COSEWIC
Assessment and Status Report

on the

Nine-spotted Lady Beetle
Coccinella novemnotata

in Canada

ENDANGERED
2016

COSEWIC
Committee on the Status
of Endangered Wildlife
in Canada

COSEPAC
Comité sur la situation
des espèces en péril
au Canada

COSEWIC status reports are working documents used in assigning the status of wildlife species suspected of being at risk. This report may be cited as follows:

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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: ec.cosepac-cosewic.ec@canada.ca
http://www.cosewic.gc.ca

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Nine-spotted Lady Beetle — Photo by John Acorn.

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COSEWIC
Assessment Summary

Assessment Summary – May 2016

Common name
Nine-spotted Lady Beetle

Scientific name
Coccinella novemnotata

Status
Endangered

Reason for designation
This species was once common and broadly distributed through southern Canada, from Vancouver Island through the prairies to southern Québec. It has since declined significantly and is now rarely seen. Despite targeted search efforts over the last decade, the species has decreased in abundance relative to other lady beetle species. Specific causes of the decline are unknown. Possible threats include introduction of non-native lady beetles, which could affect this native species through competition, intraguild predation, or introduction of pathogens. Other possible threats include decline in habitat quality through indirect effects of pesticide/chemical use associated with agriculture to control their prey species, urban expansion, and, abandonment and subsequent natural succession of farmland.

Occurrence
British Columbia, Alberta, Saskatchewan, Manitoba, Ontario, Quebec

Status history
Designated Endangered in April 2016.

COSEWIC
Executive Summary

Nine-spotted Lady Beetle
Coccinella novemnotata

Wildlife Species Description and Significance

The Nine-spotted Lady Beetle (*Coccinella novemnotata* Herbst) is a small beetle (4.7 – 7.0 mm) that is native to North America. Adults are readily identifiable by external morphological features: their wing covers are pale orange to red, with a dark line where the two wing covers meet. They generally have nine black spots on their wing covers, but the size and number of these spots can vary. Furthermore, the head and pronotum are black with white markings. This charismatic species was once one of the more common and widespread lady beetles in North America, playing an important role as a biological control agent of aphids and other insect pests.

Distribution

The Nine-spotted Lady Beetle is a wide-ranging species occurring throughout most of southern Canada with a range that extends along the international border from Vancouver Island to southern Quebec; with northern range limits near: Quesnel, British Columbia; Edmonton, Alberta; Lake Athabasca, Saskatchewan and Roberval, Quebec. The Nine-spotted Lady Beetle also ranges across the continental United States southwards almost to the Mexican border.

Habitat

Nine-spotted Lady Beetles are habitat generalists, known to consume a wide variety of prey across a wide range of habitats. They occur within agricultural areas, suburban gardens, parks, coniferous forests, deciduous forests, prairie grasslands, meadows, riparian areas and isolated natural areas. This broad habitat range reflects their ability to exploit seasonal changes in prey availability across different vegetation types.

Biology

Nine-spotted Lady Beetles have four life stages: egg, larva, pupa and adult, and can have two generations per year. Adults of the spring generation can undergo aestivation to avoid high summer temperatures and lay eggs in early autumn. Adults of the autumn generation congregate over winter and undergo diapause; becoming active and reproducing when temperatures warm in the early spring. This species occupies a wide ecological niche across a wide variety of habitats and temperature regimes in Canada.

Little is known on the natural dispersal rates for the Nine-spotted Lady Beetle. In general, lady beetles are very mobile, display low site fidelity, and readily engage in short- and long-distance dispersal. Drivers of dispersal are a combination of prey density and environmental variables such as temperature, wind speed and rainfall. This species does not migrate. Both adult and larval stages are predatory and prey primarily on aphids. In turn, this species is also subject to predation by introduced lady beetles, other invertebrates and vertebrates, and susceptible to parasitoids and pathogens.

Population Sizes and Trends

The historically broad geographic range and prominence of the Nine-spotted Lady Beetle stands in stark contrast to its current distribution. Prior to 1975, this species was widely distributed across North America and was one of the more common lady beetles collected. This species has since declined and is rarely collected despite targeted searches. Over the last decade the Nine-spotted Lady Beetle has continued to decrease in relative abundance when compared to other lady beetles.

Threats and Limiting Factors

The specific causes of decline in the Nine-spotted Lady Beetle are unknown. Possible threats to this species include negative interactions with recently arrived non-native species, such as the Seven-spotted Lady Beetle and the Multi-coloured Asian Lady Beetle, through competition, intraguild predation or indirect effects through the introduction of pathogens. Other possible threats include direct and indirect effects of pesticide/chemical use associated with agriculture to control their main prey species aphids, and habitat loss through urban expansion, abandonment of farmland, and other human disturbances.

Protection, Status and Ranks

There are no laws in Canada that protect the Nine-spotted Lady Beetle, its residence or habitat. The NatureServe global conservation status rank is G2 (imperilled). The species has not been assigned a conservation status rank in Canadian provinces or territories. However, while this species is not currently listed in Québec, it is likely to be designated Threatened or Vulnerable in that province.

TECHNICAL SUMMARY

Coccinella novemnotata

Nine-spotted Lady Beetle

Coccinelle à neuf points

Range of occurrence in Canada: British Columbia, Alberta, Saskatchewan, Manitoba, Ontario, Quebec

Demographic Information

Generation time	Two generations per year.
Is there an [observed, inferred, or projected] continuing decline in number of mature individuals?	Yes. Inferred continuing decline based on lower relative abundance and failure to detect species at sites where it was formerly common.
Estimated percent of continuing decline in total number of mature individuals within [5 years or 2 generations]	Unknown.
[Observed, estimated, inferred, or suspected] percent [reduction or increase] in total number of mature individuals over the last [10 years, or 3 generations].	Yes. Inferred 70% reduction from 1995 – 2004 to 2005 – 2014 based on relative abundance of all (native and non-native) lady beetles collected. Inferred 62% reduction from 1995 – 2004 to 2005 – 2014 based on relative abundance of only native lady beetles collected.
[Projected or suspected] percent [reduction or increase] in total number of mature individuals over the next [10 years, or 3 generations].	Unknown.
[Observed, estimated, inferred, or suspected] percent [reduction or increase] in total number of mature individuals over any [10 years, or 3 generations] period, over a time period including both the past and the future.	Unknown.
Are the causes of the decline a) clearly reversible and b) understood and c) ceased?	a. Not clearly reversible. b. Not clearly understood. However, non-native lady beetle species are suspected to have played a role in declines. c. Unknown.
Are there extreme fluctuations in number of mature individuals?	No.

Extent and Occupancy Information

Estimated extent of occurrence (EOO) 3,253,910 km^2 (1897 – 2014). 559,510 km^2 (1995 – 2004).	716,847 km^2 (2005 – 2014).
Index of area of occupancy (IAO) (Always report 2x2 grid value). 1,308 km^2 (1897 – 2014). 64 km^2 (1995 – 2004).	40 km^2 (2005 – 2014).
Is the population "severely fragmented" i.e., is >50% of its total area of occupancy in habitat patches that are (a) smaller than would be required to support a viable population, and (b) separated from other habitat patches by a distance larger than the species can be expected to disperse?	No. This species is a mobile, habitat generalist that is not restricted to specific habitat patches or separated from other habitat patches by a distance greater than the species can disperse.
Number of "locations"* (use plausible range to reflect uncertainty if appropriate)	Not applicable. It is not possible to calculate the number of locations for this species. This species has a very broad geographic range, low site fidelity, and threats are not entirely clear.
Is there an [observed, inferred, or projected] decline in extent of occurrence?	No.
Is there an [observed, inferred, or projected] decline in index of area of occupancy?	Yes. Inferred decline of 37.5%
Is there an [observed, inferred, or projected] decline in number of subpopulations?	Likely. Inferred decline based on lower relative abundance and failure to detect species at sites where it was formerly common.
Is there an [observed, inferred, or projected] decline in number of "locations"*?	Unknown. It is not possible to calculate the number of locations for this species.
Is there an [observed, inferred, or projected] decline in [area, extent and/or quality] of habitat?	Yes. Inferred continuing decline in quality of habitat.

* See Definitions and Abbreviations on COSEWIC website and IUCN (Feb 2014) for more information on this term.

Are there extreme fluctuations in number of subpopulations?	Unlikely.
Are there extreme fluctuations in number of "locations"∗?	Unknown.
Are there extreme fluctuations in extent of occurrence?	Unlikely.
Are there extreme fluctuations in index of area of occupancy?	Unlikely.

Number of Mature Individuals (in each subpopulation)

Subpopulations (give plausible ranges)	**N Mature Individuals.**
	Unknown.
Total	Unknown.

Quantitative Analysis

Probability of extinction in the wild is at least [20% within 20 years or 5 generations, or 10% within 100 years].	Unknown.

Threats (actual or imminent, to populations or habitats, from highest impact to least)

8.1 Invasive non-native/alien species, including parasites and pathogens
9.3 Agricultural and forestry effluents, including external and systemic pesticide use;
2.1 Annual and perennial non-timber crops, including crop intensification
7.3 Other ecosystem modifications, referring to the abandonment of managed lands and farms and subsequent natural succession of these habitats.

Rescue Effect (immigration from outside Canada)

Status of outside population(s)? The range of this species extends across the United States, where subpopulations have also significantly declined. The source-sink dynamics of this species are unknown, yet this species has the potential to disperse long distances.	
Is immigration known or possible?	Yes.
Would immigrants be adapted to survive in Canada?	Yes.
Is there sufficient habitat for immigrants in Canada?	Likely.
Are conditions deteriorating in Canada?[+]	Unknown.
Are conditions for the source population deteriorating?[+]	Unknown.
Is the Canadian population considered to be a sink?[+]	Unknown.
Is rescue from outside populations likely?	Unlikely. Population has declined significantly throughout its US range.

[+] See Table 3 (Guidelines for modifying status assessment based on rescue effect).

Data Sensitive Species

Is this a data sensitive species?	No.

Status History

COSEWIC: Designated Endangered in April 2016.

Status and Reasons for Designation:

Status: Endangered	**Alpha-numeric codes:** A2bce
Reasons for designation: This species was once common and broadly distributed, primarily through southern Canada, from Vancouver Island through the prairies to southern Quebec. It has since declined significantly and is now rarely seen. Despite targeted search efforts over the last decade, the species has decreased in abundance relative to other lady beetle species. Specific causes of the decline are unknown. Possible threats include introduction of non-native lady beetles, which could affect this native species through competition, intraguild predation, or introduction of pathogens. Other possible threats include decline in habitat quality through indirect effects of pesticide/chemical use associated with agriculture to control their prey species, urban expansion, and abandonment and subsequent natural succession of farmland.	

Applicability of Criteria

Criterion A (Decline in Total Number of Mature Individuals): Meets Endangered A2bce since there is an inferred reduction of greater than or equal to 50% in abundance of mature individuals over the last 10 years. The causes may not have ceased, and are not understood or may not be reversible: (b) there is an overall decline in relative abundance; (c) there has been a decline in the IAO, and quality of habitat; and (e) introduced taxa (Seven-spotted Lady Beetle and Multi-coloured Asian Lady Beetle introductions), pathogens, parasites and pollutants are suspected to have contributed to declines.
Criterion B (Small Distribution Range and Decline or Fluctuation): Not applicable. Very wide distribution and above EOO threshold. This species doesn't meet criteria for locations; it is not severely fragmented and does not have extreme fluctuations.
Criterion C (Small and Declining Number of Mature Individuals): Not Applicable. Insufficient data on number of mature individuals.
Criterion D (Very Small or Restricted Population): Not applicable. Insufficient data on number of mature individuals. Canadian population is not restricted in IAO, doesn't meet criteria for locations, and is not prone to effects of human activities or stochastic events within a very short time period across its range.
Criterion E (Quantitative Analysis): Not Applicable. Insufficient data to make Canadian population projections showing the probability of extinction or extirpation in the wild.

COSEWIC HISTORY

The Committee on the Status of Endangered Wildlife in Canada (COSEWIC) was created in 1977 as a result of a recommendation at the Federal-Provincial Wildlife Conference held in 1976. It arose from the need for a single, official, scientifically sound, national listing of wildlife species at risk. In 1978, COSEWIC designated its first species and produced its first list of Canadian species at risk. Species designated at meetings of the full committee are added to the list. On June 5, 2003, the *Species at Risk Act* (SARA) was proclaimed. SARA establishes COSEWIC as an advisory body ensuring that species will continue to be assessed under a rigorous and independent scientific process.

COSEWIC MANDATE

The Committee on the Status of Endangered Wildlife in Canada (COSEWIC) assesses the national status of wild species, subspecies, varieties, or other designatable units that are considered to be at risk in Canada. Designations are made on native species for the following taxonomic groups: mammals, birds, reptiles, amphibians, fishes, arthropods, molluscs, vascular plants, mosses, and lichens.

COSEWIC MEMBERSHIP

COSEWIC comprises members from each provincial and territorial government wildlife agency, four federal entities (Canadian Wildlife Service, Parks Canada Agency, Department of Fisheries and Oceans, and the Federal Biodiversity Information Partnership, chaired by the Canadian Museum of Nature), three non-government science members and the co-chairs of the species specialist subcommittees and the Aboriginal Traditional Knowledge subcommittee. The Committee meets to consider status reports on candidate species.

DEFINITIONS (2016)

Wildlife Species	A species, subspecies, variety, or geographically or genetically distinct population of animal, plant or other organism, other than a bacterium or virus, that is wild by nature and is either native to Canada or has extended its range into Canada without human intervention and has been present in Canada for at least 50 years.
Extinct (X)	A wildlife species that no longer exists.
Extirpated (XT)	A wildlife species no longer existing in the wild in Canada, but occurring elsewhere.
Endangered (E)	A wildlife species facing imminent extirpation or extinction.
Threatened (T)	A wildlife species likely to become endangered if limiting factors are not reversed.
Special Concern (SC)*	A wildlife species that may become a threatened or an endangered species because of a combination of biological characteristics and identified threats.
Not at Risk (NAR)**	A wildlife species that has been evaluated and found to be not at risk of extinction given the current circumstances.
Data Deficient (DD)***	A category that applies when the available information is insufficient (a) to resolve a species' eligibility for assessment or (b) to permit an assessment of the species' risk of extinction.

* Formerly described as "Vulnerable" from 1990 to 1999, or "Rare" prior to 1990.

** Formerly described as "Not In Any Category", or "No Designation Required."

*** Formerly described as "Indeterminate" from 1994 to 1999 or "ISIBD" (insufficient scientific information on which to base a designation) prior to 1994. Definition of the (DD) category revised in 2006.

Environment and Climate Change Canada
Canadian Wildlife Service
Environnement et Changement climatique Canada
Service canadien de la faune
Canada

The Canadian Wildlife Service, Environment and Climate Change Canada, provides full administrative and financial support to the COSEWIC Secretariat.

COSEWIC Status Report

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Nine-spotted Lady Beetle

Coccinella novemnotata

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2016

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WILDLIFE SPECIES DESCRIPTION AND SIGNIFICANCE

Name and Classification

Class	Insecta – insects
Subclass	Pterygota – winged insects
Order	Coleoptera – beetles
Suborder	Polyphaga – lady beetles, longhorn beetles, weevils, click beetles, fireflies, scarab beetles, rove beetles
Superfamily	Cucujoidea – lady beetles, bark beetles, fungus beetles, sap beetles
Family	Coccinellidae – lady beetles
Subfamily	Coccinellinae
Tribe	Coccinellini
Genus	*Coccinella*
Species	*Coccinella novemnotata* Herbst, 1793 – Nine-spotted Lady Beetle

Scientific name: *Coccinella novemnotata*

English Common Names: Nine-spot ladybug, nine-spotted ladybug, nine-spotted lady bird beetle, Nine-spotted Lady Beetle

French Common Name: Coccinelle à neuf points

The family Coccinellidae contains about 6,000 species worldwide in about 360 genera (Vandenberg 2002; Giorgi and Vandenberg 2009). In Canada there are 60 genera containing 161 species, of which 9 are adventive and are now well established (Hodek *et al.* 2012; Bousquet *et al.* 2013). The taxonomy, identification and geographic distribution of these species in Canada are well known (Dobzhansky 1935; Watson 1956; Brown 1962; Brown and de Ruette 1962; Belicek 1976; Watson 1976; Larochelle 1979; Gordon 1985; Vandenberg 2002; Majka and McCorquodale 2006; Acorn 2007; Marriott *et al.* 2009; Majka and McCorquodale 2010; Hodek *et al.* 2012; Bousquet *et al.* 2013).

The genus *Coccinella* contains 15 species, found primarily in North America. Within Canada, 11 species are native, including *Coccinella novemnotata*, and 2 species have been introduced (ITIS 2015).

The Nine-spotted Lady Beetle (*Coccinella novemnotata*) (Figure 1) was first described as a distinct species by Herbst (1793). There has been no further taxonomic work on the species and this description is still considered valid. No subspecies are recognized.

Figure 1. Nine-spotted Lady Beetle (*Coccinella novemnotata*). Photo by John Acorn.

Morphological Description

Lady beetles are holometabolous insects. They have four developmental life stages (egg, larva, pupae and adult). Each stage is morphologically different from the next.

Adult Nine-spotted Lady Beetles (4.7 – 7.0 mm) have elytra (wing covers) that are pale orange to red, most commonly with nine variably sized black spots, four on each elytra, with one central spot. However, the number and size of spots can vary across individuals to the point where some lack spots entirely. In the Nine-spotted Lady Beetle, the suture (where wing covers meet) has a dark narrow line. The head is broad and black with a pale band between the eyes. The anterior margin of the pronotum is entirely pale and black posteriorly (Gordon 1985; Acorn 2007) (Figure 1). Adults do not show sexual dimorphism (Stellwag and Losey 2014). The pale anterior pronotal margin and blackish sutural margin of the elytra readily distinguish the Nine-spotted Lady Beetle from other lady beetles.

The Nine-spotted Lady Beetle has yellow- to orange-coloured elongate eggs, approximately 1 mm in length that are laid upright in tightly packed clusters of approximately eighteen (Hodek *et al.* 2012). The larvae are black with periodic orange/red markings at the sides, and are elongated diamond-shaped with stubby, sometimes prickly looking legs. Larvae terga, or dorsal segments, have mound-like projections bearing seta, or hair-like structures (Rees *et al.* 1994). For detailed descriptions and keys to larvae stages see Rees *et al.* (1994). The pupae are usually yellow to orange with black markings (Hodek *et al.* 2012).

Population Spatial Structure and Variability

In Canada, the spatial structure and variability of Nine-spotted Lady Beetle subpopulations have not been studied. Similarly, limited genetic studies have occurred on this species and there is currently no evidence of subspecies genetic structure.

Allozyme variation was investigated in non-native (n = 8) and native (n = 6) lady beetles in North America, including the Nine-spotted Lady Beetle (Krafsur *et al.* 2005). For this study 38 specimens of Nine-spotted Lady Beetle were collected from three areas in North America (Iowa, New York, and Arkansas). This study determined allele diversities and heterozygosities were similar in non-native and native lady beetles and therefore no obvious relationship existed between successful colonization of new habitats and genetic diversity (Krafsur *et al.* 2005). This study also determined that there were high rates of gene flow within in all lady beetle subpopulations (Krafsur *et al.* 2005). In addition, all lady beetles showed a remarkable degree of dispersion with little detectable subpopulation subdivision (Krafsur *et al.* 2005).

Designatable Units

The Nine-spotted Lady Beetle has one designatable unit within Canada. No subspecies are recognized. Although the species occurs across the multiple ecological areas, there is little detectable subpopulation subdivision (Krafsur *et al.* 2005).

Special Significance

Lady beetles are iconic species to the general public. Prior to significant declines, the Nine-spotted Lady Beetle was one of the more common lady beetle species in Canada. As a predator of a large variety of aphid species in addition to other pest herbivores, it had an important economic role as a biological control agent in gardens and agricultural crops (Wheeler and Hoebeke 1995; Hesler *et al.* 2012). The observed decline of this charismatic species has led to public interest in their conservation and in this species' role in ecosystem function (Evans 2004; Harmon *et al.* 2007; Losey *et al.* 2007; Gardiner *et al.* 2011; Gardiner *et al.* 2012; Losey *et al.* 2012; Bahlai *et al.* 2013; Turnipseed *et al.* 2014; Ugine and Losey 2014).

Initiatives such as the Lost Lady Bug Project, which enable citizen scientists to help find and document Nine-spotted Lady Beetles across North America, demonstrate significant public interest in this species and shifting trends in lady beetle composition across landscapes.

There is no available Aboriginal Traditional Knowledge specifically for the Nine-spotted Lady Beetle.

DISTRIBUTION

Global Range

The Nine-spotted Lady Beetle is a wide-ranging species occurring through most of southern Canada and the continental United States to the Mexican border (Brown 1962; Gordon 1985) (Figure 2).

Figure 2. The geographic range of the Nine-spotted lady Beetle (*Coccinella novemnotata*). This range map is based on a historic range map by Gordon (1985) and collection records (Grant pers. data).

Canadian Range

The Canadian range of the Nine-spotted Lady Beetle stretches from Vancouver Island, primarily through southern Canada and the prairies to southern Quebec (Brown 1962; Gordon 1985; Grant pers. data) (Figure 2). At the northernmost extent of its range the Nine-spotted Lady Beetle has been recorded near: Quesnel (BC); Edmonton (AB); Lake Athabasca (SK) and Roberval (QC). The range map for the Nine-spotted Lady Beetle in Gordon (1985) contains one record from Great Slave Lake in the Northwest Territories. This record could not be verified and is considered outside its known geographic range. It is possible Nine-spotted Lady Beetle could range within southern portions of NT and YT; however, there are no verified records as of the preparation of this report (2016). The Canadian range for this species is based on historical and current collection records, although there are gaps in survey coverage and some records are quite old (> 50 years).

Within the last ten years there have been thirteen records of Nine-spotted Lady Beetles in Canada from: two sites in Cranbrook (BC); one site in Kamloops (BC); one site in Osoyoos (BC); two sites in Williams Lake (BC); one site in Calgary (AB); one site in Cardston (AB); three sites in Medicine Hat (AB); one site in Steveville (AB); and one site in Mont St-Hilaire (QC).

Extent of Occurrence and Area of Occupancy

Extent of occurrence (EOO) for the Nine-spotted Lady Beetle is based on databased museum collections and surveys. Based on a minimum convex polygon within the extent of Canada's jurisdiction, the EOO from 1897 – 2014 (all databased records) is 3,253,910 km^2 (Figure 3). The EOO calculated from 1995 – 2004 records is 559,510 km^2 (Figure 4). The EOO calculated from 2005 – 2014 records is 716,847 km^2 (Figure 5).

An index of area of occupancy (IAO) based on the databased museum collections and surveys from 1897 – 2014 (all databased records) is 1,308 km^2 (Figure 3). The IAO calculated from 1995 – 2004 records is 64 km^2 (Figure 4). The IAO calculated from 2005 – 2014 records is 40 km^2 (Figure 5).

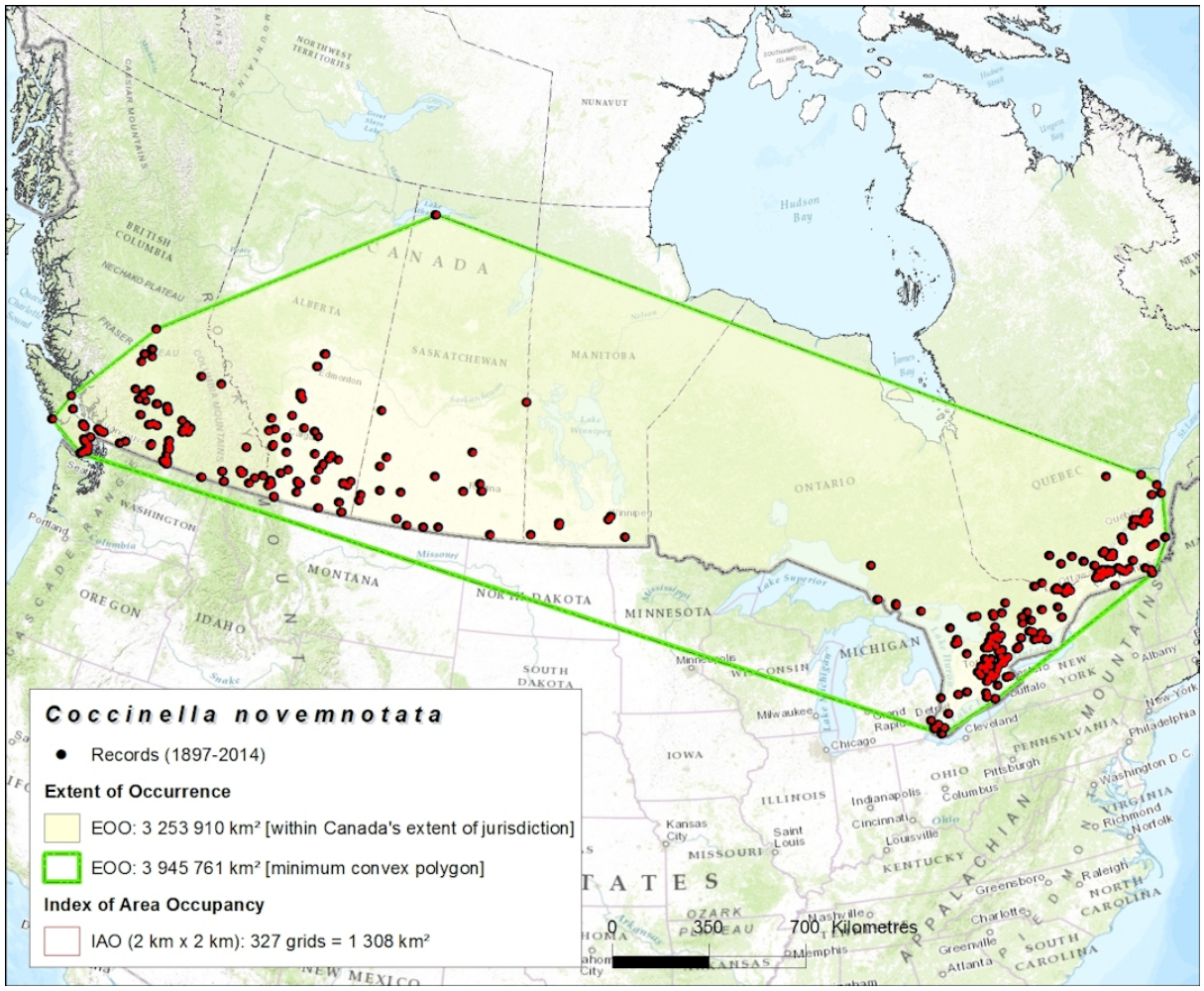

Figure 3. Extent of occurrence and index of area of occupancy for the Nine-spotted Lady Beetle based on museum collections and recent surveys (1897 – 2014).

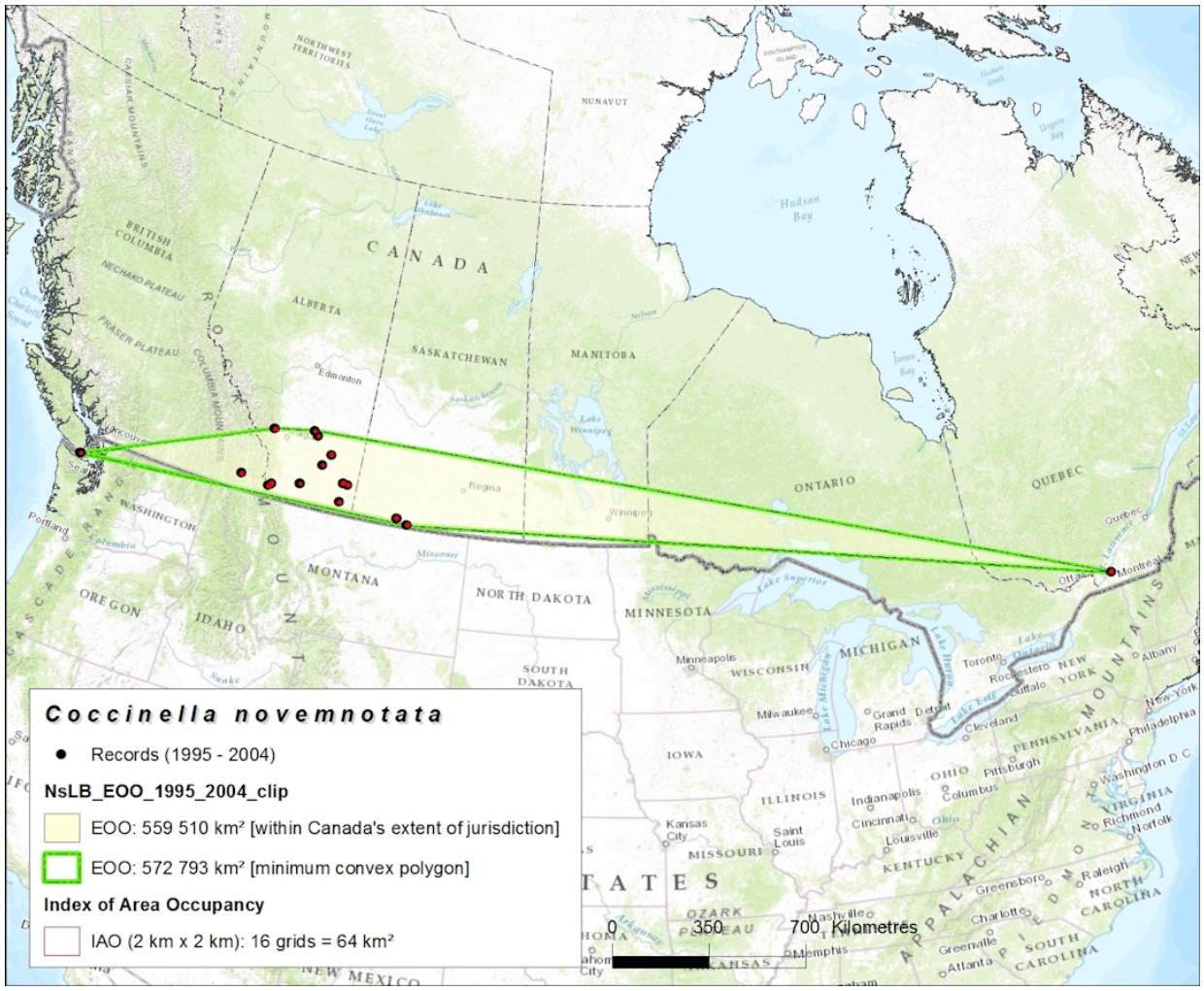

Figure 4. Extent of occurrence and index of area of occupancy for the Nine-spotted Lady Beetle based on museum collections (1995 – 2004).

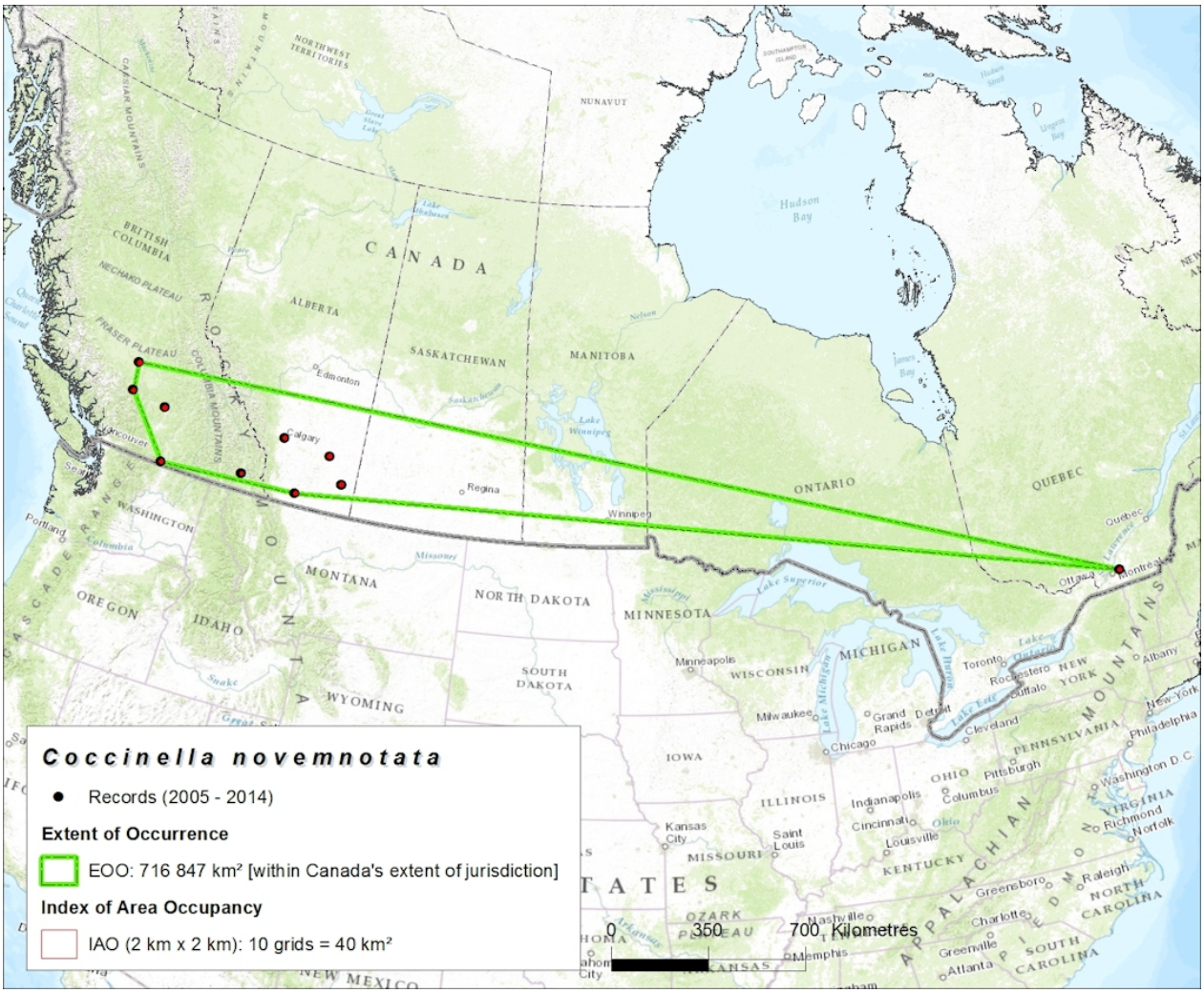

Figure 5. Recent extent of occurrence and index of area of occupancy for the Nine-spotted Lady Beetle based on museum collections and recent surveys (2005 – 2014).

Search Effort

Museum and collection records for the Nine-spotted Lady Beetle date from 1897 – 2014. A database of almost 23,000 lady beetle records (Coccinellidae), including 1,061 records for the Nine-spotted Lady Beetle have been compiled from 26 collections across Canada (see Collections Examined). While this database contains records of lady beetles across all Canadian provinces and territories, Nine-spotted Lady Beetles are only recorded from British Columbia, Alberta, Saskatchewan, Manitoba, Ontario and Quebec (Table 1).

Table 1. There are ~1,061 Nine-spotted Lady Beetle specimens databased from 1897 – 2014 in Canada (see Collections Examined).

Province	Coccinellidae Collections	Nine-spotted Lady Beetle
Yukon Territory	527	0
Northwest Territories	90	0
Nunavut	1	0
British Columbia	7017	247
Alberta	778	160
Saskatchewan	1793	35
Manitoba	2369	9
Ontario	6715	331
Quebec	1950	279
New Brunswick	658	0
Nova Scotia	686	0
Prince Edward Island	65	0
Newfoundland and Labrador	87	0
Total	**22736**	**1061**

Surveys have not been systematic or comprehensive over time and across the range of the Nine-spotted Lady Beetle. There are large areas and time periods with little data. In Canada most search effort has also been focused within agricultural systems or near urban centres, rather than in less disturbed and natural habitats (Acorn 2007; McCorquodale *et al.* 2011). While some collections across Canada currently do not have information databased, within numerous other insect collections, specimens have been reliably identified to assess the historical status of lady beetles in Canada (McCorquodale *et al.* 2011; Grant pers. data).

In preparation for this status report, sites that had recent historic records of the Nine-spotted Lady Beetle were revisited and targeted surveys were conducted within possible geographic survey gaps, including remote natural areas in northern British Columbia, Alberta, Yukon and Northwest Territories (Figure 6). There were 230 sites searched in 2013 and 2014 for a total search effort of 262.4 hours (Table 2). For an obvious, easily collected beetle, this represents a relatively large search effort per site. However, only four specimens were found in previously known sites for Nine-spotted Lady Beetles; three in Medicine Hat (AB) and one in Osoyoos (BC).

The dispersal ability of Nine-spotted Lady Beetle is unknown. However, based on potential dispersal ability (under ideal conditions) of other lady beetle species (see Dispersal and Migration) the species could potentially fly from 18 km to up to 120 km in a single flight (Jeffries *et al.* 2013). These potential dispersal distances were used to estimate overlap between search effort and databased sites of Nine-spotted Lady Beetles. An 18 km radius around the 230 search effort sites in 2013 and 2014 overlapped with 287 databased sites and 729 sites with a 120 km radius (Figure 7 and 8). As this species is broadly distributed and highly mobile, this search effort represents relatively decent coverage of known sites for Nine-spotted Lady Beetles.

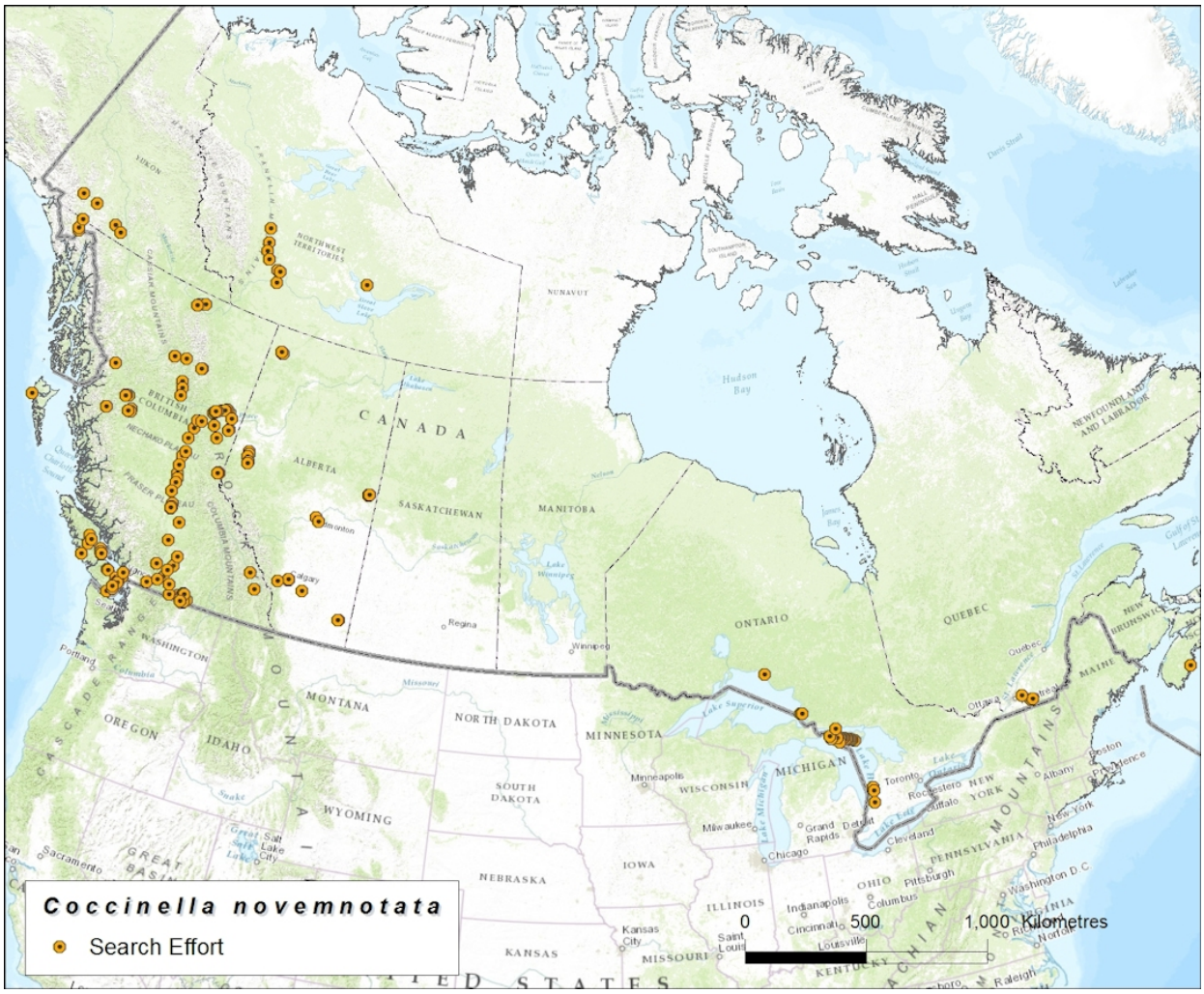

Figure 6. Search effort for the Nine-spotted Lady Beetle (*Coccinella novemnotata*).

Table 2. Targeted search effort 2013 – 2014. Total search effort of 262.4 hours across 230 sites detected four Nine-spotted Lady Beetles: one from Osoyoos (BC) and three from Medicine Hat (AB).

Province	Location	Year	Time	NSLB*	Surveyor
BC	Arras	2013	90	no	Copley C; Copley D; Heron J; Gartner H
	Arras	2013	35	no	Copley C; Copley D; Heron J; Gartner H
	Ashnola River Valley	2014	15	no	Heron J;
	Attachie	2013	462	no	Copley C; Copley D; Heron J; Gartner H
	Attachie	2013	90	no	Copley C; Copley D; Heron J; Gartner H
	Brisco	2014	15	no	Grant P
	Chetwynd	2013	120	no	Copley C; Copley D; Heron J; Gartner H
	Chetwynd	2013	90	no	Copley C; Copley D; Heron J; Gartner H
	Clinton	2013	140	no	Copley C; Copley D; Heron J; Gartner H
	Comox	2014	95	no	Heron J
	Coquihalla Lake	2013	120	no	Copley C; Copley D; Heron J; Gartner H
	Delta	2014	15	no	Heron J
	Denman island	2014	15	no	Heron J
	Denman island	2014	15	no	Heron J
	Denman island	2014	15	no	Heron J
	Denman island	2014	15	no	Heron J
	Fairmont Hot Springs	2014	15	no	Grant P
	Fairmont Hot Springs	2014	15	no	Grant P
	Fort St. John	2013	15	no	Copley C
	Fort St. John	2013	124	no	Copley C; Copley D; Heron J; Gartner H
	Fort St. John	2013	420	no	Copley C; Copley D; Heron J; Gartner H
	Fort St. John	2013	53	no	Copley C; Copley D; Heron J; Gartner H
	Fort St. John	2013	210	no	Copley C; Copley D; Heron J; Gartner H
	Fort St. John	2013	435	no	Copley C; Copley D; Heron J; Gartner H
	Fort Ware	2014	15	no	Robb B; Copley C; Copley D;
	Galiano Island	2014	30	no	Ott L
	Greater Victoria	2014	15	no	Heron J
	Greater Victoria	2014	15	no	Heron J
	Greater Victoria	2014	15	no	N/A
	Haida Gwaii	2014	60	no	McClaren E.
	Haynes Lease	2013	630	no	Sheffield C; Weston M; Heron J
	Hazelton	2014	60	no	Westcott L
	Hazelton	2014	60	no	Westcott L
	Hazelton	2014	60	no	Westcott L
	Hazelton	2014	60	no	Westcott L
	Hazelton	2014	60	no	Westcott L
	Hazelton	2014	60	no	Westcott L
	Hazelton	2014	60	no	Westcott L
	Hazelton	2014	60	no	Westcott L

Province	Location	Year	Time	NSLB*	Surveyor
	Hixon	2013	140	no	Copley C; Copley D; Heron J; Gartner H
	Hope	2013	120	no	Copley C; Copley D; Heron J; Gartner H
	Hudson's Hope	2013	120	no	Copley C; Copley D; Heron J; Gartner H
	Hudson's Hope	2013	74	no	Copley C; Copley D; Heron J; Gartner H
	Hudson's Hope	2013	255	no	Copley C; Copley D; Heron J; Gartner H; Cannings S
	Hudson's Hope	2013	360	no	Copley C; Copley D; Heron J; Gartner H
	Inkameep Prov. Park	2013	360	no	Sheffield C, Weston M; Heron J
	Iona Beach Park	2014	30	no	Cesselli S; Turner S
	Kakwa Prov. Park	2014	115	no	Ramey B; Bev B
	Kakwa Prov. Park	2014	5	no	Ramey B; Bev B
	Kakwa Prov. Park	2014	10	no	Ramey B; Bev B
	Kakwa Prov. Park	2014	10	no	Ramey B; Bev B
	Kakwa Prov. Park	2014	15	no	Ramey B; Bev B
	Kakwa Prov. Park	2014	10	no	Ramey B; Bev B
	Kakwa Prov. Park	2014	60	no	Ramey B; Bev B
	Kakwa Prov. Park	2014	5	no	Ramey B; Bev B
	Keily Prov. Park	2014	15	no	Robb B; Copley C; Copley D;
	Keily Prov. Park	2014	15	no	Robb B; Copley C; Copley D;
	Lower Mainland	2014	30	no	N/A
	Lower Mainland	2014	30	no	N/A
	Lower Mainland	2014	30	no	N/A
	Mayne Island	2014	30	no	Dunn M
	Mayne Island	2014	30	no	Dunn M
	Mayne Island	2014	30	no	Dunn M
	Mayne Island	2014	30	no	Dunn M
	Merritt	2013	120	no	Copley C; Copley D; Heron J; Gartner H
	Meziadin Junction	2014	60	no	Westcott L
	South Okanagan	2013	180	no	Sheffield C; Gardiner L; Dyer O; Heron J
	Mt. Kobau	2014	15	no	Copley C; Copley D; Heron J;
	Mt. Kobau	2014	15	no	Copley C; Copley D; Heron J;
	Mt. Kobau	2014	15	no	Copley C; Copley D; Heron J;
	Mt. Kobau	2014	15	no	Copley C; Copley D; Heron J;
	Mt. Kobau	2014	15	no	Copley C; Copley D; Heron J;
	Mt. Kobau	2014	15	no	Copley C; Copley D; Heron J;
	Nahatlach	2013	60	no	Heron J and Geoff Lynch
	Nahatlach	2013	30	no	Heron J and Geoff Lynch
	Nahatlach	2013	30	no	Heron J and Geoff Lynch
	Nahatlach	2013	30	no	Heron J and Geoff Lynch
	Northern BC	2014	60	no	Heron J
	Northern BC	2014	150	no	Heron J
	Northern BC	2014	30	no	Heron J

Province	Location	Year	Time	NSLB*	Surveyor
	Northern BC	2014	15	no	Heron J; Sheffield C
	Northern BC	2014	15	no	Heron J; Sheffield C
	Northern BC	2014	15	no	Heron J; Sheffield C
	Northern BC	2014	15	no	Heron J; Sheffield C
	Northern Vancouver I	2014	15	no	Copley C; Copley D; Heron J; Gartner H
	Northern Vancouver I	2014	15	no	Copley C; Copley D; Heron J; Gartner H
	Okanagan Falls	2014	75	no	Heron J; Burdock N
	Osoyoos	2014	15	no	Copley C; Copley D; Heron J;
	Osoyoos	2014	15	**Yes 1**	Copley C; Copley D; Heron J;
	Osoyoos	2014	15	no	Copley C; Copley D; Heron J;
	Osoyoos	2014	15	no	Copley C; Copley D; Heron J;
	Osoyoos	2013	120	no	Heron J; Sheffield C
	Pine River	2013	120	no	Copley C; Copley D; Heron J; Gartner H
	Pine River	2013	120	no	Copley C; Copley D; Heron J; Gartner H
	Prince George	2013	160	no	Copley C; Copley D; Heron J; Gartner H
	Prince George	2013	90	no	Copley C; Copley D; Heron J; Gartner H
	Prince George	2013	140	no	Copley C; Copley D; Heron J; Gartner H
	Prince George	2013	99	no	Copley C; Copley D; Heron J; Gartner H
	Princeton	2014	30	no	Heron J
	Quesnel	2013	180	no	Copley C; Copley D; Heron J; Gartner H
	Quesnel	2013	70	no	Copley C; Copley D; Heron J; Gartner H
	Keily Prov. Park	2014	15	no	Copley C; Copley D;
	Osoyoos	2013	40	no	Heron J; Sheffield C
	Russel Prov. Park	2014	15	no	Copley C; Copley D;
	Russel Prov. Park	2014	15	no	Bennett R; Copley C; Copley D;
	Russel Prov. Park	2014	15	no	Bennett R; Copley C; Copley D;
	Sage Sparrow Grasslands	2013	360	no	Heron J; Sheffield C
	Smithers	2014	60	no	Westcott L
	Smithers	2014	60	no	Westcott L
	Smithers	2014	60	no	Westcott L
	Smithers	2014	60	no	Westcott L
	Smithers	2014	60	no	Westcott L
	Sooke	2014	15	no	Grant P
	South	2014	15	no	Heron J
	South Okanagan	2014	30	no	Heron J
	South Okanagan	2014	30	no	Heron J
	South Okanagan	2014	30	no	Heron J
	South Okanagan	2014	30	no	Heron J
	South Okanagan	2014	30	no	Heron J
	South Okanagan	2014	30	no	Heron J
	South Okanagan	2014	15	no	Heron J

Province	Location	Year	Time	NSLB*	Surveyor
	South Okanagan	2014	30	no	Heron J; Sandhu J
	South Okanagan	2014	30	no	Heron J; Sandhu J
	South Okanagan	2014	30	no	Heron J; Sandhu J
	South Okanagan	2014	30	no	Heron J; Weston W; Bunge S; Pope B
	South Okanagan	2013	280	no	Sheffield C; Gardiner L; Dyer O; Heron J
	South Okanagan	2014	15	no	Heron J; Sandhu J
	Strathcona Prov. Park	2014	15	no	Bennett R; Copley C; Copley D; Heron J
	Strathcona Prov. Park	2014	15	no	Bennett R; Copley C; Copley D; Heron J
	Sydney	2014	60	no	Heron J; Gelling L
	Tatton	2013	128	no	Copley C; Copley D; Heron J; Gartner H
	Taylor	2013	40	no	Copley C; Copley D; Heron J; Gartner H
	Thompson Region	2014	30	no	Letay S
	Tsay Keh	2014	15	no	Bennett R; Copley C; Copley D;
	Tsay Keh	2014	15	no	Bennett R; Copley C; Copley D;
	Tsay Keh	2014	15	no	Bennett R; Copley C; Copley D;
	Tumbler Ridge	2013	70	no	Copley C; Copley D; Heron J; Gartner H
	Vancouver Island	2014	30	no	Casselli S; Turner S
	Vancouver Island	2014	15	no	Heron J
	Vancouver Island	2014	15	no	Heron J
	Vaseux Lake Prov. Park	2013	60	no	Heron J; Sheffield C
	Victoria	2014	15	no	Heron J; Gelling L
	Victoria	2014	15	no	Grant P
	Victoria	2014	15	no	Grant P
	Similkameen	2013	80	no	Heron J; Sheffield C
	Whiskers Point Prov. Park	2013	10	no	Copley C; Copley D; Heron J; Gartner H
	White Lake Prov. Park	2013	315	no	Sheffield C; Dyer O; Heron J
	Williams Lake	2014	30	no	Coot K
	Williams Lake	2014	60	no	Coot K; Foot T
	Williams Lake	2013	132	no	Copley C; Copley D; Heron J; Gartner H
	Williams Lake	2013	80	no	Copley C; Copley D; Heron J; Gartner H
AB	Calgary	2014	15	no	Grant P
	Calgary	2014	15	no	Grant P
	Calgary	2014	15	no	Grant P
	Calgary	2014	15	no	Grant P
	Calgary	2014	15	no	Grant P
	Calgary	2014	15	no	Grant P
	Calgary	2014	15	no	Grant P
	Calgary	2014	15	no	Grant P
	Cold Lake	2014	15	no	Grant P
	Cold Lake	2014	15	no	Grant P
	Cold Lake	2014	15	no	Grant P

Province	Location	Year	Time	NSLB*	Surveyor
	Cold Lake	2014	15	no	Grant P
	Conklin	2014	15	no	Grant P
	Conklin	2014	15	no	Grant P
	Conklin	2014	15	no	Grant P
	Conklin	2014	15	no	Grant P
	Conklin	2014	15	no	Grant P
	Edmonton	2014	30	no	Anweiler G
	Grande Prairie	2014	15	no	Grant P
	Grande Prairie	2014	15	no	Grant P
	Grande Prairie	2014	15	no	Grant P
	Grande Prairie	2014	15	no	Grant P
	Grande Prairie	2014	15	no	Grant P
	Mclean Creek	2014	15	no	Grant P
	Medicine Hat	2014	30	no	Leibel H
	Medicine Hat	2014	15	**YES 3**	Buck M
	Sherwood Park	2014	30	no	Anweiler G
	Sherwood Park	2014	30	no	Anweiler G
	Vulcan County	2014	30	no	Leibel H
	Zama City	2014	15	no	Grant P
	Zama City	2014	15	no	Grant P
	Zama City	2014	15	no	Grant P
	Zama City	2014	15	no	Grant P
	Zama City	2014	15	no	Grant P
ON	Carter Bay, Manitoulin I.	2014	300	no	Foster R; Harris A; Jones C
	Providence Bay, Manitoulin I.	2014	240	no	Foster R; Harris A; Jones C
	Dean's Bay, Manitoulin I.	2014	270	no	Foster R; Harris A; Jones C
	Lonely Bay, Manitoulin I.	2014	150	no	Foster R; Harris A; Jones C
	Square Bay, Manitoulin I.	2014	105	no	Foster R; Harris A; Jones C
	Dominion Bay, Manitoulin I.	2014	120	no	Foster R; Harris A; Jones C
	Shrigley Bay, Manitoulin I.	2014	165	no	Foster R; Harris A; Jones C
	Portage Bay, Manitoulin I.	2014	180	no	Foster R; Harris A; Jones C
	Taskerville, Manitoulin I.	2014	105	no	Foster R; Harris A; Jones C
	Murphy Harbour, Manitoulin I.	2014	30	no	Foster R; Harris A; Jones C
	Misery Bay, Manitoulin I.	2014	180	no	Foster R; Harris A; Jones C
	Sand (Hensly) Bay, Manitoulin I.	2014	96	no	Foster R; Harris A; Jones C
	Carroll Wood Bay, Manitoulin I.	2014	105	no	Foster R; Harris A; Jones C
	Burnt I. Harbour, Manitoulin I.	2014	210	no	Foster R; Harris A; Jones C
	Great Duck I.	2014	180	no	Foster R; Harris A; Jones C
	Belanger Bay, Manitoulin I.	2014	105	no	Foster R; Harris A; Jones C
	Sand Bay, Cockburn I.	2014	300	no	Foster R; Harris A; Jones C
	Airport, Cockburn I.	2014	90	no	Foster R; Harris A; Jones C

Province	Location	Year	Time	NSLB*	Surveyor
	Mississaugi River mouth	2014	102	no	Foster R; Harris A; Jones C
	Pancake Bay, Lake Superior	2014	210	no	Foster R; Harris A; Jones C
	Batchewana Bay, Lake Superior	2014	60	no	Foster R; Harris A; Jones C
	Pic River Dunes, Lake Superior	2014	48	no	Foster R; Harris A; Jones C
	Point Farms Prov. Park, Lake Huron	2014	180	no	Foster R; Harris A; Jones C
	Black's Point Beach, Lake Huron	2014	60	no	Foster R; Harris A; Jones C
	Pinery Prov. Park, Lake Huron	2014	36	no	Foster R; Harris A; Jones C
QC	Chemin Choinière	2014	60	no	Bereczky V
	Chemin Magenta	2014	60	no	Bereczky V
	Lac Gale GR11	2014	60	no	Bereczky V
	Mont St Hilaire	2014	120	no	Bereczky V
	Prairie Mt Aki	2014	120	no	Bereczky V
NT	Fort Simpson	2014	30	no	Allaire D
	Jean Marie River	2014	30	no	Allaire D
	Fort Simpson	2014	30	no	Allaire D
	Fort Simpson	2014	60	no	Allaire D
	Wrigley	2014	30	no	Allaire D
	Wrigley	2014	30	no	Allaire D
	Fort Simpson	2014	30	no	Allaire D
	Wrigley	2014	30	no	Allaire D
	Wrigley	2014	30	no	Allaire D
	Fort Simpson	2014	30	no	Allaire D
	Fort Simpson	2014	30	no	Allaire D
YT	Northern	2014	30	no	Heron J
	Northern	2014	45	no	Heron J
	Northern	2014	15	no	Heron J; Sheffield C
	Northern	2014	15	no	Heron J; Sheffield C

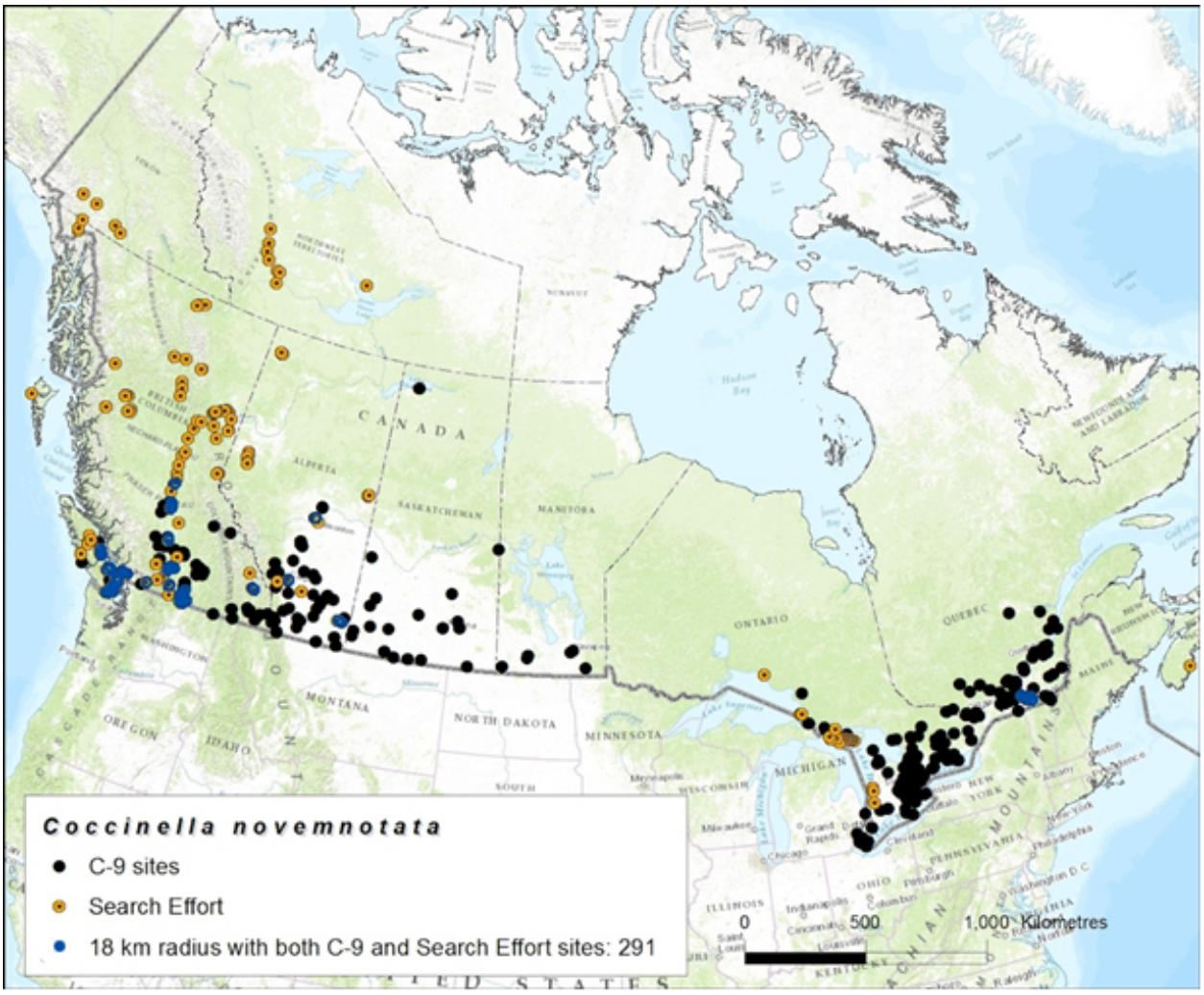

Figure 7. Search effort sites (orange dots) with an 18 km radius (blue dots), overlap with 287 known sites for the Nine-spotted Lady Beetle (*Coccinella novemnotata*) (black dots).

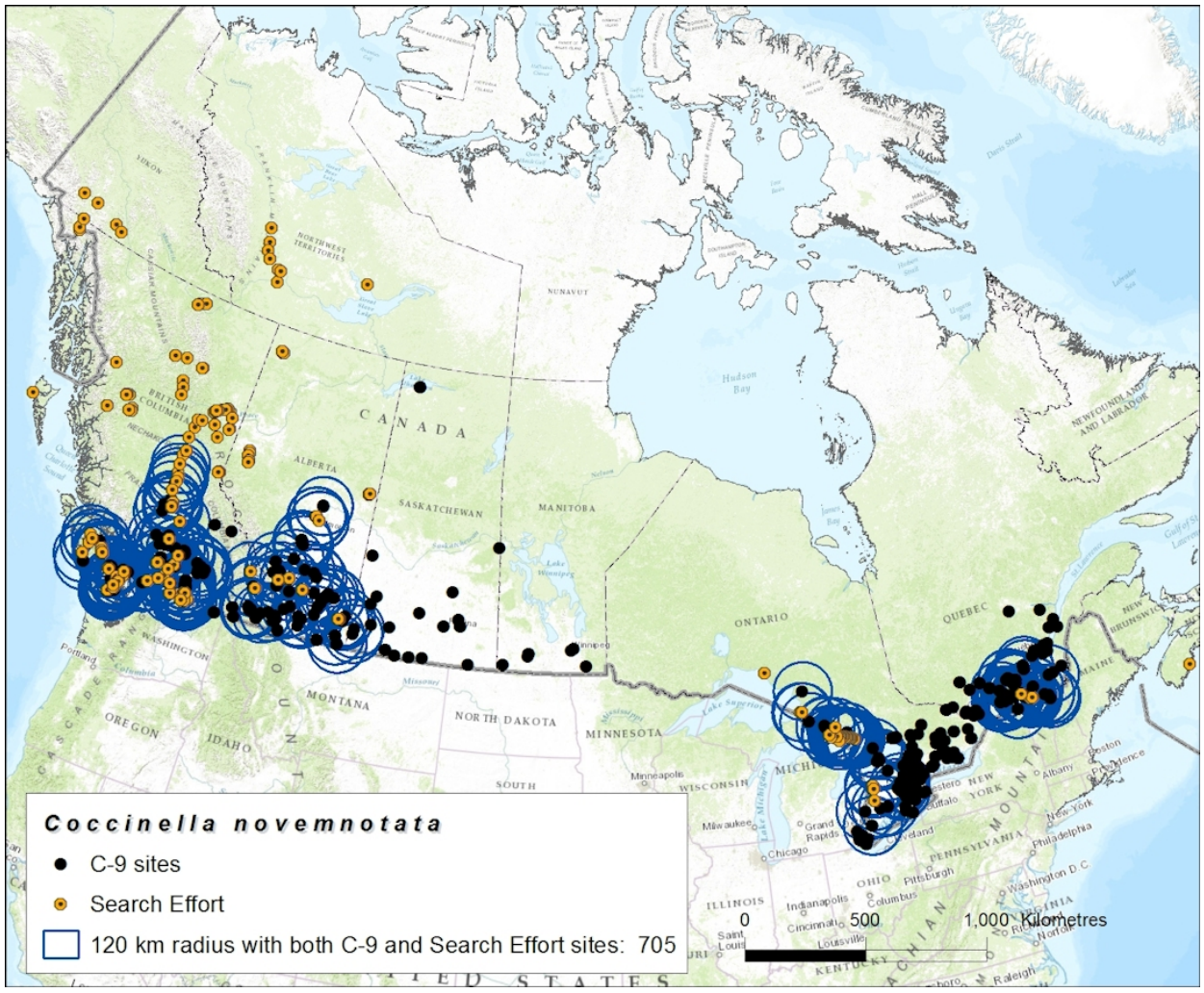

Figure 8. Search effort sites (orange dots) with a 120 km radius (blue circles) overlap with 729 known sites for the Nine-spotted Lady Beetle (*Coccinella novemnotata*) (black dots).

HABITAT

Habitat Requirements

The Nine-spotted Lady Beetle is a habitat generalist and known to occur where there are areas of shrubs or small trees interspersed with open grassy areas, but not continuous closed canopy forests. This species has been recorded within agricultural areas, suburban gardens, parks, coniferous forests, deciduous forests, prairie grasslands, meadows, riparian areas and other natural open areas. Within agricultural crops it was one of the more dominant lady beetles found on alfalfa, potatoes, corn, soybean, and cotton (Wheeler and Hoebeke 1995; Harmon *et al.* 2007; Losey *et al.* 2007; Gardiner *et al.* 2011). It was also readily found on a wide variety of other crops in gardens and on grass, clover and weeds (Wheeler and Hoebeke 1995; Harmon *et al.* 2007; Losey *et al.* 2007; Gardiner *et al.* 2011). The Nine-spotted Lady Beetle can also be found in a wide variety of non-agricultural vegetation including birch, pine, spruce, maple, mountain ash, poplar, willow, sage, cherry, alder, thistles, grasslands, and scruff pea plants along the edge of sand dunes (Wheeler and Hoebeke 1995; Acorn 2007; Harmon *et al.* 2007; Losey *et al.* 2007).

Nine-spotted Lady Beetles move across different habitats and vegetation to exploit seasonal changes in prey availability and their distribution is therefore driven to a large extent by prey availability rather than habitat type (Hagen 1962; Hodek and Honěk 1996; Sloggett and Majerus 2000; Hodek *et al.* 2012).

Overwintering adults tend to aggregate in well ventilated microhabitats such as under stones, rock crevices, in grass tussock, in leaf litter, or in tree bark (Hodek *et al.* 2012). Larvae are generally located in habitat with an abundance of prey, and pupate in the same habitat.

Habitat Trends

The Nine-spotted Lady Beetle has a large range in Canada spanning numerous ecozones and habitat types (Gordon 1985). This species also readily disperses short and long distances to exploit changes in prey availability over the season and across vegetation types. No studies have specifically related habitat trends to declines in Nine-spotted Lady Beetle subpopulations. It is unknown if specific habitat trends have caused this particular lady beetle, with its wide diet and habitat range, to decline over much of its known range across Canada.

However, widespread and cumulative habitat conversion could have potentially led to subpopulation declines in some parts of its range. Expansion of major urban centres, including areas of greater Vancouver, Victoria and Calgary, intensive use of agricultural landscapes, and other industrial practices lead to cumulative habitat quality decline and habitat loss (Federal, Provincial and Territorial Governments of Canada 2010; Javorek and Grant 2011).

In recent decades, the capacity of agricultural landscapes to provide habitat for wildlife has declined significantly across Canada's ecozones (Federal, Provincial and Territorial Governments of Canada 2010; Javorek and Grant 2011). One of the causes for this is the more intensive use of agricultural land. This includes heavier reliance on chemicals for pest control, which presumably could negatively affect Nine-spotted Lady Beetles directly, or indirectly by impacting their prey.

Abandonment of managed lands and farms resulting in regrowth of trees could also potentially result in less favourable foraging for the Nine-spotted Lady Beetle (Harmon *et al.* 2007; Bucknell and Pearson 2007). This slow natural succession has mainly occurred in eastern Canada.

While large-scale changes in habitat and prey availability suggest a possible explanation, there are no data to demonstrate causality between a changing landscape and lady beetle densities (Elliott and Kieckheffer 1990; Elliott *et al.* 1999; Harmon *et al.* 2007).

BIOLOGY

Information is compiled from general lady beetle references (Acorn 2007; Hodek *et al.* 2012) and where applicable references are provided specifically for Nine-spotted Lady Beetles.

Life Cycle and Reproduction

Lady beetles are holometabolous, meaning they have a complete metamorphosis and pass through egg, larva, pupa and adult life stages. Nine-spotted Lady Beetles can have two generations per year (McMullen 1967) but the life history of lady beetles often depends on regional climatic conditions (Hodek *et al.* 2012). Adult Nine-spotted Lady Beetles have life spans which shorten with increasing temperature (Hodek *et al.* 2012). Within laboratory settings Nine-spotted Lady Beetle adults have been recorded to live for 62, 48 and 21 days at 21°C, 27°C and 32°C, respectively (McMullen 1967). This data suggests adults may live longer in cooler regions. Adults of the spring generation can undergo aestivation to avoid high summer temperatures, and lay eggs in early autumn (McMullen 1967; Hodek *et al.* 2012). Adults of the autumn generation congregated overwinter and undergo diapause, only becoming active and reproducing when temperatures rise in the early spring (McMullen 1967; Hodek *et al.* 2012; Losey *et al.* 2012).

At 25°C the pre-oviposition period (number of days between eclosion or emergence from pupae, and first egg laying) for the Nine-spotted Lady Beetle female is approximately 5 days, followed by an oviposition period of approximately 31 days (Ugine and Losey 2014). During this period Nine-spotted Lady Beetles can lay upwards of 690 eggs (Ugine and Losey 2014). The eggs of Nine-spotted Lady Beetles are laid upright, in tightly packed clusters of approximately 18 eggs, on a range of plants that are likely to support subpopulations of aphids (Acorn 2007; Hodek *et al.* 2012). Many females also lay unfertilized eggs, along with the fertile eggs, as another food source for young larvae (Acorn 2007).

Development from egg to adult takes approximately 20 days for the Nine-spotted Lady Beetle, depending on temperature (Ugine and Losey 2014). Larvae of the Nine-spotted Lady Beetle hatch from eggs after approximately 3 days (Ugine and Losey 2014). Nine-spotted Lady Beetles then undergo 4 instars before pupating, metamorphosing and reaching adulthood (Losey *et al.* 2012). This species reaches its third instar in approximately 4 to 5 days and takes an additional 7 days to reach its fourth instar and pupate. After approximately 5 days as a pupa, Nine-spotted Lady Beetles emerge as adults (Ugine and Losey 2014). One day after emerging, the elytra on adult Nine-spotted Lady Beetles harden (Losey *et al.* 2012). Male lady beetles locate females based on chemical and visual cues, and both sexes are polygynandrous mating with multiple partners (Omkar and Srivastava 2002; Srivastava and Omkar 2004; Acorn 2007).

In many lady beetles, the sex ratio is close to 1:1 and the activity of the follicular tissue in the testes starts in the pupa, so mating can begin shortly after emerging (Acorn 2007; Hodek *et al.* 2012). In the Nine-spotted Lady Beetle the sex ratio is 56:44, with slightly more females to males. Female Nine-spotted Lady Beetles on average also weigh more than males (30.3 mg vs. 25.6 mg), yet have a fairly equal body size (Smith 1966). Weight and size of adult lady beetles are also positively correlated with increased availability of food, which in turn is correlated with their ability to survive over winter (Smith 1966). When food is scarce lady beetles will have smaller body sizes and weights and decreased survivorship over winter (Smith 1966).

Physiology and Adaptability

The Nine-spotted Lady Beetle displays aposematism, or bright warning colours to deter predators (Acorn 2007). Although undocumented, this species (like other lady beetles), likely is able to reflex bleed, releasing defensive alkaloids from tibio-femoral joints, when provoked (Hodek *et al.* 2012). There are about 50 different alkaloids that have been identified in lady beetles (Laurent *et al.* 2005). The various alkaloid compositions across species also vary in respect to their effects on predators (Marples *et al.* 1989; Laurent *et al.* 2005; Hodek *et al.* 2012).

Nine-spotted Lady Beetles also occupy a wide ecological niche across a variety of temperature regimes in Canada, are cold-tolerant, and as adults are able to overwinter. This plasticity also enables this species to exploit seasonal changes in prey availability across different habitats and vegetation (Hodek *et al.* 2012). Its ability to adapt, however, may be limited. Competition with other introduced species of lady beetles may be a factor in recent decreases in body size of Nine-spotted Lady Beetles (Losey *et al.* 2012) (see Interspecific Interactions).

Dispersal and Migration

Little is known on the natural dispersal rates specifically for the Nine-spotted Lady Beetle. In general lady beetles are very mobile, display low site fidelity, and readily engage in short- and long-distance dispersal (van der Werf 2000; Acorn 2007; Hodek *et al.* 2012). The ability to disperse relatively long distances has resulted in high rates of gene flow between subpopulations (Krafsur *et al.* 2005) and enables lady beetles to exploit changes in prey availability (Hodek *et al.* 2012).

Drivers of dispersal are a combination of prey density and environmental variables such as temperature, wind speed and rainfall (Ives *et al.* 1993; Hodek and Honěk 1996; van der Werf 2000; Cardinale *et al.* 2006; Krivan 2008; Jeffries *et al.* 2013). Previous work has also shown that lady beetle emigration decreases with increasing prey abundance (Ives 1981; Ives *et al.* 1993; Elliott 2000; van der Werf 2000; Cardinale *et al.* 2006; Jeffries *et al.* 2013) and the density of adult lady beetles is positively correlated with aphid density (Turchin and Kareiva 1989; Hodek and Honěk 1996; Osawa 2000; Evans and Toler 2007).

Calculating dispersal rates over longer distances has been hampered by the difficulty of tracking the insects in the field. One study using vertical-looking entomological radars determined that the majority of lady beetles fly at 150 – 479 metres above ground level (m AGL) perhaps due to decreasing air temperatures and increasing energetic requirements of reaching higher altitudes (Jeffries *et al.* 2013). Mean flight speed of lady beetles ranged from 31 km/h at 150 m AGL to 59 km/h at 1500 m AGL (Jeffries *et al.* 2013). Using tethered flight experiments, this study also estimated a mean flight time of 36.5 minutes, with a maximum of over 2 hours (Jeffries *et al.* 2013). Extrapolating from these results it was estimated that with ideal meteorological conditions, lady beetles could fly 18 km in a single flight (30 km/h for 36.5 minutes) and a few individuals flying at high altitudes and speeds (59 km/h for two hours) could potentially fly 120 km in a single flight (Jeffries *et al.* 2013).

Interspecific Interactions

Nine-spotted Lady Beetles are generalists in food and habitat use, often tracking changes in aphid abundance across many types of habitats (Hagen 1962; Hodek and Honěk 1996; Sloggett and Majerus 2000). Both adult and larval stages of the Nine-spotted Lady Beetle prey primarily on a wide variety of aphids (Acorn 2007; Hodek *et al.* 2012). They also prey on other small insects and eggs including spider mites, alfalfa weevils, leafhoppers, scale insects, psyllids, lepidopteran eggs, in addition to sap, nectar and pollen (Wheeler and Hoebeke 1995; Acorn 2007; Hesler *et al.* 2012; Losey *et al.* 2012). Lady beetles in general can be attracted to aphid densities of below 10 individuals per square metre, and even volatiles produced by herbivore-injured plants (Hodek *et al.* 2012).

The Nine-spotted Lady Beetle itself is also subject to intraguild predation by other introduced lady beetles (Turnipseed *et al.* 2014). There is a broad coincidence between subpopulation decline for the Nine-spotted Lady Beetle and the introduction and spread of the Seven-spotted Lady Beetle (*Coccinella septempunctata*) and the Multi-coloured Asian Lady Beetle (*Harmonia axyridis*). A direct causal link is not obvious, though potential mechanisms include direct competition for food, intraguild predation, and spread of new parasitoids or pathogens. Competition with introduced lady beetle species over aphid prey and other food is also suspected to have led to declines in the body size of Nine-spotted Lady Beetles (Losey *et al.* 2012) (see Threats). Declines in body size through competition may also reduce their ability to survive over winter (Smith 1966; Losey *et al.* 2012).

General predation on lady beetles by vertebrates such as birds is reduced by aposematic warning colours and distasteful defensive alkaloids excreted by reflex bleeding from the tibio-femoral joints (Laurent *et al.* 2005; Acorn 2007; Hodek *et al.* 2012). Despite these defences, lady beetles have been reported to be eaten by a wide range of vertebrate and invertebrate predators (Acorn 2007; Hodek *et al.* 2012). Web-building spiders are also frequently reported preying on lady beetles (Nentwig 1983; Richardson and Hanks 2009; Sloggett 2010).

Lady beetles, in general suffer from parasitism by various tachinid flies, phorid flies, chalcidoid wasps, parasitic mites, nematodes, sporazoans, fungi and bacteria (Wheeler and Hoebeke 1995; Acorn 2007; Bjornson 2008; Roy and Cottrell 2008; Hodek *et al.* 2012).

The braconid wasp (*Dinocampus coccinellae*) is the main parasitoid of numerous lady beetle species, including the Seven-spotted Lady Beetle and the Multi-coloured Asian Lady Beetle and can cause substantial reductions in subpopulations of the Nine-spotted Lady Beetle (Ceryngier and Hodek 1996; Abassi *et al.* 2001; Acorn 2007; Hodek *et al.* 2012). The braconid wasp currently has a cosmopolitan distribution covering all continents except Antarctica, and many islands (Hodek *et al.* 2012). The natural geographic range of the braconid wasp is difficult to reconstruct as it is believed this species arrived in some parts of its present distribution with lady beetles released for biological control purposes (Hodek *et al.* 2012).

Other interspecific interactions include parasitic mites (i.e., *Coccipolipus hippodamiae*), fungal pathogens (i.e., *Beauveria bassiana*), microsporidia (Nosematidae) and bacteria, which can all negatively impact lady beetle fitness and reduce survival over winter (Cali and Briggs 1967; Hurst *et al.* 1995; Barron and Wilson 1998; Webberley and Hurst 2002; Webberley *et al.* 2004).

POPULATION SIZES AND TRENDS

Sampling Effort and Methods

Insect collections are important sources for information on geographic distribution of species (Wiggins *et al.* 1991). Specimens within Canadian collections have been collected by a mix of professional entomologists, students and keen amateurs during biodiversity inventories, general collections, taxon specific collections, ecological studies and applied studies on crops and forests. Data from collections have helped delineate geographic ranges of lady beetles and can be used to assess temporal changes in distribution and abundance if the strengths and weaknesses of collection data are understood and considered (McCorquodale *et al.* 2011).

Due to associated biases, accurately documenting changes in the geographic distribution of a species is a difficult task (Fortin *et al.* 2005; Elith *et al.* 2006; Koch and Strange 2009). Maps of geographic distribution may show a decrease in geographic range when in fact they reflect a decrease in subpopulation size, because with a reduced subpopulation there is a decrease in probability of collection (McCorquodale *et al.* 2011). In addition, collections can potentially be time series biased and may not reflect the true abundance of a species as experts may not continue to collect specimens of common lady beetles (McCorquodale *et al.* 2011). Conversely, newly introduced and invasive species might be collected out of proportion to the actual relative abundance of the species (McCorquodale *et al.* 2011).

Trends in absolute abundance are also biased by search effort. Therefore, relative abundance or the percent composition of a particular species relative to the total number of species is a common approach used to measure insect populations and reduce bias with search effort. For the Nine-spotted Lady Beetle, collection records are compared to all lady beetles (Coccinellidae) collected across similar time periods and geographic range as a proxy of abundance. In addition, collection records are also compared to only native lady beetles collected. As non-native species can potentially experience rapid subpopulation expansion and growth, inclusion of non-native species may produce artificially inflated declines. Conversely, as many species of native lady beetles are in decline across Canada, their use in measures of relative abundance may underestimate declines.

Multiple datasets from collections across Canada (see Collections Examined) were used to assess overall patterns of change in geographic distribution and relative abundance of the Nine-spotted Lady Beetle. The collated dataset contains almost 23,000 records of Coccinellidae from 1895 to 2014, including 1,061 Nine-spotted Lady Beetle specimens dated from 1897 - 2014. McCorquodale *et al.* (2011) visited numerous collections to identify and verify Coccinellidae specimens, before specimen label information was databased. Subsequently, additional museum and specimen data were compiled from surveys and collections during the preparation of this status report (Grant pers. data). Localities were georeferenced so that species could be mapped using geographic information system (GIS) software. Latitude and longitude were taken from labels when available, but for others, the latitude and longitude of the town centre on the label was used, unless a more specific locality could be determined. In 2013 and 2014 there were over 262.4 hours of field surveys conducted across 230 sites within this database (Table 2).

The following methods were used to characterize changes in the distribution of the Nine-spotted Lady Beetle over time and characterize search effort coverage:

1) Changes in the COSEWIC extent of occurrence (EOO) within the last ten years (2005 – 2014) compared to the previous decade (1995 – 2004) and all databased records (1897 – 2014) (Figures 3 – 5).
2) Changes in the COSEWIC index of area of occupancy (IAO) within the last ten years (2005 – 2014) compared to the previous decade (1995 – 2004) and all databased records (1897 – 2014) (Figures 3 – 5).
3) Search effort was combined with potential dispersal distances of 18 km and 120 km (Jeffries *et al.* 2013) to estimate overlap with databased Nine-spotted Lady Beetles sites (Figures 6 – 8).
4) The relative abundance of Nine-spotted Lady Beetles within museum collections, in ten-year increments across each jurisdiction where it is found. Relative abundance of the Nine-spotted Lady Beetle was calculated against all native and non-native lady beetles collected, in addition to all native lady beetles collected (Figure 9; Tables 3 and 4).

These data were supplemented by published research and expert opinion documenting subpopulation and range declines of the Nine-spotted Lady Beetle in North America.

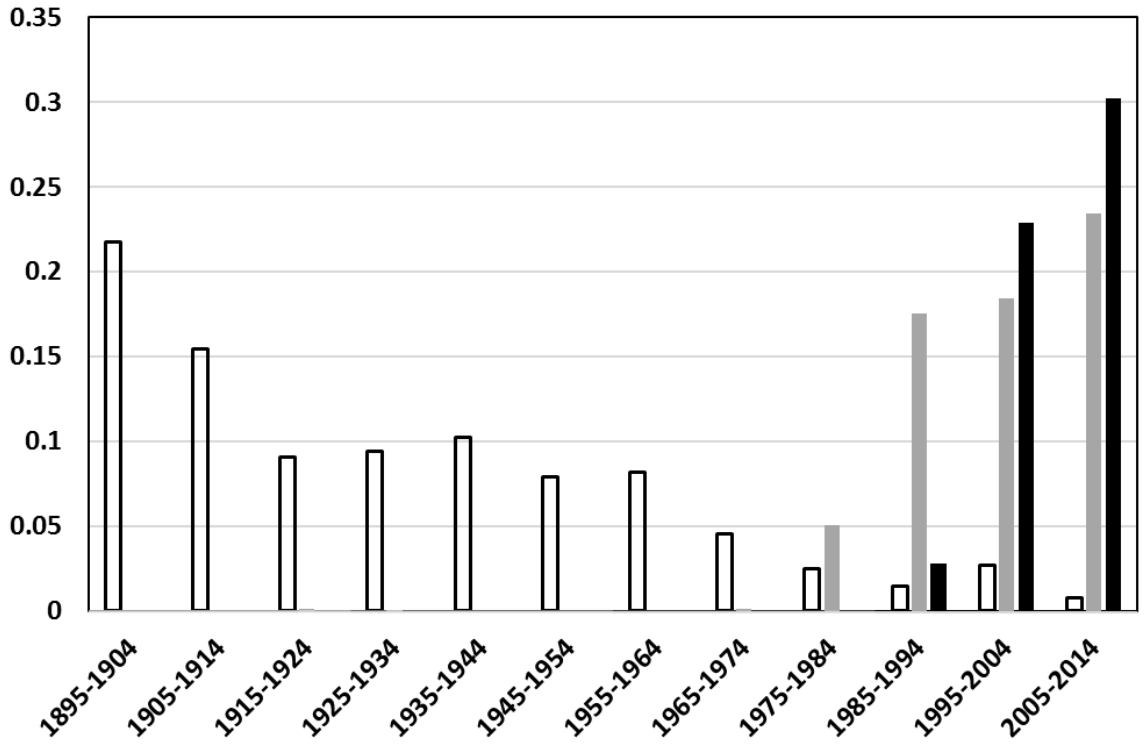

Figure 9. Changes in relative abundance of the native Nine-spotted Lady Beetle (*Coccinella novemnotata*) (white fill), and the non-native Seven-spotted Lady Beetle (*Coccinella septempunctata*) (grey fill) and Multi-coloured Asian Lady Beetle (*Harmonia axyridis*) (black fill) compared to all databased Coccinellidae in BC, AB, SK, MN, ON and QC.

Abundance

Estimating abundance for wide-ranging insects such as the Nine-spotted Lady Beetle is not possible with current available data. As described above, changes in extent of occurrence (EOO), index of area of occupancy (IAO), and relative abundance will be used to measure conservation status.

Based on all databased records and surveys (1897 – 2014), the Nine-spotted Lady Beetle has an EOO of 3,253,910 km^2 and IAO of 1,308 km^2 (Figure 3). During 1995 – 2004 the EOO was calculated as 559,510 km^2 with an IAO of 64 km^2 (Figure 4). During the last decade (2005 – 2014) the EOO increased to 716,847 km^2, but IAO decreased to 40 km^2 (Figure 5). This is an estimated 28% increase in EOO and 37.5% reduction in IAO from the previous decade. The Nine-spotted Lady Beetle is a broadly distributed species across Canada and is highly mobile; surveys have not been complete over its entire range or time. Trends in this species' geographic distribution could reflect issues with survey coverage or detection rather than expansion or retraction of its range.

Historically the Nine-spotted Lady Beetle was widely distributed, occurring in southern British Columbia, Alberta, Saskatchewan, Manitoba, Ontario and Quebec. Within these areas, it was one of the more common lady beetles collected before 1975 (Brown 1940; Gordon 1985) but subsequently declined significantly (Acorn 2007; McCorquodale *et al.* 2011). During the previous decade (1995 – 2004) there were 65 Nine-spotted Lady Beetle records with a relative abundance of 0.027 compared to all native and non-native lady beetles (Coccinellidae) collected (Table 3a). During the last ten years (2005 – 2014), the number of records decreased to 13 from British Columbia, Alberta, and Quebec (Table 3a). During this decade it was not detected in Saskatchewan, and remained undetected in Manitoba, and Ontario, where it was found historically. The relative abundance of the Nine-spotted Lady Beetle therefore declined by -0.019 to only 0.008, which represents a national decline of 70.7% over the last ten years (Table 4a).

As non-native species can potentially experience rapid subpopulation expansion and growth, inclusion of non-native species may produce artificially inflated declines. Therefore, relative abundance calculations for the Nine-spotted Lady Beetle were also compared to only native species (non-native records removed). However, as many species of native lady beetles are in decline across Canada, their use in measures of relative abundance may underestimate declines. Relative abundance of Nine-spotted Lady Beetles, compared to native lady beetles declined from 0.057 (1995 – 2004) to 0.022 (2005 – 2014) (Table 3b), which represents a national decline of 62% over the last ten years (Table 4b). Therefore, national trends of decline are likely greater than 62% and potentially as high as 70.7%. Over the last decade and across the vast majority of its range this species is now absent or continues to decline and likely only persists in extremely low numbers.

Table 3a. Changes in relative abundance (RA) of the Nine-spotted Lady Beetle (NSLB) to native and non-native lady beetles (Coccinellidae) collected in British Columbia, Alberta, Saskatchewan, Manitoba, Ontario and Quebec.

	Decade	BC	AB	SK	MB	ON	QC	Total	Change in RA*
All	1895-1904	78	2	0	9	32	3	**124**	-
NSLB		5	1	0	2	16	3	**27**	
RA		0.064	0.500	0.000	0.222	0.500	1.000	**0.218**	
All	1905-1914	108	27	16	52	80	8	**291**	-0.063
NSLB		11	7	0	1	18	8	**45**	
RA		0.102	0.259	0.000	0.019	0.225	1.000	**0.155**	
All	1915-1924	495	40	0	124	95	16	**770**	-0.064
NSLB		18	20	0	1	18	13	**70**	
RA		0.036	0.500	0	0.008	0.189	0.813	**0.091**	
All	1925-1934	1415	79	5	74	201	156	**1930**	0.003
NSLB		61	27	1	0	24	68	**181**	
RA		0.043	0.342	0.200	0.000	0.119	0.436	**0.094**	
All	1935-1944	340	50	112	46	160	159	**867**	0.009
NSLB		8	2	0	0	12	67	**89**	
RA		0.024	0.040	0.000	0.000	0.075	0.421	**0.103**	
All	1945-1954	816	30	111	350	707	172	**2186**	-0.024
NSLB		25	9	3	2	100	33	**172**	

	Decade	BC	AB	SK	MB	ON	QC	Total	Change in RA*
RA		0.031	0.300	0.027	0.006	0.141	0.192	**0.079**	
All	1955-1964	770	144	82	121	1077	201	**2395**	0.003
NSLB		21	43	5	1	75	51	**196**	
RA		0.027	0.299	0.061	0.008	0.070	0.254	**0.082**	
All	1965-1974	224	79	338	45	648	372	**1706**	-0.037
NSLB		6	13	9	1	30	18	**77**	
RA		0.027	0.165	0.027	0.022	0.046	0.048	**0.045**	
All	1975-1984	543	66	563	402	1637	232	**3443**	-0.020
NSLB		19	7	8	0	36	16	**86**	
RA		0.035	0.106	0.014	0.000	0.022	0.069	**0.025**	
All	1985-1994	874	18	283	759	658	196	**2788**	-0.011
NSLB		28	7	2	1	2	0	**40**	
RA		0.032	0.389	0.007	0.001	0.003	0.000	**0.014**	
All	1995-2004	563	50	178	331	1153	158	**2433**	0.012
NSLB		39	18	7	0	0	1	**65**	
RA		0.069	0.360	0.039	0.000	0.000	0.006	**0.027**	
All	2005-2014	791	193	105	56	242	276	**1663**	-0.019
NSLB		6	6	0	0	0	1	**13**	
RA		0.008	0.031	0.000	0.000	0.000	0.004	**0.008**	

* Change in RA is from previous decade

Table 3b. Changes in relative abundance (RA) of the Nine-spotted Lady Beetle (NSLB) compared to native lady beetles (Coccinellidae) collected in British Columbia, Alberta, Saskatchewan, Manitoba, Ontario and Quebec.

	Decade	BC	AB	SK	MB	ON	QC	Total	Change in RA*
All	1895-1904	67	2	0	9	32	3	**113**	-
NSLB		5	1	0	2	16	3	**27**	
RA		0.075	0.500	0.000	0.222	0.500	1.000	**0.239**	
All	1905-1914	96	27	16	51	80	8	**278**	-0.077
NSLB		11	7	0	1	18	8	**45**	
RA		0.115	0.259	0.000	0.020	0.225	1.000	**0.162**	
All	1915-1924	452	37	0	122	95	16	**722**	-0.065
NSLB		18	20	0	1	18	13	**70**	
RA		0.040	0.541	0.000	0.008	0.189	0.813	**0.097**	
All	1925-1934	1333	79	5	73	201	156	**1847**	0.001
NSLB		61	27	1	0	24	68	**181**	
RA		0.046	0.342	0.200	0.000	0.119	0.436	**0.098**	
All	1935-1944	337	50	112	46	159	158	**862**	0.005
NSLB		8	2	0	0	12	67	**89**	
RA		0.024	0.040	0.000	0.000	0.075	0.424	**0.103**	
All	1945-1954	801	30	111	349	707	172	**2170**	-0.024
NSLB		25	9	3	2	100	33	**172**	
RA		0.031	0.300	0.027	0.006	0.141	0.192	**0.079**	
All	1955-1964	741	144	82	121	1061	199	**2348**	0.004
NSLB		21	43	5	1	75	51	**196**	
RA		0.028	0.299	0.061	0.008	0.071	0.256	**0.083**	

	Decade	BC	AB	SK	MB	ON	QC	Total	Change in RA*
All	1965-1974	217	80	339	45	618	294	**1593**	-0.035
NSLB		6	13	9	1	30	18	**77**	
RA		0.028	0.163	0.027	0.022	0.049	0.061	**0.048**	
All	1975-1984	509	67	563	391	1447	149	**3126**	-0.021
NSLB		19	7	8	0	36	16	**86**	
RA		0.037	0.104	0.014	0.000	0.025	0.107	**0.028**	
All	1985-1994	687	19	245	634	333	115	**2033**	-0.008
NSLB		28	7	2	1	2	0	**40**	
RA		0.041	0.368	0.008	0.002	0.006	0.000	**0.020**	
All	1995-2004	295	37	151	240	355	59	**1137**	0.037
NSLB		39	18	7	0	0	1	**65**	
RA		0.132	0.486	0.046	0.000	0.000	0.017	**0.057**	
All	2005-2014	337	91	33	12	71	54	**598**	-0.035
NSLB		6	6	0	0	0	1	**13**	
RA		0.018	0.066	0.000	0.000	0.000	0.019	**0.022**	

* Change in RA is from previous decade

Table 4a. Percent change in relative abundance over two decades of the Nine-spotted Lady Beetle (NSLB) to all native and non-native lady beetles (Coccinellidae) collected in British Columbia, Alberta, Saskatchewan, Manitoba, Ontario and Quebec.

Province	Collections 1995-2004			Collections 2005-2014			% Change in RA from last decade
	No. Native and Non-native lady beetles	No. of NSLB	RA	No. Native and Non-native lady beetles	No. of NSLB	RA	
BC	563	39	0.069	791	6	0.008	**-89.0**
AB	50	18	0.360	193	6	0.031	**-91.4**
SK	178	7	0.039	105	0	0.000	**-100.0**
MB	331	0	0.000	56	0	0.000	**0.0**
ON	1153	0	0.000	242	0	0.000	**0.0**
QC	158	1	0.006	276	1	0.004	**-42.8**
Total	**2433**	**65**	**0.027**	**1663**	**13**	**0.008**	**-70.7**

Table 4b. Percent change in relative abundance over two decades of the Nine-spotted Lady Beetle (NSLB) to all native lady beetles (Coccinellidae) collected in British Columbia, Alberta, Saskatchewan, Manitoba, Ontario and Quebec.

Province	Collections 1995-2004			Collections 2005-2014			% Change in RA from last decade
	No. Native lady beetles	No. of NSLB	RA	No. Native lady beetles	No. of NSLB	RA	
BC	295	39	0.132	337	6	0.018	**-86.5**

Province	Collections 1995-2004			Collections 2005-2014			% Change in RA from last decade
	No. Native lady beetles	No. of NSLB	RA	No. Native lady beetles	No. of NSLB	RA	
AB	37	18	0.486	91	6	0.066	**-86.4**
SK	151	7	0.046	33	0	0.000	**-100.0**
MB	240	0	0.000	12	0	0.000	**0.0**
ON	355	0	0.000	71	0	0.000	**0.0**
QC	59	1	0.017	54	1	0.019	**9.3**
Total	**1137**	**65**	**0.057**	**598**	**13**	**0.022**	**-62.0**

The decline in relative abundance of Nine-spotted Lady Beetles is concurrent with an increase in collection of non-native species such as the Seven-spotted Lady Beetle and the Multi-coloured Asian Lady Beetle (Figure 9).

McCorquodale *et al.* (2011) also reviewed evidence from literature and collection data from Quebec and Ontario to look at relative abundance and geographic ranges of a subset of 10 species of native and non-native lady beetles over time. This study focused on regions with high quality data, complete over the time period non-natives arrived in Canada. Collections used in this study were made by university students and broad surveys and are a reasonable reflection of local relative abundance. Within this study McCorquodale *et al.* (2011) inferred that Nine-spotted Lady Beetles declined in geographic range and relative abundance from about 18% prior to 1960 to <0.05% after 1980, concurrent with an increase in collection of non-native species. However, the relative abundance of other native species such as the Spotted Lady Beetle (*Coleomegilla maculata lengi*) also increased after the arrival of non-native species (McCorquodale *et al.* 2011). Importantly, this contrast in trends suggest declines of the Nine-spotted Lady Beetle are not explained by collecting bias (McCorquodale *et al.* 2011).

Combined, data on changes in relative abundance and maps of changes in geographic range in Canada suggest that collecting effort has been comprehensive enough to observe lady beetle patterns and these declines are real, not artifacts of inadequate sampling and that the Nine-spotted Lady Beetle, while managing to persist in very low numbers, has continued to decline over the last ten years across its range in Canada.

In the northeastern United States, the decline of the Nine-spotted Lady Beetle 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, yet rarely encountered after 1985. Intensive surveys of lady beetles in Iowa show that Nine-spotted Lady Beetles were common and widespread prior to 1980, but are now very rare or extirpated (Hesler 2009). In Minnesota Nine-spotted Lady Beetles were abundant prior to 1980 but recent search effort suggests this species is absent from or below the detection threshold across the majority of the state (Koch 2011). Harmon *et al.* (2007) reviewed published literature as well as United States Department of Agriculture (USDA) records and concluded the relative abundance of Nine-spotted Lady Beetle subpopulations have declined significantly in the United States and Canada since the 1970s.

In general, trends in the relative abundance of native to non-native lady beetle assemblages of Canada and the United States declined by 68% after 1986 (Harmon *et al.* 2007). A similar study conducted in Michigan over 24 years from 1989 to 2012 found lady beetle assemblages became increasingly non-native dominated with 71% of lady beetles collected being non-native (Bahlai *et al.* 2013). Gardiner *et al.* (2009) found that non-native Seven-spotted Lady Beetles and Multi-coloured Asian Lady Beetles accounted for up to 90% of lady beetle communities in soybean fields in Michigan, Wisconsin and Iowa. Tumminello *et al.* (2015) suggest declines of the Nine-spotted Lady Beetle can be attributed to the establishment, spread and subpopulation increase of the Seven-spotted Lady Beetle. While reasons for the decline in native lady beetles remain unclear, there is a very clear and real trend in declines of native lady beetles across their range, including the Nine-spotted Lady Beetle.

In summary, this once-common lady beetle now appears to be very rare or below detection thresholds in many parts of its range. Continued declines in relative abundance and geographic range have been documented in numerous studies, throughout the Nine-spotted Lady Beetle's range across Canada and the United States (Staines *et al.* 1990; Wheeler and Hoebeke 1995; Marshall 1999; Stephans 2002; Acorn 2007; Harmon *et al.* 2007; Hesler and Kieckhefer 2008; Fothergill and Tindall 2010; Skinner and Domaine 2010; Evans *et al.* 2011; Koch 2011; McCorquodale *et al.* 2011).

Fluctuations and Trends

Natural population fluctuations in lady beetle subpopulations are related to dispersal, prey availability, climatic conditions and overwinter survivorship. However, lady beetles, including the Nine-spotted Lady Beetle, do not experience extreme fluctuations (Acorn 2007; Harmon *et al.* 2007; McCorquodale *et al.* 2011). The recent and steady decline of this species across its entire global range, in many disparate areas, suggests that this trend is not likely a natural fluctuation.

Rescue Effect

The Nine-spotted Lady Beetle is broadly distributed and its range extends into the United States from coast to coast. As this species is highly mobile and readily disperses, subpopulations could potentially disperse and recolonize areas where the Nine-spotted Lady Beetle has declined, provided suitable habitat was available. However, as this species has also declined in the United States, and the reasons for the decline remain unknown, it is unlikely that rescue effect is possible.

THREATS AND LIMITING FACTORS

The International Union for the Conservation of Nature - Conservation Measures Partnership (IUCN-CMP) threats calculator (Salafsky *et al.* 2008; Master *et al.* 2009) was used to classify and list threats to the Nine-spotted Lady Beetle. The results of the threats calculator show an overall threat impact of very high to high (Appendix 1). Threats below are listed in order of highest to lowest threat.

Invasive and other problematic species and genes (Threat 8.)

<u>Invasive non-native/alien species (8.1)</u>

It has been widely reported that the accidental and intentional introduction of non-native species can negatively impact flora and fauna (New 1995; Cottrell and Shapiro-Ilan 2003; Evans 2004; Snyder and Evans 2006; Finlayson *et al.* 2008; Kenis *et al.* 2008; Kajita and Evans 2009; Crowder and Snyder 2010; Smith and Gardiner 2013; Ugine and Losey 2014; Tumminello *et al.* 2015). Insect generalist predators have been introduced outside their native range inadvertently or intentionally as biocontrol agents during the last century (Obrycki and Kring 1998; Evans *et al.* 2011). In North America alone, at least 179 non-native lady beetle species have been introduced, leading to nine non-native species becoming well established in Canada, including the Seven-spotted Lady Beetle and the Multi-coloured Asian Lady Beetle (Gordon 1985; Gordon and Vandenberg 1991; Harmon *et al.* 2007; Evans *et al.* 2011; McCorquodale *et al.* 2011; Bousquet *et al.* 2013). These non-native species continue to be widely available and released for biocontrol.

Significant declines in geographic range and abundance of native lady beetles are frequently due to changes in habitat or interactions with non-native species (New 1995; Cottrell and Shapiro-Ilan 2003; Evans 2004; Snyder and Evans 2006; Finlayson *et al.* 2008; Kenis *et al.* 2008; Kajita and Evans 2009; Crowder and Snyder 2010; Smith and Gardiner 2013; Ugine and Losey 2014; Tumminello *et al.* 2015).

The invasion of the Seven-spotted Lady Beetle and Multi-coloured Asian Lady Beetle into North America has been implicated in an overall reduction in Nine-spotted Lady Beetle and other native lady beetle subpopulations (Wheeler and Hoebeke 1995; Elliott *et al.* 1996; Marshall 1999; Ellis *et al.* 1999; Brown 2003; Cottrell and Shapiro-Ilan 2003; Turnock *et al.* 2003; Hesler *et al.* 2004; Acorn 2007; Harmon *et al.* 2007; Hesler and Kieckhefer 2008; Fothergill and Tindall 2010; Skinner and Domaine 2010; Evans *et al.* 2011; Losey *et al.* 2012; Comont *et al.* 2013; Turnipseed *et al.* 2014; Ugine and Losey 2014; Tumminello *et al.* 2015). Most explanations for this reduction in native subpopulations focus on negative interactions through competition, intraguild predation or indirect effects such as the introduction of pathogens (Schaefer *et al.* 1987; Ehler 1990; Cottrell and Shapiro-Ilan 2003; Louda *et al.* 2003; Evans 2004; Lucas 2005; Snyder and Evans 2006; Lucas *et al.* 2007; Kenis *et al.* 2008; Riddick *et al.* 2009; Evans *et al.* 2011; Turnipseed *et al.* 2014; Ugine and Losey 2014; Tumminello *et al.* 2015).

Competition and intraguild predation:

The geographic distribution of Nine-spotted Lady Beetles has declined rapidly across North America closely following the establishment, spread and subpopulation growth of non-native Seven-spotted Lady Beetles and Multi-coloured Asian Lady Beetles (Turnipseed *et al.* 2014; Ugine and Losey 2014; Tumminello *et al.* 2015). Before the 1980s Nine-spotted Lady Beetles were a fairly common lady beetle in North America (Gordon 1985; Tumminello *et al.* 2015). However, declines of Nine-spotted Lady Beetles were not widely recognized until the mid-1990s, almost 20 years after the arrival and subsequent spread and establishment of non-native lady beetles (Wheeler and Hoebeke 1995; McCorquodale *et al.* 2011).

Hodek and Michaud (2008) argued that the Seven-spotted Lady Beetle is a good competitor under a wide variety of conditions. Its ability to compete for food, mate, and lay eggs under a variety of conditions result in its doing well overall, rather than its being the best under a particular set of conditions (Hodek and Michaud 2008; McCorquodale *et al.* 2011). Losey *et al.* (2012) determined that scramble competition with Seven-spotted Lady Beetles has resulted in limited prey availability and decreased body size of Nine-spotted Lady Beetles. In support of scramble competition, where a finite resource is accessible to all competitors, Hoki *et al.* (2014) showed that Seven-spotted Lady Beetles were more voracious, had a higher aphid attack rate and lower aphid handling time compared with Nine-spotted Lady Beetles. Tumminello *et al.* (2015) also investigated scramble competition and intraguild predation, concluding that the displacement of the Nine-spotted Lady Beetle from its native range was likely driven by the Seven-spotted Lady Beetle, based on its faster development times, higher attack rate, larger body size and high rate of intraguild predation of Nine-spotted Lady Beetle.

Other studies have also shown that Nine-spotted Lady Beetle larvae are more likely to survive to become adults when reared with native larvae than with Seven-spotted Lady Beetle larvae, due to low predation rates on their eggs and larvae by native species (Turnipseed *et al.* 2014). Similar results were found for other native and introduced lady beetle species (Obrycki *et al.* 1998; Michaud 2002; Sato *et al.* 2004; Snyder *et al.* 2004; Lucas *et al.* 2007; Pell *et al.* 2008; Gardiner *et al.* 2011; Hodek *et al.* 2012; Smith and Gardiner 2013). Intraguild predation also plays a major role in preventing recolonization by native lady beetles, and females also avoid oviposition sites where intraguild predators are present (Ruzicka 1997; Hodek *et al.* 2012). Establishment of Seven-spotted Lady Beetles in agricultural landscapes has also resulted in documented declines of native lady beetles and aphid density (Alyokhin and Sewell 2004; Evans 2004).

Despite documented declines in subpopulations 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.* 2007), the links between the non-native species and causes of the declines are not clear. For example, Acorn (2007) and Harmon *et al.* (2007) argued that there is little direct evidence that competition or other interactions with recently arrived non-native species have caused the declines in native species. While trends are consistent with expectations if Seven-spotted Lady Beetles and Multi-coloured Asian Lady Beetles negatively impact Nine-spotted Lady Beetles through scramble competition and intraguild predation, other potential mechanisms include introduction of parasitoids or pathogens (Losey *et al.* 2012).

Parasites, parasitoids, pathogens and fungi:

Non-native species may also affect native lady beetles indirectly through the introduction and transmission of new natural enemies such as parasites and pathogens (Bjornson 2008). Lady beetles are hosts to a variety of parasitoids (i.e., braconid wasp), parasitic mites (i.e., *Coccipolipus hippodamiae*), nematodes, protozoans, fungal pathogens (i.e., *Beauveria bassiana*), microsporidia (Nosematidae), and bacteria can all negatively impact lady beetle fitness and reduce survivorship overwinter (Cali and Briggs 1967; Hurst *et al.* 1995; Ceryngier and Hodek 1996; Barron and Wilson 1998; Webberley and Hurst 2002; Cottrell and Shapiro-Ilan 2003; Webberley *et al.* 2004; Bjornson 2008; Roy and Cottrell 2008; Riddick *et al.* 2009; Bjornson *et al.* 2011). Although the effect of these natural enemies on the Nine-spotted Lady Beetle is uncertain, native species often have a greater susceptibility to exotic pathogens (Cottrell and Shapiro-Ilan 2003). Obrycki (1989) reported on greater susceptibility of native lady beetles to the braconid wasp parasitoid compared to non-native species, such as the Multi-coloured Asian Lady Beetle. Cottrell and Shapiro-Ilan (2003) also reported on greater susceptibility of native lady beetles to a fungal pathogen (*Beauveria bassiana*) compared to the Multi-coloured Asian Lady Beetle. Greater susceptibility to exotic pathogens may therefore provide an intraguild advantage to non-native lady beetles and could have been a contributing factor in declines of Nine-spotted Lady Beetles.

Pollution (Threat 9.)

Agricultural and forestry effluents (9.3)

While lady beetles can be more tolerant of pesticides than their prey (Gesraha 2007), pollution via agrochemicals to reduce insect pests can impact non-target lady beetles directly through topical contact; residual contact; inhalation of volatiles; and ingestion of insecticide-contaminated prey, nectar or pollen (Smith and Krischik 1999; Youn *et al.* 2003; Singh *et al.* 2004; Moser *et al.* 2008; Moser and Obrycki 2009; Eisenback *et al.* 2010) and indirectly through eliminating their food supply (Hodek *et al.* 2012; Bahlai *et al.* 2015). Zoophytophagy, omnivorous feeding behaviour that occurs when plant material (pollen, nectar, leaf tissue) is consumed by primarily predaceous species, increases fecundity and reduces development time (Coll 1998; Patt *et al.*, 2003; Moser and Obrycki 2009). However, zoophytophagy can also be harmful if the plant material is chemically protected by insecticides (Moser and Obrycki 2009). Lady beetle susceptibility to insecticides varies with the species and the type of pesticide and can range from acute lethal effects to reduction in fecundity, behaviourally or reproductively by non-lethal concentrations of insecticides (Theiling and Croft 1988). Many insect predators exposed to more than one compound suffer synergistic detrimental effects, even for compounds that were equitably harmless when tested separately (Petersen 1993).

In urban and agricultural landscapes, lady beetle subpopulations may be threatened by a variety of pesticides including neonicotinoids, insect growth regulators and broad-spectrum pyrethroids, which tend to be more destructive to lady beetles than organophosphates (Kumar and Bhatt 2002; Moser and Obrycki 2009). Insect growth regulators such as buprofezen and pyriproxyfen generally lack acute toxicity to lady beetles, but may impair development and fecundity (Olszak *et al.* 1994). Neonicotinoids are a class of systemic pesticides that travel and accumulate throughout the plant, including in pollen and nectar. While very effective against plant pests, especially aphids, these pesticides have proven to be detrimental to insects at concentrations in the parts per billion (ppb) (Smith and Krischik 1999; Marletto *et al.* 2003). Neonicotinoids can also be applied to seeds prior to planting to protect seedlings from early-season root and leaf-feeding. In one study 72% of Multi-coloured Asian Lady Beetle larvae (*Harmonia axyridis*) exposed to seedlings treated with neonicotinoids developed neurotoxic symptoms (trembling, paralysis, and loss of coordination) from which only 7% recovered (Moser and Obrycki 2009). Therefore, the use of neonicotinoids may have negative effects on non-target species especially if zoophytophagy occurs.

Natural System Modifications (Threat 7.)

Other ecosystem modifications (7.3)

Abandonment of managed lands and farms, specifically in eastern Canada, could potentially be a factor in the decline of the Nine-spotted Lady Beetle (Bucknell and Pearson 2007; Harmon *et al.* 2007). Urban expansion and abandonment of farmland may mean less favourable foraging for the Nine-spotted Lady Beetle (Harmon *et al.* 2007). While these large-scale changes in habitat and prey availability suggest a possible explanation, there are no data to demonstrate causality between a changing landscape and lady beetle densities (Elliott and Kieckheffer 1990; Elliott *et al.* 1999; Harmon *et al.* 2007).

Agriculture and Aquaculture (Threat 2.)

Habitat loss and declines in habitat quality are ongoing throughout the species' range (Federal, Provincial and Territorial Governments of Canada 2010; Javorek and Grant 2011). Homogenization of agricultural landscapes and changing agricultural practices such as intensive reliance on fertilizers and pesticides may also be contributing to local declines in native species (Wheeler and Hoebeke 1995; Bianchi *et al.* 2007; Evans *et al.* 2011). This is discussed in the pollution section (Threat 9).

Planting of genetically modified (GM) insect-resistant crops, e.g., GM maize engineered to express *Bacillus thuringiensis* (Bt) toxins was considered a potential risk to lady beetles because the toxin was present in pollen (Harwood *et al.* 2007), but not present in aphids (Hodek *et al.* 2012). While most studies have found no effect of Bt corn pollen consumption on fitness parameters of lady beetles (Duan *et al.* 2002; Lundgren and Wiedenmann 2002; Porcar *et al.* 2010), others have detected reduced fecundity and developmental delays (Moser *et al.* 2008).

Residential and Commercial Development (Threat 1.)

Habitat loss and declines in habitat quality from expansion of residential and commercial developments may be contributing to local declines of this species. Green areas and local gardens within smaller urbanized area, however, may also still provide habitat for the Nine-spotted Lady Beetle.

Number of Locations

It is not possible to calculate the number of locations for this species. The term 'location' defines a geographically or ecologically distinct area in which a single threatening event can rapidly affect all individuals of the taxon present. This species has a very broad geographic range, it is highly mobile and threats to it remain unclear. In absence of clearly defined threats over its range, the term 'location' cannot be used and the subcriteria that refer to the number of locations will not be met.

In regard to the number of sites, within the last ten years there have been thirteen records of the Nine-spotted Lady Beetle in Canada from nine sites: two sites in Cranbrook (BC); one site in Kamloops (BC); one site in Osoyoos (BC); two sites in Williams Lake (BC); one site in Calgary (AB); one site in Cardston (AB); three sites in Medicine Hat (AB); one site in Steveville (AB); and one site in Mont St-Hilaire (QC). Given its broad geographic range and dispersal ability, it is likely this species occurs at additional sites throughout its range.

PROTECTION, STATUS AND RANKS

Legal Protection and Status

There are no federal or provincial laws that protect the Nine-spotted Lady Beetle, mitigate threats to this group of insects or protect the species' nest sites or habitat.

In Quebec, this species is not currently listed as Threatened or Vulnerable (LEMV 2015). However, it is integrated on the list of Threatened or Vulnerable species (LEMV 2015) and therefore considered an at-risk species and afforded protection under sections 22 and 31.1 of the "Loi sur la qualité de l'environnement" (RLRQ, c. Q-2) (*Environment Quality Act*) (CQLR, c. Q-2).

Non-Legal Status and Ranks

The global status rank is G2 (imperilled) and the national status rank is unranked in Canada and the United States (NatureServe 2014). It is also unranked in most states, provinces and territories, but considered possibly extirpated in Alberta (SNR), Ontario (SH), Connecticut (SH), and Florida (SH).

The Canada National Status Ranks (Canadian Endangered Species Conservation Council [CESCC 2010]): Sensitive in Canada and provincially in NT, BC, AB and SK; Maybe At Risk in MN; Extirpated in ON and QC.

The IUCN Red list (2013): None

The species has not been reviewed or listed under the USA - federal *Endangered Species Act*.

Habitat Protection and Ownership

Given the expansive range and broad habitat niche of the Nine-spotted Lady Beetle across Canada, several suitable areas of habitat occur within privately owned, urban and agricultural land, public land and protected areas.

The Canadian range of Nine-spotted Lady Beetle spans numerous provincial and national parks and protected areas.

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BIOGRAPHICAL SUMMARY OF REPORT WRITER(S)

Dr. Paul Grant is an avid entomologist who has worked with many insect groups including dragonflies, butterflies, katydids and beetles. Currently, his research focus involves insect bioacoustics, specifically, the limitations and solutions for effective communication, predator-prey relationships, and utilizing insect calls to monitor species and habitats. Paul is also a Grasshopper Specialist Group member (GSG) for the International Union for Conservation of Nature & Species Survival Commission (IUCN / SSC) and Co-Chair for the Arthropod Species Specialist Committee (SSC) for the Committee on the Status of Endangered Wildlife in Canada (COSEWIC).

COLLECTIONS EXAMINED

- Acadia University *
- Atlantic Forestry Centre, Fredericton *
- Canadian Forestry Service, Newfoundland *
- Canadian National Collection, Ottawa
- Canadian Museum of Nature *
- Claude Chantal Collection, Quebec
- Collection d'insecte du Québec
- Collection Ouellet-Robert, Quebec
- Great Lakes Forestry Centre *
- Greg Pohl pers. comm. 2014
- Insectarium Montréal
- IRM Collection, Quebec
- John Acorn pers. comm. 2014
- Laurentian Forestry Centre *
- Lost Lady Bug Project
- Musée d'Entomologie Lyman
- Nova Scotia Agricultural College *
- Royal Alberta Museum
- Royal BC Museum
- Royal Ontario Museum *
- Université Laval
- University of Alberta
- University of British Columbia
- University of Guelph *
- University of Manitoba
- University of New Brunswick *

* *Databased by David McCorquodale (McCorquodale* et al*. 2011)*

Appendix 1. IUCN Threats calculation on the Nine-spotted Lady Beetle.

Species Scientific name:	Nine-spotted Lady Beetle - *Coccinella novemnotata*
Date:	February 13, 2015
Assessor(s)	Paul Grant (Author) Jenny Heron (Co-chair); Angele Cyr (COSEWIC), Dave McCorquodale (Arthropods SSC); Syd Cannings (CWS); Michelle (CWS-QC)
	References:

Overall Threat Impact Calculation		**Level 1 Threat Impact Counts**	
Threat Impact		**high range**	**low range**
A	Very High	0	0
B	High	2	0
C	Medium	0	1
D	Low	2	3
Calculated Overall Threat Impact:		Very High	High

Threat		**Impact (calculated)**	**Scope (next 10 Yrs)**	**Severity (10 Yrs or 3 Gen.)**	**Timing**	**Comments**
1	**Residential & commercial development**	Negligible	Small (1-10%)	Negligible (<1%)	High (Continuing)	
1.1	Housing & urban areas	Negligible	Small (1-10%)	Negligible (<1%)	High (Continuing)	Habitat loss and declines in habitat quality from expansion of residential developments may be contributing to local declines of this species. However green areas and local gardens within smaller urbanized areas may provide habitat for the Nine-spotted Lady Beetle.
1.2	Commercial & industrial areas	Negligible	Negligible (<1%)	Negligible (<1%)	High (Continuing)	Habitat loss and declines in habitat quality from expansion of commercial developments may be contributing to local declines of this species, but overall this threat is considered negligible.
1.3	Tourism & recreation areas	Negligible	Negligible (<1%)	Negligible (<1%)	High (Continuing)	Habitat loss and declines in habitat quality from recreation and tourism is low because most recreation areas have open areas that are suitable for Lady Beetles.
2	**Agriculture & aquaculture**	Low	Small (1-10%)	Slight (1-10%)	High (Continuing)	
2.1	Annual & perennial non-timber crops	Low	Small (1-10%)	Slight (1-10%)	High (Continuing)	Habitat loss and declines in habitat quality are ongoing throughout the species range (Federal, Provincial and Territorial Governments of Canada 2010; Javorek and Grant 2011). Homogenization of agricultural landscapes, and changing agricultural practices such as intensive reliance on fertilizers and pesticides could also contribute to local declines in native species (Wheeler and Hoebeke 1995; Bianchi *et al.* 2007; Evans *et al.* 2011). This is discussed in the pollution section below (Threat 9).

Threat		Impact (calculated)	Scope (next 10 Yrs)	Severity (10 Yrs or 3 Gen.)	Timing	Comments
2.2	Wood & pulp plantations	Negligible	Negligible (<1%)	Negligible (<1%)	High (Continuing)	Negligible. Wood and pulp plantations are typically not botanically diverse, and this may lead to less prey (aphids). In the prairies wood and pulp plantations are not important.
2.3	Livestock farming & ranching	Negligible	Small (1-10%)	Negligible (<1%)	High (Continuing)	Negligible. Grazing may have a direct impact on lady beetles, by direct consumption. This is unlikely a major factor. There are extensive areas of southern Alberta that are grazed, and Nine-spotted Lady Beetle has been recorded from some of these areas. Grazing may also be beneficial - may allow for the creation of open habitat.
2.4	Marine & freshwater aquaculture					Not applicable.
3	**Energy production & mining**					
3.1	Oil & gas drilling					Not applicable. Potential benefits are likely to offset detriments. Roads and seismic lines and open linear features that have new generation growth/grasses, may create some habitat and help with dispersal. Overall, it is likely not a threat, perhaps somewhat beneficial.
3.2	Mining & quarrying					Not applicable. Some sand quarrying can be beneficial to this species in habitat creation.
3.3	Renewable energy					Not applicable. Access roads and disturbed habitats may potentially benefit the species. Likely not a threat due to preference for open habitat.
4	**Transportation & service corridors**					
4.1	Roads & railroads					Potential benefit (see Threat 3). Likely not a threat due to preference for open habitat.
4.2	Utility & service lines					Potential benefit (see Threat 3). Likely not a threat due to preference for open habitat.
4.3	Shipping lanes					Not applicable.
4.4	Flight paths					Not applicable.
5	**Biological resource use**					
5.1	Hunting & collecting terrestrial animals					Not applicable. This species isn't collected in the wild for biological control. Most harvested species come from the United States; or reared from culture.
5.2	Gathering terrestrial plants					Not applicable.
5.3	Logging & wood harvesting					Not applicable. Clearcutting would likely have a positive short-term impact for the species. Most of the species range is on the prairies and more open habitats.
5.4	Fishing & harvesting aquatic resources					Not applicable.
6	**Human intrusions & disturbance**					
6.1	Recreational activities					Not applicable.
6.2	War, civil unrest & military exercises					Not applicable.

Threat		Impact (calculated)	Scope (next 10 Yrs)	Severity (10 Yrs or 3 Gen.)	Timing	Comments
6.3	Work & other activities					Not applicable.
7	**Natural system modifications**	Low	Restricted - Small (1-30%)	Moderate - Slight (1-30%)	High (Continuing)	
7.1	Fire & fire suppression					Not applicable. Fire in general creates open habitat and succession of flowering plants which would likely have a net benefit in certain regions.
7.2	Dams & water management/use					Not applicable.
7.3	Other ecosystem modifications	Low	Restricted - Small (1-30%)	Moderate - Slight (1-30%)	High (Continuing)	Abandonment of managed lands and farms, primarily in eastern Ontario, could potentially be a factor in the decline of the Nine-spotted Lady Beetle. These areas have ongoing natural forest succession. Urban expansion and abandonment of farmland may mean less favorable foraging for the Nine-spotted Lady Beetle.
8	**Invasive & other problematic species & genes**	High - Medium	Pervasive (71-100%)	Serious - Moderate (11-70%)	High (Continuing)	
8.1	Invasive non-native/alien species	High - Medium	Pervasive (71-100%)	Serious - Moderate (11-70%)	High (Continuing)	Insect generalist predators have been introduced outside of their native range inadvertently or intentionally as biocontrol agents since the late nineteenth century. Significant declines in geographic range and abundance of native insects are frequently due to changes in habitat or interactions with non-native species. The invasion of the Seven spotted Lady Beetle (*Coccinella septempunctata*), into North America has been implicated in an overall reduction in Nine-spotted Lady Beetle and other native lady beetle subpopulations. Most explanations focus on interactions with the recently arrived non-native species through competition, intraguild predation or indirect effects of through introduction of pathogens. Introduced weeds may not be good for native lady beetles. Pathogens are potentially a large threat to this species.
8.2	Problematic native species					Not applicable. No known native birds or beetle predators that are problematic.
8.3	Introduced genetic material					Not applicable.
9	**Pollution**	High - Low	Large - Restricted (11-70%)	Serious - Moderate (11-70%)	High (Continuing)	
9.1	Household sewage & urban waste water					Not applicable.
9.2	Industrial & military effluents					Not applicable.
9.3	Agricultural & forestry effluents	High - Low	Large - Restricted (11-70%)	Serious - Moderate (11-70%)	High (Continuing)	Pesticides used in agricultural areas have potential to directly impact lady beetles but also indirectly impact food source by killing aphids on crop plants.
9.4	Garbage & solid waste					Not applicable.

Threat		Impact (calculated)	Scope (next 10 Yrs)	Severity (10 Yrs or 3 Gen.)	Timing	Comments
9.5	Air-borne pollutants					Not applicable.
9.6	Excess energy					Not applicable.
10	**Geological events**					
10.1	Volcanoes					Not applicable.
10.2	Earthquakes/tsunamis					Not applicable.
10.3	Avalanches/landslides					Not applicable.
11	**Climate change & severe weather**					
11.1	Habitat shifting & alteration					Unknown. Habitat may be shifting for the lady beetle, however, over the next ten years should not be major but the effect beyond the changes in the next ten years may be significant.
11.2	Droughts					Unknown. When trees get stressed, they become vulnerable to aphids and other insect pests, so it's hard to ascribe a severity to drought.
11.3	Temperature extremes					Unknown. Late season frosts may effect plants, aphids and lady beetles. Some stressors improve aphids and others are a detriment.
11.4	Storms & flooding					Not applicable.