalia bipunctata*, *C. novemnotata*, *C. transversoguttata richardsoni*, *Coleomegilla maculata* and *Hippodamia tredecimpunctata tibialis*).

Currently the database includes about 24,000 records from a wide variety of collections (Appendix I). Since the 2009 interim report, Ontario and Quebec records for the 10 species from CNC, and all records from the large collections of the Quebec provincial government, Complexe Scientifique du Quebec (including Ministère de l'Agriculture, des Pêcheries et de l'Alimentation du Québec (MAPAQ) et Ressources naturelles et faunes du Quebec) have been added. Several small collections from Atlantic Canada, including three from Newfoundland, have also been added.

Collections to be added

Collaborations with several collections (Appendix I) are ongoing and when the data are available they will be added to the database for this project. There are also several collections that have not been included in this project (Appendix II), either due to time constraints or to difficulty of access. Collaborations with several of these are being pursued where possible, and further collaborations would be welcomed. Some details of these collaborations are shown below.

British Columbia:

Many identifications were verified by D. McCorquodale at the Spencer collection at UBC in November 2010. A database of about 3,000 specimens was provided by Karen Needham and will soon be added to the analysis for this project. Dr. R. Cannings has provided a database of about 2,500 specimens from the Royal British Columbia Museum. Work is continuing to verify some identifications and data will be added when complete.

Alberta:

Alberta collections (e.g. Strickland Museum, University of Alberta, Royal Alberta Museum, Northern Forestry Centre) were databased and reviewed by Acorn (2007) for his book on Alberta lady beetles, but are not included in this report. Acorn's book summarizes the declines in native species in a qualitative way, and future collaboration is anticipated.

Saskatchewan:

Two collections based in Saskatchewan, Agriculture and Agrifood Canada, Saskatoon and University of Saskatchewan were examined by D. McCorquodale in 2007, but not databased. Both collections are curated by retired entomologist Bob Rendell. Little recent material (post 1990) was included in either collection. They are not included in this report because label data are not currently available.

Manitoba:

The two major collections (Wallis Entomology Museum, University of Manitoba and Manitoba Museum) were examined in October 2009 by M. Marriott and D. McCorquodale to verify identifications. The death of Dr. Rob Roughley delayed the transfer of data from the Wallis Museum, but ongoing collaboration with Dr. Terry Galloway and museum technician Dave Holder should result in the availability of these data in the near future. A preliminary spreadsheet was received in early March 2011. It includes several minor details that need to be sorted out before the data can be included in an archived database.

Ontario:

Collaboration with small collections from the University of Western Ontario, Agriculture Canada in Harrow and Algonquin Park is ongoing. These data are anticipated by June 2011.

Quebec:

The collection at the Lyman Entomological Museum was databased in 2006 and is now being georeferenced, and data will be added as they become available. Most significant collections in Quebec were reviewed by Skinner and Domaine (2010). Most of the data are archived at le Ministère des Ressources naturelles et faunes du Quebec. We databased several significant collections and have not pursued the data from three large collections (UQAM, University of Montreal, and Montreal Insectarium) as yet. There are also many important private collections in Quebec, but these had limited accessibility for this project.

Nunavut, Northwest Territories, Yukon Territory:

These regions do not have permanent collections and so we relied on visiting collectors who deposited their northern material in large collections in the south. Lady beetles from the Territories are underrepresented in collections.

Archiving the database

Lady beetles are good candidates for a freely accessible on-line archive with mapping capabilities. The insects are popular, showy, well represented in collections, and fairly straightforward to identify, suggesting that data quality should be high. However, this goal has not been achieved because of difficulties in obtaining high quality data, and difficulties in finding a host for the product that will include a mechanism for maintaining the data and ensuring software compatibility. In this section, we review our attempts to find a mechanism to archive the lady beetle data in a publically accessible format.

<u>Data Quality</u>

Despite our expectation that data on this showy beetle group should be easily available, and relatively easy to database, we found that a surprising number of specimens in collections across the country were unidentified or misidentified. Identifications took more time than anticipated, and resulted in the need to physically visit all collections, rather than relying on data from individual collections. This work is ongoing. A previous attempt at a national on-line lady beetle project with public participation (Canadian Nature Federation) failed, largely because of inaccurate identifications. That project highlighted the importance of having a good quality control filter. Accurate georeferencing, particularly older localities on specimen labels, also took significant time.

On-line hosting

As the data are becoming more complete, two possible avenues for on-line archiving appear possible. The first is to host it through the “Virtual Research Environment” at the University of Prince Edward Island (contact: Mark Leggott, University Librarian). The second is to partner with a group such as CBIF (Canadian Biodiversity Information Facility, Guy Baillargeon), or the new Canadian University Biodiversity Consortium (CANADENSYS, Peter Desmet). Talks with representatives of these latter groups at a GBIF (Global Biodiversity Information Facility) meeting in Guelph, August 2010, generated some interest for a lady beetle project, as detailed below. Unfortunately, there are several hurdles that could limit partnership with these groups.

CBIF, which currently hosts data for other insect groups (e.g. Carabidae, Lepidoptera, *Bombus*), pointed out that additional metadata would be needed in the database (e.g. how data were collected, what percentage of each collection was databased). It is not clear that there are provisions to update with new material from the collections and observers, and there are examples on the website where data are quite dated. Butterfly data in the archive, for example was collected in the late 1990s, and the archive does not include data that has been collected since. Consider the example of the butterfly collection at the Nova Scotia Department of Natural Resources, started in the late 1980s, and added to every year since then. Although this collection is represented on the CBIF website (http://www.cbif.gc.ca/portal/digir-meta.php?p_sourceid=82&p_classid=1&p_lang=en), only records up to 1999 are included. There are also potential problems with software compatibility. CBIF is a digr based platform. Participants at the GBIF meeting in August 2010 focused considerable discussion on the limitations of digr, the next generation of software, and the effort required to transfer data from one platform to another. The resources to frequently upgrade data and computer software are beyond the scope of this project, and would need to be in place before considering public archiving of the data.

The university consortium, CANADENSYS, has a broad mandate and if the consortium grows as anticipated, the lady beetle data would be a valuable addition to their portfolio. Their mission statement is particularly applicable to the lady beetle project:

> *“Biological collections are replete with taxonomic, geographic, temporal, numerical, and historical information. This information is crucial for understanding and properly managing biodiversity and ecosystems, but is often difficult to access. CANADENSYS, operated from the Biodiversity Centre, is a Canada-wide effort to unlock the biodiversity information held in biological collections.”* (http://www.canadensys.net/about)

Several of the major collections that contributed lady beetle data (Lyman Entomological Collection, University of Guelph, Wallis Entomological Museum, Strickland Museum) are partners in the consortium.

A third option is to approach the “Lost Ladybug Project” (http://www.lostladybug.org/) based at Cornell University, Ithaca, New York, to see whether they would be interested in adding a Canadian historical component. They currently have online maps of current sightings, with a quality control filter, across North America.

Long-term Archiving of data

The high quality of this data set makes it valuable for scientific, conservation and management work, but also time consuming and expensive to keep updated. For longer term archives three issues will recur:

1. the ongoing efforts required to adequately filter and check the data.
2. the acquisition of new data and updating of metadata on various collections, monitoring programs and georeferencing data.
3. the resources needed to keep the data available on a web platform as software requirements change.

Any of the above choices would require considerable IT resources to set up and maintain, especially as new records continue to amass. Results from this study make it clear that the web hosting of a dynamic dataset is a project at least as large and complex as amassing the original data. However, we believe that it is still a goal that should be pursued.

Data gaps and ongoing monitoring

Natural history, habitat use and phenology of native species

Acorn (2007) noted the importance of intensive searches and understanding of habitat use by native species in any conservation effort. In the United Kingdom and Europe, specific habitat use is known for most species (e.g. Honek 1985; Hodek and Honek 1996; Majerus and Kearns 1989), but in Canada this type of natural history information is generally lacking. The most useful information for conservation would be data on preferred habitats in the spring, how habitat use changes through the summer and preferred overwintering sites.

Adalia bipunctata is one species for which there is considerable information, but this is because it is a widespread species in both North America and Europe, and most of the information comes from Europe (e.g. Hemptinne and Naisse 1988). Adults overwinter either in houses or in deeply creviced trees. Early in the spring they frequent shrubs and bushes, especially fruit trees in blossom, then when egg laying starts in June, they are found on both herbaceous vegetation and bushes. Through the summer trees and crops are used more frequently than herbaceous vegetation. Throughout the active season many shrubs and bushes are used. In North America the emphasis for this species has been on thermal requirements for development, aiding our understanding of why it is one of the first species to be active in the spring (Obrycki and Tauber 1981). For some species we also know that they prefer one crop over another. For example, *Coleomegilla maculata* is more common in wheat than potato early in the growing season, even though potato beetle larvae are a prime food at this time (Nault and Kennedy 2000). Despite this level of detail, relatively little is known about non-agricultural habitats used by most native lady beetles.

Some of the differences in seasonal habitat choices result from seasonal patterns in their food sources. Aphids vary in their feeding preferences and habitat use through the year (Dixon 1985; Moran 1992). Some species are monophagous (e.g. *Uroleucroncirsii* (Linnaeus) on thistles), others are polyphagous (e.g. *Myzuspersicae* (Sulzer)), while still others feed on one plant in the early season and switch later in the growing season (e.g. soybeans then buckthorn for Soybean aphid, *Aphis glycines*). This interaction of time of year and the habitats of plants that support aphids needs to be integrated in an understanding of their natural history. Therefore, three factors need to be considered when outlining habitat use by lady beetles: time of year, habitat, and facultative responses to changing localities with high concentrations of aphids.
There are also important spatial gaps in our understanding of lady beetle life histories and ecology in natural habitats. In Canada, as elsewhere, most attention has been focused on lady beetles in agricultural systems rather than in less disturbed habitats and information is available for lady beetles associated with specific crops (e.g Wright and Laing 1980) or particular species of lady beetle in agroecosystems (e.g. Bahlai *et al.* 2008; Lucas *et al.* 2007a). For example, there are good data available for occurrence, phenology and flight patterns of lady beetles in potato fields in New Brunswick (Boiteau 1983; Boiteau *et al.* 1999). Studies have also focused on overwintering ecology (e.g. Turnock and Wise 2004) and parasitism (Smith 1960). However, little is known about ecology away from these managed habitats, for example in the in the extensive boreal forest zone.

Currently, the most accessible sources of natural history information on lady beetles are Acorn (2007) and Larochelle (1979). However, additional regional treatments focusing on what is known about identification and natural history in specific habitats and ecozones are needed, since habitat use and phenology will vary from zone to zone. One resource for this sort of information may be local naturalists, who could be guided by information in Acorn (2007) to make and contribute their own observations to a national archive, should it be developed.

Distribution

Although we have a broad-scale understanding of distributions for most species of Coccinellinae in southern Canada, we still lack fine-scale information level even in the settled areas of southern Ontario, Quebec and British Columbia. In reviewing museum specimens, only minor inconsistencies with the maps and descriptions of geographic range in Gordon (1985) were noted. The most obvious was the omission of the Island of Newfoundland as part of the range for widespread native species such as *Adalia bipunctata* and *Hippodamia tredecimpunctata tibialis*. Another inconsistency comes from the use of distributional maps that essentially "connect the dots" between recorded specimen locations, and the assumption of continuous distribution between the points. Lady beetles undertake long distance dispersal flights which can result in individuals being collected outside of their normal range. Some dispersing individual inadvertently land in large bodies of water and the subsequent wash-up along shores of large bodies of water can be an effective way of monitoring regional populations, even if they could also distort understanding of geographic range (Lee 1980; Turnock and Turnock 1979; Hodek *et al.* 1993). Ideally, distribution data should incorporate information on number of records and potential outlier points.

The best overviews of distribution within provinces/regions come from Alberta (Acorn 2007), Larochelle (1979) for Quebec, and Majka and McCorquodale (2006, 2010) for the Maritimes, and the older review of lady beetles in British Columbia (Dobzhansky 1935). In contrast, major gaps remain in our understanding of lady beetle distribution in most of Saskatchewan, the northern parts of boreal forest zone across Canada, and the three northern Territories. The large gap in understanding in the boreal forest is especially problematic because it comprises the bulk of the range of the potentially threatened *C. t. richardsoni*.

A first step towards updating distribution records could be broad encouragement of people to participate in the Lost Lady Beetle Project (http://www.lostladybug.org/). For example, observations of *C. novemnotata* near Calgary in 2009 were reported here. This project allows people to send in sightings, and most importantly, has a quality filter to address the problem of data quality. Photographs are submitted online and identifications are confirmed by experts which should reduce the frequency of misidentifications.

Monitoring

Monitoring methods vary considerably across regions and study goals, so it is important to define the critical components that will lead to quality data on lady beetle populations. A good program should use a variety of methods and at least two spatial scales to give reasonable estimations of lady beetles in an area. Broad scale monitoring across the country can be based on sweep net sampling, visual inspection, sampling wash-ups on the shores of large water bodies and yellow sticky traps. A standardized unit of 100 sweeps in an open habitat, two or three times during the summer, repeated every year, would provide valuable comparable information in specific sites, which can be combined to provide data on broad patterns. The best time to carry out surveys will vary with region, as well with the main study goals of the monitoring projects. Lady beetle specimens can be retained in a collection, or be identified in the field, with a few voucher specimens retained for quality control. Specimens can also be photographed in the field for verification of identification. Photographs can also be used to help assess ecological patterns, providing information on habitat and plant types.

One way to access survey data is to obtain data on “by-catch” from other studies, and researchers in government laboratories can be contacted to ask that they retain lady beetles from on-going insect surveys in crops and forests. For example, crop monitoring for aphids with yellow sticky traps often has lady beetles as by-catch. Interest has been expressed from Agriculture and Agrifood Canada in Harrow, ON and Beaverlodge, AB (D. Gagnier and J. Otani, respectively) to participate in such monitoring programs. The advantage of partnering in these programs would be the accumulation of data on broad geographic scales and over long time periods, since crop and forest surveys often include multiple sites and years. A key component must be easy to use, accurate identification materials and a quality control filter on identifications, or a mechanism where regional partners could assist in identification of specimens

Broad scale monitoring programs can also make use of amateur naturalists, as shown in the previously discussed “Lost Ladybug Project”. This project incorporates a protocol aimed at finding scarce species through broad network of naturalists working in habitats across wide geographical areas. After new populations are found, they could be targeted for study to improve our understanding of habitat use at different times of year, overwintering ecology, interactions with natural enemies and population fluctuations. Functionally, this is what happened in Quebec when *C. novemnotata* was found in 2006, 26 years after the previous record. The Quebec government subsequently targeted monitoring in the area and has been cooperating with local entomologists to better understand the habitat, phenology and other lady beetles in the area (Skinner and Domaine 2010).

Monitoring based on broad scale voluntary programs or on by-catch from targeted insect surveys may both be biased toward human disturbed habitats, where we already have a better understanding of lady beetle populations than in more natural open habitats (Acorn 2007). Therefore, these programs should be supplemented by focused searches in more natural open habitats. In particular, searches for populations of scarce species, such as *C. novemnotata* and *C. t. richardsoni* should be a priority. The broad scale search should involve many people, from the general public to the science community, and the focused study will involve serious students of lady beetles, potentially naturalists clubs, conservation NGOs, graduate students and government species at risk biologists.

Useful templates to review while establishing monitoring programs are the UK ladybird survey (http://www.ladybird-survey.org/monitoring.aspx) and the recent work on bumble bees in the United States (Cameron *et al.* 2011).

CONCLUSIONS

Historical specimen data from a large number of insect collections across Canada provides evidence for precipitous declines in two native lady beetles in eastern Canada and declines in those two species and at least 6 others across Canada since 1980. In some regions, and for some species, these declines are broadly coincident with increases in numbers of non-native species. Declines in both area of occupancy and relative abundance are most obvious in two previously common species, *C. novemnotata* and *C. t. richardsoni*. However, gaps in data on both historical and present day patterns make it difficult to assess many species, including *C. novemnotata* and *C. t. richardsoni*, in the boreal forest region. Reasons for the declines are not clear, but may include some combination of interactions with non-native species and habitat alterations.

Other gaps in our understanding of lady beetles come from gaps in data on natural history, seasonal patterns and habitat use. Although not critical in specifically identifying species of conservation concern, such information helps to understand why species have declined, and are important for predicting conditions for recovery or re-establishment.

LITERATURE CITED

Acorn, J. 2007. Ladybugs of Alberta: Finding the spots and connecting the dots. The University of Alberta Press, Edmonton, Alberta.

Alyokhin, A. and Sewell, G. 2004. Changes in a lady beetle community following the establishment of three alien species. Biological Invasions 6: 463-471.

Bahlai, C.A., Welsman, J.A., MacLeod, E.C., Schaafsma, A.W., Hallett, R.H. and Sears, M.K. 2008. Role of visual and olfactory cues from agricultural hedgerows in the orientation behavior of Multicolored Asian Lady Beetle (Coleoptera: Coccinellidae). Environmental Entomology 37: 973-979.

Belicek, J. 1976. Coccinellidae of western Canada and Alaska with analyses of the transmontane zoogeographic relationships between the fauna of British Columbia and Alberta (Insecta: Coleoptera: Coccinellidae). Quaestiones Entomologicae 12: 283-409.

Bjornson, S. 2008. Natural enemies of the convergent lady beetle, *Hippodamia convergens* Guerin-Meneville: their inadvertent importation and potential significance for augmentative biological control. Biological Control 44: 305-311.

Bjornson, S., Le, J., Saito, T. and Wang, H. 2011. Ultrastructure and molecular characterization of a microsporidium, *Tubulinosema hippodamiae*, from the convergent lady beetle, *Hippodamia convergens* Guérin-Méneville. Journal of Invertebrate Pathology 106: 280-288.

Boiteau, G. 1983. The arthropod community of potato fields in New Brunswick. The Canadian Entomologist 115: 847-853.

Boiteau, G., Bousquet, Y. and Osborn, W.P.L. 1999. Vertical and temporal distribution of Coccinellidae (Coleoptera) in flight over an agricultural landscape. The Canadian Entomologist 131: 269-277.

Brewer, M.J. and Elliott, N.C. 2004. Biological control of cereal aphids in North America and mediating effects of host plant and habitat manipulations. Annual Review of Entomology 49: 219-242.

Brown, W.J. 1940. Notes on the American distribution of some species of Coleoptera common to the European and North American continents. The Canadian Entomologist 72: 65-78.

Brown, W.J. 1962. A revision of the forms of *Coccinella* L., occurring in America north of Mexico (Coleoptera: Coccinellidae). The Canadian Entomologist 94: 785-808.

Brown, W.J. and de Ruette, R. 1962. An annotated list of the Hippodamiini of Northern America, with a key to the genera (Coleoptera: Coccinellidae). The Canadian Entomologist 94: 643-652.

Browne, S. and Davis, D.S. 1996. The Natural History of Nova Scotia. Volume I Topics and Habitats. Nova Scotia Museum and Nimbus Publishing, Halifax, NS.

Bucknell, D. and Pearson, C.J. 2007. A spatial analysis of land-use change and agriculture in eastern Canada. International Journal of Agricultural Sustainability 4: 22-38.

Cameron, S., Lozier, J.D., Strange, J.P., Koch, J.B., Cordes, N., Solter, L.F., and Griswold, T.L. 2011. Patterns of widespread decline in North American bumble bees. Proceedings of the National Academy of Science108: 662-667.

Ceryngier, P. and Hodek, I. 1996. Enemies of the Coccinellidae. In Hodek, I. and A. Honek (eds). Ecology of Coccinellidae. pp 319-350. Kluwer Academic, Dordecht.

Chapin, J.B. and Brou, V.A. 1991. *Harmonia axyridis* (Pallas), the third species of the genus to be found in the United States (Coleoptera: Coccinellidae). Proceedings of the Entomological Society of Washington 93: 630-635.

Coderre, D., Lucas, E. and Gagne, I. 1995. The occurrence of *Harmonia axyridis* (Pallas) (Coleoptera: Coccinellidae) in Canada. The Canadian Entomologist 127: 609-611.

Colunga-Garcia, M. and Gage, S.H. 1998. Arrival, establishment, and habitat use of the multicolored Asian lady beetle (Coleoptera: Coccinellidae) in a Michigan landscape. Environmental Entomology 27: 1574-1580.

Cormier, C.M., Forbes, T.A., Jones, T.A., Morrison, R.D. and McCorquodale, D.B. 2000. Alien invasion: the status of non-native lady beetles (Coleoptera: Coccinellidae) in industrial Cape Breton, Nova Scotia. Northeastern Naturalist 7: 241-247.

Cottrell, D.E. and Shapiro-Ilan, D.I. 2003. Susceptibility of a native and an exotic lady beetle (Coleoptera: Coccinellidae) to *Beauveria bassania*. Journal of Invertebrate Pathology 84: 137-144.

Dixon, A.F.G. 1985. Structure of aphid populations. Annual Review of Entomology 30: 155–174.

Dobzhansky, T. 1935. A list of Coccinellidae of British Columbia. Journal of the New York Entomological Society 43:331-336.

Elith, J., Graham, C.H., Anderson, R.P., Dudik, M., Ferrier, S., Guisan, A., Hijmans, R.J., Huettmann, F., Leathwick, J.R., Lehmann, A., Li, J., Lohmann, L.G., Loiselle, B.A., Manion, G., Moritz, C., Nakamura, M., Nakazawa, Y., Overton, J.M.M., Peterson, A.T., Phillips, S.J., Richardson, K., Scachetti-Pereira, R., Schapire, R.E., Soberon, J., Williams, S., Wisz, M.S. and Zimmermann, N.E. 2006. Novel methods improve prediction of species' distributions from occurrence data. Ecography 29: 129-151.

Elliott, N.C., Kieckhefer,R.W. and Kauffman,W.C. 1996. Effects of an invading coccinellid on native coccinellids in an agricultural landscape. Oecologia 105: 537-544.

Ellis, D.R., Prokrym, D.E. and Adams, R.G. 1999. Exotic lady beetle survey in northeastern United States: *Hippodamia variegata* and *Propylea quatuordecimpunctata* (Coleoptera: Coccinellidae). Entomological News 111: 73-84.

Evans, E.W. 2000. Morphology of invasion: body size patterns associated with establishment of *Coccinella septempunctata* (Coleoptera: Coccinellidae) in western North America. European Journal of Entomology 97: 469–474.

Evans, E.W. 2004. Habitat displacement of North American ladybirds by an introduced species. Ecology 85: 637-647.

Finlayson, C.J., Landry, K.M. and Alyokhin, A.V. 2008. Abundance of native and non-native lady beetles (Coleoptera: Coccinellidae) in different habitats in Maine. Annals of the Entomological Society of America 101: 1078-1087.

Fortin, M-J., Keitt, T.H., Maurer, B.A., Taper, M.L., Kaufman, D.M. and Blackburn, T.M. 2005. Species' geographic ranges and distributional limits: pattern analysis and statistical issues. Oikos 108: 7-17.

Fothergill, K. and Tindall, K.V. 2010. Lady beetle (Coleoptera: Coccinellidae: Coccinellinae) occurrences in southeastern Missouri agricultural systems: differences between 1966 and present. The Coleopterists Bulletin 64: 379-382.

Fox, M.F. and Macenko, S.L. 1985. The agriculture-forest interface: an overview of land use change. Working Paper, Lands Directorate, Environment Canada. No. 38. pp. ix + 132pp.

Gardiner, M.M., Landis, D.A., Gratton, C., Schmidt, N., O'Neal, M., Mueller, E., Chacon, J., Heimpel,G.E. and Difonzo, C.D. 2009. Landscape composition influences patterns of native and exotic lady beetle abundance. Diversity and Distributions 15: 554-564.

Giorgi, J. A., Vandenberg, N. J., McHugh, J.V., Forrester, J.A., Slipinski, A., Miller, K.B., Shapiro, L.R. and Whiting, M.F. 2009. The evolution of food preferences in Coccinellidae. Biological Control 51: 215-231.

Giorgi, A. and Vandenberg, J. 2009. Coccinellidae. Lady beetles, Ladybird beetles, Ladybugs. Version 09 November 2009 (under construction). http://tolweb.org/Coccinellidae/9170/2009.11.09 in The Tree of Life Web Project, http://tolweb.org/

Gordon, R.D. 1985. The Coccinellidae (Coleoptera) of America North of Mexico. Journal of New York Entomological Society 95: 1-912.

Gordon, R.D. and Vandenberg, N. 1991. Field guide to recently introduced species of Coccinellidae (Coleoptera) in North America, with revised key to North America genera of Coccinellini. Proceedings of the Entomological Society of Washington 93: 845-864.

Hagen, K. S. 1962. Biology and ecology of predaceous Coccinellidae. Annual Review of Entomology 7:289-326.

Harmon, J.P., Stephens, E. and Losey, J. 2007. The decline of native coccinellids (Coleoptera: Coccinellidae) in the United States and Canada. Journal of Insect Conservation 11: 85-94.

Heimpel, G.E., Ragsdale, D.W., Venette, R., Hopper, K.R., O'Neil, R.J., Rutledge, C.E. and Wu, Z. 2004. Prospects for importation biological control of the soybean aphid: anticipating potential costs and benefits. Annals of the Entomological Society of America 97: 249-258.

Hemptinne, J-L. and Naisse, J. 1988. lfe cycle of *Adalia bipunctata* (L.) (Col., Coccinellidae) in a temperate country. In Niemczyck, E. and Dixon, A.F.G. (eds.) Ecology and Effectiveness of Aphidophaga, pp. 71-77. SPB Academic Publishing, The Hague, The Netherlands.

Hesler, L.S. 2009. An annotated checklist of the lady beetles (Coleoptera: Coccinellidae) of Iowa, U.S.A. Insecta Mundi 91: 1-10.

Hesler, L.S., Kieckhefer, R.W., and Catangui, M.A. 2004. Surveys and field observations of *Harmonia axyridis* and other Coccinellidae (Coleoptera) in eastern and central South Dakota. Transactions of the American Entomological Society 130: 113-133.

Hesler, L.S. and Kieckhefer, R.W. 2008. Status of exotic and previously common native coccinellids (Coleoptera) in South Dakota landscapes. Journal of the Kansas Entomological Society 81: 29-49.

Hicks, B., Majka, C.G. and Moores, S.P. 2010. *Harmonia axyridis* (Pallas) (Coleoptera: Coccinellidae) found in Newfoundland. The Coleopterists Bulletin 64: 50.

Hodek, I. and Honek, A. 1996.Ecology of Coccinellidae. Kluwer Academic Publishers, Dordecht, The Netherlands.

Hodek, I., Iperti, G, and Hodkova, M. 1993. Long-distance flights in Coccinellidae (Coleoptera). European Journal of Entomology 90: 403-414.

Hodek, I. and Michaud, J.P. 2008. Why is *Coccinella septempunctata* so successful? (A point-of-view). European Journal of Entomology 105: 1-12.

Honek, A. 1985. Habitat preferences of aphidophagous coccinellids [Coleoptera]. Entomophaga 30: 253–264.

Kenis, M., Auger-Rozenberg, M-A., Roques, A., Timms, L., Pere, C., Cock, M.J.W., Settele, J., Augustin, S. and Lopez-Vaamonde, C. 2008. Ecological effects of invasive alien insects. Biological Invasions 11: 21-45

Koch, J.B. and Strange, J.P. 2009. Constructing a species database and historic range maps for North American bumblebees (*Bombus sensu stricto* Latreille) to inform conservation decisions. Uludag Bee Journal 9: 97-108.

Larochelle, A. 1979. Les Coleopteres Coccinellidae du Quebec. Cordulia (Supplement) 10: 1-111.

Lee, R.E. 1980. Aggregation of lady beetles on the shores of lakes (Coleoptera: Coccinellidae). American Midland Naturalist 104: 295-304.

Loo, J. and Ives, N. 2003. The Acadian forest: historical condition and human impacts. The Forestry Chronicle 79: 462-474.

Losey, J., Perlman, J. and Hoebeke, E.R. 2007. Citizen scientist rediscovers rare nine-spotted lady beetle*, Coccinella novemnotata*, in eastern North America. Journal of Insect Conservation 11: 415-417.

Lucas, E. 2005. Intraguild predation among aphidophagous predators. European Journal of Entomology 102: 351-364.

Lucas, E., Gagnon, I. and Coderre, D. 2002. Impact of the arrival of *Harmonia axyridis* on adults of *Coccinella septempunctata* and *Coleomegilla maculata* (Coleoptera: Coccinellidae). European Journal of Entomology 99: 457-463.

Lucas, E., Labrie, G., Vincent, C. and Kovach, J. 2007a. The Multicouloured Asian Ladybird Beetle: Beneficial or nuisance organism? In Vincent, C., Goettel, M. and Lazarovits, G. (eds.), Biological Control: A global perspective. pp 38-52. CABI, London.

Lucas, E., Vincent, C., Labrie, G., Chouinard, G., Fournier, F., Pelletier, F., Bostanian, N.J., Coderre, D., Mignault,M.-P. and Lafountaine, P. 2007b. The multicolored Asian ladybeetle *Harmonia axyridis* (Coleoptera : Coccinellidae) in Quebec agroecosystems ten years after its arrival. European Journal of Entomology 104: 737-743.

Majerus, M.E.N. 1994. Ladybirds. New Naturalist Series, #81. HarperCollins, London. 367 pp.

Majerus, M.E.N. and Kearns, P. 1989. Ladybirds (Naturalists' Handbooks 10). Richmond, Slough, England. 103 pp.

Majka, C. G. and McCorquodale, D.B. 2006. The Coccinellidae (Coleoptera) of the Maritime Provinces of Canada: new records, biogeographical notes, and conservation concerns. Zootaxa 1154: 49-68.

Majka, C.G., and McCorquodale, D.B. 2010. Ladybird beetles (Coleoptera: Coccinellidae) of the Atlantic Maritime Ecozone.Chapter 21. In D.F. McAlpine and I.M. Smith (eds). Assessment of Species Diversity in the Atlantic Maritime Ecozone. pp 439-452. NRC Research Press, Ottawa, Canada.

Maredia, K.M., Gage, S.H., Landis, D.A. and Wirth, T.M. 1992. Ecological observations on predatory Coccinellidae (Coleoptera) in southern Michigan. The Great Lakes Entomologist 25: 265-270.

Marshall, S. 1999. Alien invasions, Ontario's ever changing bug landscape. Seasons. Spring 1999: 26-29.

Marshall, S. 2008. Lady beetles of Ontario. Retrieved December, 2008, from http://www.uoguelph.ca/debu/lady/lady-beetles.htm.

Martin, J.L. 1966. The Insect Ecology of Red Pine Plantations in Central Ontario IV.The Crown Fauna. The Canadian Entomologist 98: 10-27.

Marriott, S.M, Giberson, D.J. and McCorquodale, D.B. 2009. Changes in the status and geographic ranges of Canadian Lady Beetles (Coccinellidae) and the selection of candidates for risk assessment. Part I Foundation Report. Report to COSEWIC Arthropods Species Specialist Committee. 53 pp.

Matheson, F.O. 1989. *Coccinella septempunctata* (L.) in Manitoba. Biocontrol News 2:1. Agriculture Canada. Ottawa.

McCorquodale, D.B. 1998. Adventive lady beetles (Coleoptera: Coccinellidae) in eastern Nova Scotia, Canada. Entomological News 109: 15-20.

McNamara, J. 1991. Family Coccinellidae (lady beetles). Retrieved July, 2008, from http://www.canacoll.org/Coleo/Checklist/checklist.htm.

Michaud, J.P. 2002. Invasion of the Florida citrus ecosystem by *Harmonia axyridis* (Coleoptera: Coccinellidae) and asymmetric competition with a native species, *Cycloneda sanguinea*. Environmental Entomology 31: 827-835.

Moran, N. 1992. The evolution of aphid life cycles. Annual Review of Entomology 37: 321- 348.

Nault, B.A. and Kennedy, G.G. 2000. Seasonal changes in habitat preference by *Coleomegilla macaulata*: Implications for Colorado potato beetle management in potato. Biological Control 17: 164-173.

New, T. R. 1995. Introduction to Invertebrate Conservation Biology. Oxford University Press, New York. 194pp.

Obrycki, J.J., Elliott, N.C. and Giles, K.L. 2000. Coccinellid introductions: potential for and evaluation of non-target effects, In Follet, P.A. and Duan, J.J. (Eds.) Nontarget Effects of Biological Control. Dordrecht, Netherlands; Kluwer. pp. 127-145.

Obrycki, J.J., Harwood, J.D., Kring, T.J. and O'Neil, R.J. 2009. Aphidophagy by Coccinellidae: application of biological control in agroecosystems. Biological Control 51: SI244-SI254.

Obrycki, J.J. and Kring, T.J. 1998. Predaceous Coccinellidae in biological control. Annual Review of Entomology 43: 295-321.

Obrycki, J.J. and Tauber, M.J. 1981. Phenology of three coccinellid species: thermal requirements for development. Annals of the Entomological Society of America 74: 31-36.

Pell, J.K., Baverstock, J., Roy, H.E., Ware, R.L. and Majerus, M.E.N. 2008. Intraguild predation involving *Harmonia axyridis*: a review of current knowledge and future perspectives. BioControl 53: 147-168.

Ragsdale, D.W., McCornack, R.P., Venette, R.C., Potter, B.D., MacRae, I.V., Hodgson, E.W., O'Neal, M.E., Johnson, K.D., O'Neil, R.J., Difonzo, C.D., Hunt, T.E., Glogoza, P.A. and Cullen, E.M. 2007. Economic threshold for soybean aphid (Hemiptera: Aphididae). Journal of Economic Entomology 100: 1258-1267.

Ragsdale, D.W., Voegtlin, D.J. and O'Neil, R.J. 2004. Soybean aphid biology in North America. Annals of the Entomological Society of America 97: 204-208.

Riddick, E.W., Cottrell, T.E. and Kidd, K.A. 2009. Natural enemies of the Coccinellidae: Parasites, pathogens, and parasitoids. Biological Control 51: 306-312.

Rutledge, C.E., O'Neil, R.J., Fox, T.B. and Landis, D.A. 2004. Soybean aphid predators and their use in integrated pest management. Annals of the Entomological Society of America. 97: 240-248.

Schaeffer, C. 1912. *Coccinella undecimpunctata* Linn. in Massachusetts. Psyche 19: 104-105.

Skinner, B. and Domaine, E. 2010. Rapport sur la situation de la cocinnelle a neuf points (*Coccinella novemnotata*) au Quebec. Pour le Ministère des Ressources naturelles et de la Faune. Faune Québec. 37 pp.

Sloggett, J.J. and Majerus, M.E.N. 2000. Habitat preferences and diet in the predatory Coccinellidae (Coleoptera): an evolutionary perspective. Biological Journal of the Linnaean Society 70: 63-88.

Smith, B.C. 1960. Note on parasitism of two Cocclnellids, *Coccinella trifasciata perplexa* Muls. and *Coleomegilla maculate lengi* Timb. (Coleoptera: Coccinellidae) in Ontario. The Canadian Entomologist 92: 652.

Snyder, W.E., Clevenger, G.M. and Eigenbrode, S.D. 2004. Intraguild predation and successful invasion by introduced ladybird beetles. Oecologia 140: 559-565.

Snyder, W.E. and Evans, E.W. 2006. Ecological effects of invasive arthropod generalist predators. Annual Review of Ecology, Evolution and Systematics 37: 95-122.

Turnock, W.J. and Turnock, R.W. 1979. Aggregations of lady beetles (Coleoptera: Coccinellidae) on the shores of Lake Manitoba. Manitoba Entomologist 13: 21-22.

Turnock, W.J. and Wise, I.L. 2004. Density and survival of lady beetles (Coccinellidae) in overwintering sites in Manitoba. Canadian Field Naturalist 118: 309-317.

Turnock, W.J., Wise,I.L. and Matheson,F.O. 2003. Abundance of some native coccinellines (Coleoptera: Coccinellidae) before and after the appearance of *Coccinella septempunctata*. The Canadian Entomologist 135: 391–404.

Vandenberg, N. J. 2002. 93. Coccinellidae Latreille 1807. In Arnett, R.H., Thomas, M.C., Skelley, P.E. and Frank, J.H. American Beetles, Volume 2 Polyphaga: Scarabaeoidea through Curculionoidea, pp.371-389. CRC Press, Boca Raton, FL. 861pp.

Watson, W.Y. 1956. A study of the phylogeny of the genera of the tribe Coccinellini (Coleoptera).Contributions of the Royal Ontario Museum Life Sciences Division.42: 1-52.

Watson, W.Y. 1976. A review of the genus *Anatis* Mulsant (Coleoptera: Coccinellidae). The Canadian Entomologist 108: 935-944.

Watson, W.Y. 1979. North American distribution of *Coccinella u. undecimpunctata* L. (Coleoptera: Coccinellidae). The Coleopterists Bulletin 33: 85-86.

Wheeler, Jr., A.G. and Hoebeke, E.R. 1995. *Coccinella novemnotata* in northeastern North America: historical occurrence and current status (Coleoptera: Coccinellidae). Proceedings of the Entomological Society of Washington 97: 701-716.

Wheeler, Jr., A.G. and Hoebeke, E.R. 2008. Rise and fall of an immigrant lady beetle: Is *Coccinella u. undecimpunctata* L. (Coleoptera: Coccinellidae) still present in North America? Proceedings of the Entomological Society of Washington 110: 817-823.

Wheeler, Jr., A.G. and Stoops, C.A. 1996. Status and spread of the Palaearctic lady beetles *Hippodamia variegata* and *Propylea quatuordecimpunctata* (Coleoptera: Coccinellidae) in Pennsylvania, 1993-1995. Entomological News 107: 291-298.

Wiggins, G.B., Marshall, S.A. and Downes, J.A. 1991. The importance of research collections of terrestrial arthropods. Brief for the Biological Survey of Canada (Terrestrial Arthropods). http://www.biology.ualberta.ca/bsc/briefs/brimportance.htm

Wise, I.L., Turnock, W.J. and Roughley, R.E. 2001. New records of coccinellid species for the province of Manitoba. Proceedings of the Entomological Society of Manitoba 57: 5-10.

Wright, E.J. and Laing, J. 1980. Numerical response of coccinellids to aphids in corn in southern Ontario. The Canadian Entomologist 112: 977-988.

Wyckhuys, K.A.G., Koch, R.L., Kula, R.R. and Heimpel, G.E. 2009. Potential exposure of a classical biological control agent of the soybean aphid, *Aphis glycines*, on non-target aphids in North America. Biological Invasions 11: 857-871.

Yasuda, H., Evans, E.W., Kajita, Y., Urakawa, K. and Takizawa T. 2004. Asymmetric larval interactions between introduced and indigenous ladybirds in North America. Oecologia 141: 722-731.

EDITORIAL NOTES

Prepared by David McCorquodale and Donna Giberson, based on collaborative work with M.Sc. candidate Meghan Marriott.

Thank you to John Acorn for permission to use his lady beetle photographs on cover page.

The collaboration and support of entomologists across the country was essential. Our gratitude and thanks to all curators, technicians, and students who provided access to collections, answered questions about lady beetles, databases, and locations and provided hospitality.

Thank you to COSEWIC for a non-traditional contract and to Monique Goit and Paul Catling for support and patience. The reviews and comments from the reviewers for COSEWIC, John Acorn, Robb Bennett, Henri Goulet, and Colin Jones were valuable and improved the report.

Contact information

David B. McCorquodale, Department of Biology, Cape Breton University, Sydney, NS B1P 6L2.

Donna J. GIberson, Department of Biology, University of Prince Edward Island, Charlottetown, PE C1A 4P3.

Appendix I: Insect collections in Canada, Coccinellinae databased

Province	Institution	Contact	Notes
British Columbia	George J. Spencer Entomological Museum, University of British Columbia	Karen Needham	Databased about 2,500 specimens to be added.
British Columbia	University of Northern British Columbia	Steffan Lindgren lindgren@unbc.ca	Identified by DBMcC Dec. 2010, database being completed (about 25 specimens).
British Columbia	Royal British Columbia Museum	Robert Cannings	Databased (about 3,000 specimens), some identifications need to be checked before being added.
Alberta	Royal Alberta Museum	Tyler Cobb	Coccinellines reviewed by Acorn (2007), not in database.
Alberta	E.H. Strickland Entomological Museum	Danny Shpeley Felix Sperling John Acorn	Coccinellines reviewed by Acorn (2007), not in database.
Alberta	Northern Forestry Research Collection	Greg Pohl	Coccinellines reviewed by Acorn (2007), not in database.
Manitoba	J.B. Wallis Entomological Museum, University of Manitoba	Terry Galloway Dave Holder	Databased (>1000 specimens). Identifications confirmed October 2009 by Marriott and DBMcC. Working with D. Holder to get database.
Manitoba	The Manitoba Museum, 190 Rupert Avenue,Winnipeg, MB R3B 0N2	Randall D. Mooi, Curator of Zoology	Identifications done October 2009 by Marriott and DBMcC (<100 specimens). Working to complete database
Ontario	Canadian Museum of Nature	Robert Anderson	335 specimens for 10 species Databased by M.Marriott, November 2008
Ontario	CFS Great Lakes Forestry Centre	Kathryn Nystrom	1343 specimens, all species.Marriott databased, May 2009.
Ontario	Canadian National Collection of Insects	Patrice Bouchard	8172 specimens 10 species databased for ON, QC, all species for NB, NS, PE, NL. Partial database for western material. Most databased by CNC with assistance from Marriott and DBMcC for Ontario east. Partially databased for Manitoba west by Roughley and DBMcC.
Ontario	University of Guelph	S.A. Marshall	5118 specimens for 13 species Databased by M. Marriott, November 2008 and May 2009.
Ontario	Royal Ontario Museum	Doug Currie Brad Hubley, Collection Manager	1246 specimens for 10 species Databased by M. Marriott, November 2008.

Province	Institution	Contact	Notes
Ontario	University of Western Ontario	Sarah Lee sarahlee@uwo.ca	Identified and databased by DBMcC, about 400 specimens will be added.
Quebec	Complexe Scientifique du Quebec	Céline Piché Michele Roy	1646 specimens all species. Databased by MAPAQ with assistance from Marriott, April 2009. (Including Ministère de l'Agriculture, des Pêcheries et de l'Alimentation du Québec (MAPAQ) et Ressources naturelles et faunes du Quebec)
Quebec	René Martineau Insectarium, Laurentian Forestry Centre, St Foy	Jan Klimaczewski	444 specimens all species. Databased, identifications confirmed by Marriott, April 2009
Quebec	Laval University	Conrad Cloutier,	710 specimens for 10 species. Databased by Marriott April 2009.
Quebec	Lyman Entomological Museum, McDonald Campus, McGill University	Terry Wheeler, Stephanie Boucher	Databased by McCorquodale and MacDonald (>1000 specimens) 2006, still to be added.
New Brunswick	Atlantic Forestry Centre, Fredericton, NB	Jon Sweeney Ed Hurley	538 specimens all species. Databased by M. Marriott, August 2008
New Brunswick	University of New Brunswick, Forestry	Dan Quiring	324 specimens all species. McCorquodale, 2007.
New Brunswick	New Brunswick Museum	Don McAlpine	282 specimens all species Databased by NBM and identifications confirmed by McCorquodale and Doucet, April 2009.
New Brunswick	Université de Moncton	Gaetan Moreau, Pauline Duerr	173 specimens all species. Databased by Majka and Doucet, April 2009..
Nova Scotia	St. Francis Xavier University	Randy Lauff	51 specimens all species. Databased by Majka
Nova Scotia	Acadia University	Soren Bondrup-Nielsen	85 specimens all species.
Nova Scotia	Nova Scotia Agriculture & Agri-Food Canada – Kentville	Peter Hicklenton peter.hicklenton@agr.gc.ca	148 specimens all species.
Nova Scotia	Nova Scotia Department of Natural Resources – Shubenacadie	Jeff Ogden	222 specimens all species, updated Marriott April 2009
Nova Scotia	Nova Scotia Agricultural College	Chris Cutler	331 specimens all species
Nova Scotia	Nova Scotia Museum of Natural History	Andrew Hebda, Curator of Zoology	Databased by NS Museum, identifications confirmed by Majka and McCorquodale (323 specimens all species).
Prince Edward Island	Agriculture & Agri-Food Canada - Charlottetown	Christine Noronha Mary Smith	66 specimens all species

Province	Institution	Contact	Notes
Prince Edward Island	University of Prince Edward Island, Charlottetown PE	Donna Giberson	441 specimens all species by Marriott.
Newfound-land	Memorial University of Newfoundland, St. John's, NL	David Langor	170 specimens all species. Collection is currently in Edmonton, AB.
Newfound-land	Newfoundland Insectarium 2 Bonne Bay Road Reidville, NL A8A 2V1	Lloyd Hollet	7 specimens all species, Marriott August 2009.
Newfound-land	AAFC St John's, NL	Peggy Dixon	250 specimens, all species by Marriott August 2009.
Newfound-land	Atlantic Forestry Service, Corner Brook Office, University Dr. Corner Brook, NL A2H 6J3	Lucie Royer	138 specimens, all species by Marriott August 2009.

Appendix II: Insect collections in Canada Coccinellinae still to be databased

Province	Institution	Contact	Notes
British Columbia	Pacific Forestry Centre Arthropod Collection	Lee Humble	Mostly databased, status of identifications needs to be checked.
British Columbia	University of Victoria	Neville Winchester	Not contacted
Alberta	Waterton Lakes National Park	Cyndi Smith	Not contacted.
Alberta	Lethbridge Research Centre	Tracy Dickinson	Not contacted.
Saskatchewan	Agriculture & Agri-Foods Canada – Saskatoon	Bob Randell (retd)	Overview of collection by DBMcC (<100 specimens) in October 2007, not databased.
Saskatchewan	University of Saskatchewan	Bob Randell (retd)	Overview of collection by DBMcC (<100 specimens) in October 2007, not databased.
Saskatchewan	PFRA Shelterbelt Centre	Don Reynard	Not contacted yet.
Saskatchewan	Royal Saskatchewan Museum	Keith Roney	Not contacted yet.
Ontario	Algonquin Park Visitor Centre	Justin Peter	½ drawer from Algonquin Park. (< 100 specimens).
Ontario	Carleton University	Joyce Cook	Identified, not databased. (< 100 specimens).
Ontario	York University	Laurence Packer	Not contacted.
Quebec	Université du Québec a Montréal	Timothy Work	Not contacted.
Quebec	Collection de l'Insectarium de Montréal (collection Firmin-Laliberté)	Stéphane LeTirant René Limoges.	Not contacted.
Quebec	Collection Ouellet-Robert de l'Université de Montréal	Louise Cloutier	Not contacted.
Quebec	Collection de Claude Chantal	Claude Chantal	Not contacted.
New Brunswick	Agriculture & Agri-Food Canada – Fredericton	Gilles Boiteau	Not contacted. Significant data on lady beetles published by Boiteau.

Appendix III: People with significant expertise on Coccinellinae in Canada

British Columbia:

Heron, Jennifer, Invertebrate *Species at Risk* Specialist, British Columbia Ministry of Environment, Vancouver, BC

Humble, Lee, Canadian Forest Service, Victoria, BC

Thormin, Terry, Comox, BC

Alberta:

Acorn, John, Department of Renewable Resources, University of Alberta, Edmonton, AB T6G 2E9

Manitoba:

Ontario:

Gagnier, Dana, Agriculture and Agri-Food Canada, Harrow Research Station, Harrow, ON.

Goulet, Henri, Canadian National Collection of Insects, K.W. Neatby Bldg. 960 Carling Avenue, Ottawa, OntarioK 1A 0C6

Lesage, Laurent, Canadian National Collection of Insects, K.W. Neatby Bldg. 960 Carling Avenue, Ottawa, OntarioK1A 0C6

Leplante, Serge, Canadian National Collection of Insects, K.W. Neatby Bldg. 960 Carling Avenue, Ottawa, OntarioK1A 0C6

Marshall, Stephen, Department of Environmental Biology, University of Guelph, Guelph, ON.

Pratt, Paul, Ojibway Prairie Centre, Windsor, ON

Quebec:

Chantal, Claude

Coderre, Daniel, University of Quebec at Montreal, Montreal, QC

Domaine, Eric, BPHenvironnement, 6490 Rue du Griffon app 1, Québec, QC G2J 1N5

Lucas, Eric, Department des Sciences Biologiques, Universite du Quebec a Montreal, Montreal, QC H3C 3P8

Labrie, Genevieve, Department des Sciences Biologiques, Universite du Quebec a Montreal, Montreal, QC H3C 3P8

Piché, Céline, Ministère de l'Agriculture, des Pêcheries et de l'Alimentation, Sainte-Foy, QuébecG1H 1R2

Skinner, Brian.

Roy, Michele, Ministère de l'Agriculture, des Pêcheries et de l'Alimentation, Sainte-Foy, Québec G1H 1R2

<u>Maritimes:</u>

Doucet, Denis, Pellerin, NB ddodeguy57@gmail.com

Giberson, Donna, Department of Biology, University of Prince Edward Island, Charlottetown, PE

Majka, Christopher, Nova Scotia Museum, 1747 Summer St., Halifax, NS

Marriott, Meghan, M.Sc. candidate Department of Biology, University of Prince Edward Island, Charlottetown, PE

McCorquodale, David, Department of Biology, Cape Breton University, Sydney, NS B1P 6L2