

COSEWIC
Assessment and Status Report

on the

Transverse Lady Beetle
Coccinella transversoguttata

in Canada



SPECIAL CONCERN
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:

COSEWIC. 2016. COSEWIC assessment and status report on the Transverse Lady Beetle *Coccinella transversoguttata* in Canada. Committee on the Status of Endangered Wildlife in Canada. Ottawa. xi + 57 pp. (<http://www.registrelep-sararegistry.gc.ca/default.asp?lang=en&n=24F7211B-1>).

Production note:

COSEWIC would like to acknowledge Paul Grant for writing the status report on the Transverse Lady Beetle (*Coccinella transversoguttata*) in Canada, prepared under contract with Environment and Climate Change Canada. This status report was overseen and edited by Jennifer Heron, Co-chair of the COSEWIC Arthropods Specialist Subcommittee.

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Également disponible en français sous le titre Évaluation et Rapport de situation du COSEPAC sur la Coccinelle à bandes transverses (*Coccinella transversoguttata*) au Canada.

Cover illustration/photo:

Transverse Lady Beetle — Photo by Steve Marshall.

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Catalogue No. CW69-14/742-2017E-PDF

ISBN 978-0-660-07724-6



COSEWIC Assessment Summary

Assessment Summary – November 2016

Common name

Transverse Lady Beetle

Scientific name

Coccinella transversoguttata

Status

Special Concern

Reason for designation

This species was once common and broadly distributed throughout most of Canada. Declines started in the 1970s and the species is now absent in southern Ontario and the Maritimes. In some parts of its western and northern range, the species is still commonly recorded. The spread of non-native lady beetles is considered one of the possible threats to this species through competition, intraguild predation, or introduction of pathogens. Non-native lady beetles are less commonly found in places where this species remains.

Occurrence

Yukon, Northwest Territories, Nunavut, British Columbia, Alberta, Saskatchewan, Manitoba, Ontario, Quebec, New Brunswick, Prince Edward Island, Nova Scotia, Newfoundland and Labrador

Status history

Designated Special Concern in November 2016.



COSEWIC Executive Summary

Transverse Lady Beetle *Coccinella transversoguttata*

Wildlife Species Description and Significance

Transverse Lady Beetles are small, round beetles (5.0 to 7.8 mm) that are native to North America. Adults have orange to red wing covers with black markings, consisting of a black band and four elongate spots, which distinguish them from other species. 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 Transverse Lady Beetle is a wide-ranging species occurring from coast to coast across Canada and the United States. The Canadian range of the Transverse Lady Beetle stretches from St. John's, Newfoundland and Labrador, west to Vancouver Island. The northernmost extent of its range includes Yukon, the Northwest Territories and likely Nunavut.

Habitat

Transverse Lady Beetles are habitat generalists, primarily feeding on aphids and occurring across a wide range of habitats. This lady beetle inhabits agricultural areas, suburban gardens, parks, coniferous forests, deciduous forests, prairie grasslands, meadows, riparian areas and other natural areas. This broad habitat range reflects their ability to exploit seasonal changes in prey availability across different vegetation types.

Biology

Transverse 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 to overwinter 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. In general lady beetles are very mobile, display low site fidelity, and readily engage in short (few hundred metres) and long (18 – 120 km) distance dispersal. This species does not migrate. Both adult and larval stages are predatory and primarily prey on aphids. In turn,

this species is also subject to predation by other invertebrates, vertebrates, and is susceptible to parasitoids and pathogens.

Population Sizes and Trends

The historically broad geographic range and abundance of the Transverse Lady Beetle stands in stark contrast to its current distribution. Prior to 1986, this species was widely distributed and abundant across North America and was one of the most common lady beetles collected. Currently, in many parts of its range this species is either absent or below detection thresholds where it was formerly common. In other regions it persists in low numbers. In Yukon, the Northwest Territories and British Columbia, however, this species seems to be abundant and common. These regions also have a smaller proportion of non-native lady beetle species, which are considered one of the potential threats to this species and other native lady beetles.

Threats and Limiting Factors

The specific range-wide causes of decline in the Transverse Lady Beetle are currently unknown. Possible threats to this species may include negative interactions with recently arrived non-native species, such as the Seven-spotted Lady Beetle and Multicolored Asian Lady Beetle through competition, intraguild predation or indirect effects through introduction of pathogens. Other possible localized and cumulative threats include land use changes, such as direct and indirect effects of agricultural pesticide/chemical use to control their prey species, habitat loss through urban expansion, conversion of farmland to forest, and other human disturbances.

Protection, Status and Ranks

There are no laws in Canada that protect the Transverse Lady Beetle. This species has not yet been ranked globally or nationally. The Conservation Data Centres across Canada have assigned conservation status ranks as follows: ON: S1, YT: S4; NT: S4S5; BC: S5; AB, SK, MB: S4S5; ON: S1; QC: S4; NB, NS, PE: SH; NF: SU; NF (Labrador only): S5.

TECHNICAL SUMMARY

Coccinella transversoguttata

Transverse Lady Beetle

Coccinelle à bandes transverses

Range of occurrence in Canada: Alberta, British Columbia, Manitoba, New Brunswick, Newfoundland and Labrador, Nova Scotia, Northwest Territories, Ontario, Prince Edward Island, Quebec, Saskatchewan, Yukon, Nunavut.

Demographic Information

Generation time	Two generations per year.
Is there an [observed, inferred, or projected] continuing decline in number of mature individuals?	Inferred. There are inferred continuing declines based on past declines. Over the last ten years this species has remained undetected in areas where it was formerly common (SK, ON, NB, NS) or detected in low numbers (QC, AB). In other parts of its range (BC, YT, NT and likely NU) it remains 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]	Unknown. Historical declines. Over the last 10 years it has remained undetected in areas where it was formerly common (SK, ON, NB, NS) or detected in low numbers (QC, AB). Currently, it is common in BC, YT, NT and likely NU.
[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. c. Unknown.
Are there extreme fluctuations in number of mature individuals?	No.

Extent and Occupancy Information

Estimated extent of occurrence (EOO)	<p>10.6 million km² (all records 1889 – 2015).</p> <p>EOO > 6.9 million km² (2006 – 2015)</p> <p>Trends in this species' geographic distribution reflect issues with survey coverage and detection rather than expansion or contraction of its range.</p>
Index of area of occupancy (IAO) (Always report 2x2 grid value).	<p>Inferred IAO is > 2,000 km².</p> <p>Trends in this species' geographic distribution reflect issues with survey coverage and detection rather than expansion or contraction of its range.</p>
Is the population "severely fragmented"	<p>No.</p> <p>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.</p>
Number of "locations" (use plausible range to reflect uncertainty if appropriate)	<p>Not applicable.</p> <p>It is not possible to calculate the number of locations for this species. This species has a broad geographic range, low site fidelity, and threats that are not entirely clear.</p>
Is there an [observed, inferred, or projected] decline in extent of occurrence?	<p>No. Inferred.</p> <p>Surveys have not been systematic or comprehensive over the species' range or through time; therefore trends in this species EOO reflect issues with survey coverage and detection rather than expansion or contraction of its range. This species has undergone historical declines (> 10 years before this assessment) although it remains undetected in areas where it was formerly common (SK, ON, NB, NS) or detected in low numbers (QC, AB). In other parts of its range (BC, YT, NT and likely NU) it remains common. It is plausible that the EOO for this species has not changed significantly, even though it has declined in abundance in some regions.</p>

Is there an [observed, inferred, or projected] decline in index of area of occupancy?	Unknown. Surveys have not been systematic or comprehensive over the species' range or through time; therefore trends in this species EOO reflect issues with survey coverage and detection rather than expansion or contraction of its range. This species has undergone historical declines (> 10 years before this assessment) although it remains undetected in areas where it was formerly common (SK, ON, NB, NS) or detected in low numbers (QC, AB). In other parts of its range (BC, YT, NT and likely NU) it remains common. It is plausible that the IAO for this species has not changed significantly, even though it has declined in abundance in some regions.
Is there an [observed, inferred, or projected] decline in number of subpopulations?	Yes. Observed and inferred. Over the last ten years this species has remained undetected in areas where it was formerly common.
Is there an [observed, inferred, or projected] decline in number of "locations"?*	Not applicable. 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.
Are there extreme fluctuations in number of subpopulations	No.
Are there extreme fluctuations in number of "locations"?	No.
Are there extreme fluctuations in extent of occurrence?	No.
Are there extreme fluctuations in index of area of occupancy?	No.

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

Was a threats calculator was completed for this species? Yes, overall threat impact High-Medium.

8.1 Introduced species, Parasites/ Pathogens (High – Medium impact);

9.3 Pesticide Use (Low impact);

7.3 Other ecosystem modifications (Low impact).

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 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? ⁺	Likely, in some parts of the species' range.
Are conditions for the source population deteriorating? ⁺	Yes, in some parts of the species' range.
Is the Canadian population considered to be a sink? ⁺	Unknown.
Is rescue from outside populations likely?	Unlikely. Populations have declined throughout its range in the United States.

Data Sensitive Species

Is this a data sensitive species?	No.
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Status History

COSEWIC: Designated Special Concern in November 2016.

Status and Reasons for Designation:

Status: Special Concern	Alpha-numeric codes: Not applicable
Reasons for designation: This species was once common and broadly distributed throughout most of Canada. Declines started in the 1970s and the species is now absent in southern Ontario and the Maritimes. In some parts of its western and northern range, the species is still commonly recorded. The spread of non-native lady beetles is considered one of the possible threats to this species through competition, intraguild predation, or introduction of pathogens. Non-native lady beetles are less commonly found in places where this species remains.	

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

Applicability of Criteria

Criterion A (Decline in Total Number of Mature Individuals): Not applicable. Insufficient information on population trends.

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

on the

Transverse Lady Beetle

Coccinella transversoguttata

in Canada

2016

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WILDLIFE SPECIES DESCRIPTION AND SIGNIFICANCE

Name and Classification

Class	Insecta – insects
Subclass	Pterygota – winged insects
Order	Coleoptera – beetles
Family	Coccinellidae – lady beetles
Genus	<i>Coccinella</i>
Species	<i>Coccinella transversoguttata</i> Falderman, 1835
Subspecies	<i>Coccinella transversoguttata richardsoni</i> Brown, 1962
Scientific name:	<i>Coccinella transversoguttata richardsoni</i>
English Common Names:	Transverse Lady Beetle
French Common Name:	Coccinelle à bandes transverses

The family Coccinellidae contains approximately 6,000 species worldwide in about 360 genera (Vandenberg 2002; Giorgi and Vandenberg 2009). In Canada there are approximately 60 genera containing 161 species, including nine non-native species that are now well established throughout the country (Hodek *et al.* 2012; Bousquet *et al.* 2013). The taxonomy, identification and geographic distribution of lady beetles in Canada are relatively well known (Dobzhansky 1935; Watson 1956; Brown 1962; Brown and de Ruelle 1962; Belicek 1976; Watson 1976; Laroche 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).

Coccinella transversoguttata (Transverse Lady Beetle) is widely distributed in the Holarctic region and is represented by four subspecies in the New World and one subspecies from the Old World (Kovář 2005). All *C. transversoguttata* subspecies are distinct morphologically and geographically (Brown 1962; Gordon 1985; Kovář 2005). Subspecies *C. t. transversoguttata* occurs in China, Kazakhstan, Kyrgyzstan, Mongolia, Nepal, and Russia (Kovář 2005). Two subspecies *C. t. nugatoria* and *C. t. sonora* occur in Mexico and *C. t. ephippiata* occurs in Greenland (Kovář 2005).

Only the subspecies *C. t. richardsoni* occurs north of Mexico. It is widely distributed in Canada and the United States (Kovář 2005). Because it is the only subspecies that occurs in Canada, this report will assess the full species (*Coccinella transversoguttata*).

Morphological Description

Lady Beetles are holometabolous insects, meaning they have four developmental life stages (egg, larva, pupa and adult). Each stage is morphologically different from the next.

Adults:

Colour pattern is sufficient to distinguish adult Transverse Lady Beetles from other lady beetles (Gordon 1985). In comparison to other lady beetles, the Transverse Lady Beetle is considered relatively large. Adults are round, slightly oval beetles measuring 5.0 to 7.8 mm in length (Figure 1). Their elytra (wing covers) are orange to red with black markings. The markings include a black band behind the pronotum stretching across both elytra and two elongated black markings posteriorly on each elytra. The pronotum is black with white markings on either side. The head is black with two well separated pale spots. Adults do not show exaggerated sexual dimorphism (Stellwag and Losey 2014).



Figure 1. Transverse Lady Beetle (*Coccinella transversoguttata richardsoni*). Photo by Steve Marshall.

Eggs:

No detailed description for this species exists. Other *Coccinella* species have yellow-to orange-coloured elongate eggs, approximately 1 mm in length that are laid upright in tightly packed clusters (Hodek *et al.* 2012).

Larvae:

No detailed description for this species exists. The larval form develops through four instars and the final instar is likely elongate and black with orange spots dorsolaterally. Similar to other closely related *Coccinella*, the abdomen likely has nine segments and has mound-like projections bearing seta, or hair-like structures (Gordon and Vanderberg 1995).

Pupae:

No description for this species exists. However, the pupae are likely yellow to orange with black markings, as in similar species (Hodek *et al.* 2012).

Population Spatial Structure and Variability

In Canada, the spatial structure and variability of Transverse Lady Beetle subpopulations have not been studied. Similarly, limited genetic studies have occurred on this species or its genetic structure.

Allozyme variation was investigated in non-native ($n = 8$) and native ($n = 6$) lady beetles in North America from Iowa, New York, and Arkansas (Krafsur *et al.* 2005). 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 Transverse Lady Beetle has one designatable unit within Canada. The Transverse Lady Beetle occurs across multiple ecozones and there are likely high rates of gene flow and little detectable subpopulation subdivision (Krafsur *et al.* 2005).

Special Significance

The Transverse Lady Beetle was previously 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 also 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 their 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; Uguine and Losey 2014).

Initiatives such as the Lost Lady Bug Project (<http://www.lostladybug.org/>), which enable citizen scientists to document the distributions of native species, such as the Transverse Lady Beetle, across North America, demonstrate significant public interest and shifting trends in lady beetle composition across landscapes.

There is no available Aboriginal Traditional Knowledge specifically for the Transverse Lady Beetle.

DISTRIBUTION

Global Range

The Transverse Lady Beetle is a wide-ranging species occurring across Canada and the United States, from Newfoundland to Virginia, and west to Alaska and California (Brown 1962; Gordon 1985) (Figure 2). Approximately 65% of its historical global range is within Canada.



Figure 2. The geographic range of the Transverse Lady Beetle (*Coccinella transversoguttata*). This range map is based on a historical range map by Gordon (1985) and recent collection records (Grant pers. data).

Canadian Range

The Canadian range of the Transverse Lady Beetle stretches from St. John's, Newfoundland and Labrador, west to Vancouver Island. At the northernmost extent of its range the species occurs throughout Yukon and mainland Northwest Territories (Brown 1962; Gordon 1985; Grant pers. data) (Figure 2). Although there are no confirmed records, the species may also occur in Nunavut. The Canadian range for this species is based on historical and current collection records, although there are gaps in survey coverage across geographic regions and time.

Extent of Occurrence and Area of Occupancy

Extent of occurrence (EOO) for the Transverse Lady Beetle is based on databased museum collections and recent surveys. Based on a minimum convex polygon within the extent of Canada's jurisdiction, the EOO from 1889 – 2015 records is 10.6 million km² (Figure 3). The EOO calculated from 1996 – 2005 records is 5.3 million km² (Figure 4). The EOO calculated from 2006 – 2015 records is 6.9 million km² (Figure 4). This is an estimated 30% increase in EOO over the previous decade.

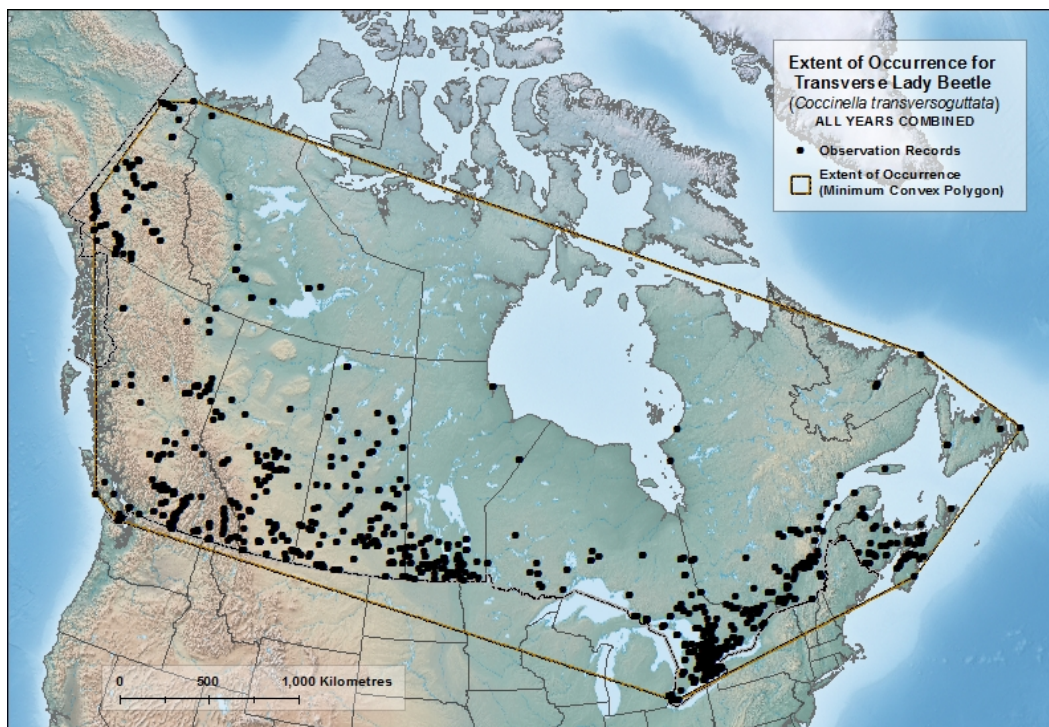


Figure 3. Extent of occurrence (EOO: 10.6 million km²) and index of area of occupancy (IAO: 2884 km²) for the Transverse Lady Beetle (*Coccinella transversoguttata*) based on museum collections and recent surveys (1889 - 2015).

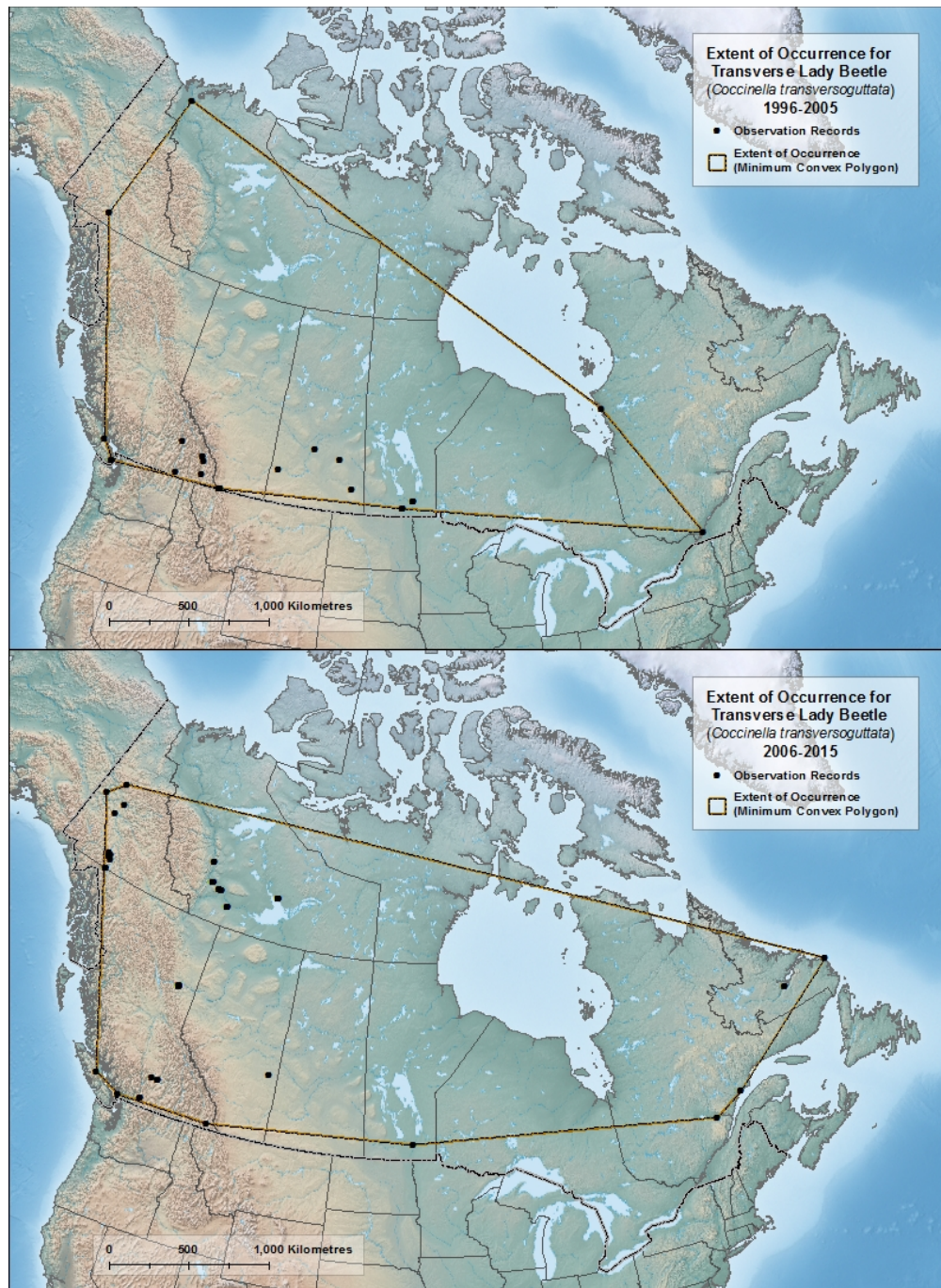


Figure 4. Extent of occurrence (EOO) and index of area of occupancy (IAO) for the Transverse Lady Beetle (*Coccinella transversoguttata*). 1996 – 2005: EOO = 5.30 million km², IAO = 76 km². 2006 – 2015: EOO = 6.97 million km², IAO = 144 km². Trends in EOO and IAO for this species reflect issues with survey coverage and detection across its geographic range and over time, rather than expansion or contraction of its range.

An index of area of occupancy (IAO) based on the databased museum collections and surveys from 1889 – 2015 is 2,884 km² (Figure 3); 1996 – 2005 records is 76 km² (Figure 4) and 2006 – 2015 records is 144 km² (Figure 4). This is an estimated 89% change in IAO over the previous decade, due mainly to increased search effort.

Changes in EOO and IAO for this species reflect the lack of historical survey coverage and detection across its geographic range throughout time, rather than expansion or contraction of its range. Changes in EOO and IAO are therefore not considered reliable evidence of population trends (see **Fluctuations and Trends** for further discussion).

Search Effort

Museum and collection records for the Transverse Lady Beetle date from 1889 – 2015. A database of over 23,000 lady beetle records (Coccinellidae), including 2,606 records for the Transverse Lady Beetle, has been compiled from 26 collections across Canada (see Collections Examined; Grant pers. data) (Table 1).

Table 1. There are 2,606 Transverse Lady Beetle specimens known from 1896 – 2015 in Canada (see Collections Examined).

Province	Total Coccinellidae	Transverse Lady Beetle
Yukon Territory	583	133
Northwest Territories	90	48
British Columbia	7017	272
Alberta	778	182
Saskatchewan	1793	203
Manitoba	2369	323
Ontario	6688	934
Quebec	1949	219
New Brunswick	658	109
Nova Scotia	686	104
Prince Edward Island	65	2
Newfoundland and Labrador	87	15
<i>Unknown*</i>	336	61
Total	23100	2606

**Unknown Canadian location but specimens have date information*

Insect collections are important sources for information on geographic distribution, especially for wide-ranging insects. However, collection records are generally not systematic or comprehensive over time or across geographic ranges, resulting in large areas and time periods with few data. In Canada most search effort has also been focused within agricultural systems or near urban centres, rather than in less disturbed habitats (Acorn 2007). Additionally, a number of collections across Canada are not currently databased, which creates additional gaps in information and past survey coverage.

Although the number of records for lady beetles are similar from 1996 – 2005 (2110 records) compared to 2006 – 2015 (1912 records), there has been an increased awareness of native lady beetle declines across Canada over the last decade. This awareness has translated into greater search effort for this species over the last decade. Nevertheless, gaps in search effort still remain.

In preparation for this status report, sites that had recent records of the Transverse Lady Beetle were re-visited and surveys were carried out within geographic survey gaps, including remote natural areas in northern BC, AB, YT and NT. There were 285 sites searched in 2013 to 2015 for a total search effort of over 296 hours (Table 2, Figure 5). For a conspicuous, easily collected beetle, this represents a relatively large search effort per site. A total of 75 specimens were found at 20 sites within known regions for Transverse Lady Beetles, including Newfoundland and Labrador, BC, YT and NT. The Canadian Wildlife Service in Yukon, and the Government of the Northwest Territories, also conducted recent surveys specifically for the Transverse Lady Beetle, which are included in search effort (Leung 2016). Search effort during the preparation of this status report resulted in 75 (71%) of the 105 recorded specimens of Transverse Lady Beetle collected from 2006 – 2015.

Table 2. Target search effort 2013 – 2015. Total search effort of 291.3 hours across 280 sites detected 64 Transverse Lady Beetles (Grant pers. data).

Prov.	Place	Year	Min	TLB*	Surveyor
YT	Whitehorse	2014	30	no	Heron J
YT	Whitehorse	2014	45	no	Heron J
YT	Whitehorse	2014	15	no	Heron J; Sheffield C
YT	Whitehorse	2014	15	no	Heron J; Sheffield C
YT	Whitehorse	2015	60	1	Leung M
YT	Whitehorse	2015	60	1	Leung M
YT	Whitehorse	2015	60	5	Leung M
YT	Whitehorse	2015	60	1	Leung M
YT	Whitehorse	2015	60	3	Leung M
YT	Whitehorse	2015	5	1	Coleman S; Bennett B
NT	Fort Simpson	2014	30	no	Allaire D
NT	Fort Simpson	2014	30	no	Allaire D

Prov.	Place	Year	Min	TLB*	Surveyor
NT	Fort Simpson	2014	60	21	Allaire D
NT	Fort Simpson	2014	30	2	Allaire D
NT	Fort Simpson	2014	30	2	Allaire D
NT	Fort Simpson	2014	30	no	Allaire D
NT	Hay River	2014	5	no	Smith G
NT	Jean Marie River	2014	30	no	Allaire D
NT	Jean Marie River	2015	30	5	Allaire D
NT	Wrigley	2014	30	no	Allaire D
NT	Wrigley	2014	30	no	Allaire D
NT	Wrigley	2014	30	3	Allaire D
NT	Wrigley	2014	30	no	Allaire D
NT	Yellowknife	2014	5	no	Kalnay-Watson S
NT	Yellowknife	2014	5	1	Kalnay-Watson S
NT	Yellowknife	2014	5	1	Pike E
BC	Arras	2013	90	no	Copley C; Copley D; Heron J; Gartner H
BC	Arras	2013	35	no	Copley C; Copley D; Heron J; Gartner H
BC	Ashnola River Valley	2014	15	no	Heron J;
BC	Attachie	2013	462	no	Copley C; Copley D; Heron J; Gartner H
BC	Attachie	2013	90	no	Copley C; Copley D; Heron J; Gartner H
BC	Brisco	2014	15	no	Grant P
BC	Chetwynd	2013	120	no	Copley C; Copley D; Heron J; Gartner H
BC	Chetwynd	2013	90	no	Copley C; Copley D; Heron J; Gartner H
BC	Clinton	2013	140	no	Copley C; Copley D; Heron J; Gartner H
BC	Comox	2014	95	no	Heron J
BC	Coquihalla	2015	30	no	Grant P
BC	Coquihalla Lake	2013	120	no	Copley C; Copley D; Heron J; Gartner H
BC	Delta	2014	15	no	Heron J
BC	Denman Island	2014	15	no	Heron J
BC	Denman Island	2014	15	no	Heron J
BC	Denman Island	2014	15	no	Heron J
BC	Denman Island	2014	15	no	Heron J

Prov.	Place	Year	Min	TLB*	Surveyor
BC	Fairmont Hot Springs	2014	15	no	Grant P
BC	Fairmont Hot Springs	2014	15	no	Grant P
BC	Fort St. John	2013	15	no	Copley C
BC	Fort St. John	2013	124	no	Copley C; Copley D; Heron J; Gartner H
BC	Fort St. John	2013	420	no	Copley C; Copley D; Heron J; Gartner H
BC	Fort St. John	2013	53	no	Copley C; Copley D; Heron J; Gartner H
BC	Fort St. John	2013	210	no	Copley C; Copley D; Heron J; Gartner H
BC	Fort St. John	2013	435	no	Copley C; Copley D; Heron J; Gartner H
BC	Fort Ware	2014	15	no	Bennett R; Copley C; Copley D;
BC	Galiano Island	2014	30	no	Ott L
BC	Greater Victoria	2014	15	no	Heron J
BC	Greater Victoria	2014	15	no	Heron J
BC	Greater Victoria	2014	15	no	N/A
BC	Haida Gwaii	2014	60	no	McClaren E.
BC	Haida Gwaii	2015	30	no	Wijdeven B.
BC	Haida Gwaii	2015	30	no	Wijdeven B.
BC	Haida Gwaii	2015	30	no	Wijdeven B.
BC	Haida Gwaii	2015	30	no	Wijdeven B.
BC	Haynes Lease	2013	630	no	Sheffield C; Weston M; Heron J
BC	Hazelton	2014	60	no	Westcott L
BC	Hazelton	2014	60	no	Westcott L
BC	Hazelton	2014	60	no	Westcott L
BC	Hazelton	2014	60	no	Westcott L
BC	Hazelton	2014	60	no	Westcott L
BC	Hazelton	2014	60	no	Westcott L
BC	Hazelton	2014	60	no	Westcott L
BC	Hixon	2013	140	no	Copley C; Copley D; Heron J; Gartner H
BC	Hope	2013	120	3	Copley C; Copley D; Heron J; Gartner H
BC	Hudson's Hope	2013	120	no	Copley C; Copley D; Heron J; Gartner H
BC	Hudson's Hope	2013	74	no	Copley C; Copley D; Heron J; Gartner H

Prov.	Place	Year	Min	TLB*	Surveyor
BC	Hudson's Hope	2013	255	13	Copley C; Copley D; Heron J; Gartner H; Cannings S
BC	Hudson's Hope	2013	360	8	Copley C; Copley D; Heron J; Gartner H
BC	Inkaneep Prov. Park	2013	360	no	Sheffield C, Weston M; Heron J
BC	Iona Beach Park	2014	30	1	Cesselli S; Turner S
BC	Iona Beach Park	2014	30	1	Cesselli S; Turner S
BC	Kakwa Prov. Park	2014	115	no	Ramey B; Ramey B
BC	Kakwa Prov. Park	2014	5	no	Ramey B; Ramey B
BC	Kakwa Prov. Park	2014	10	no	Ramey B; Ramey B
BC	Kakwa Prov. Park	2014	10	no	Ramey B; Ramey B
BC	Kakwa Prov. Park	2014	10	no	Ramey B; Ramey B
BC	Kakwa Prov. Park	2014	15	no	Ramey B; Ramey B
BC	Kakwa Prov. Park	2014	10	no	Ramey B; Ramey B
BC	Kakwa Prov. Park	2014	60	no	Ramey B; Ramey B
BC	Kakwa Prov. Park	2014	5	no	Ramey B; Ramey B
BC	Kamloops	2015	15	no	Grant P
BC	Kamloops	2015	30	no	Grant P
BC	Keily Prov. Park	2014	15	no	Bennett R; Copley C; Copley D
BC	Keily Prov. Park	2014	15	no	Copley C; Copley D
BC	Keily Prov. Park	2014	15	no	Bennett R; Copley C; Copley D
BC	Lower Mainland	2014	30	no	N/A
BC	Lower Mainland	2014	30	no	N/A
BC	Lower Mainland	2014	30	no	N/A
BC	Mayne Island	2014	30	no	Dunn M
BC	Mayne Island	2014	30	no	Dunn M
BC	Mayne Island	2014	30	no	Dunn M
BC	Mayne Island	2014	30	no	Dunn M
BC	Merritt	2013	120	no	Copley C; Copley D; Heron J; Gartner H
BC	Merritt	2015	30	no	Grant P
BC	Meziadin Junction	2014	60	no	Westcott L
BC	Mt. Kobau	2013	180	no	Sheffield C; Gardiner L; Dyer O; Heron J
BC	Mt. Kobau	2014	15	no	Copley C; Copley D; Heron J;
BC	Mt. Kobau	2014	15	no	Copley C; Copley D; Heron J;
BC	Mt. Kobau	2014	15	no	Copley C; Copley D; Heron J;
BC	Mt. Kobau	2014	15	no	Copley C; Copley D; Heron J;

Prov.	Place	Year	Min	TLB*	Surveyor
BC	Mt. Kobau	2014	15	no	Copley C; Copley D; Heron J;
BC	Mt. Kobau	2014	15	no	Copley C; Copley D; Heron J;
BC	Nahatlach	2013	60	no	Heron J; Lynch G
BC	Nahatlach	2013	15	no	Heron J; Lynch G
BC	Nahatlach	2013	30	no	Heron J; Lynch G
BC	Nahatlach	2013	30	no	Heron J; Lynch G
BC	Northern BC	2014	60	no	Heron J
BC	Northern BC	2014	150	no	Heron J
BC	Northern BC	2014	30	no	Heron J
BC	Northern BC	2014	15	no	Heron J; Sheffield C
BC	Northern BC	2014	15	no	Heron J; Sheffield C
BC	Northern BC	2014	15	no	Heron J; Sheffield C
BC	Northern BC	2014	15	no	Heron J; Sheffield C
BC	Northern Vancouver I	2014	15	no	Copley C; Copley D; Heron J; Gartner H
BC	Northern Vancouver I	2014	15	no	Copley C; Copley D; Heron J; Gartner H
BC	Okanagan Falls	2014	75	no	Heron J; Burdock N
BC	Osoyoos	2014	15	no	Copley C; Copley D; Heron J;
BC	Osoyoos	2014	15	no	Copley C; Copley D; Heron J;
BC	Osoyoos	2014	15	no	Copley C; Copley D; Heron J;
BC	Osoyoos	2014	15	no	Copley C; Copley D; Heron J;
BC	Osoyoos	2013	120	no	Heron J; Sheffield C
BC	Osoyoos	2013	40	no	Heron J; Sheffield C
BC	Pine River	2013	120	no	Copley C; Copley D; Heron J; Gartner H
BC	Pine River	2013	120	no	Copley C; Copley D; Heron J; Gartner H
BC	Prince George	2013	160	no	Copley C; Copley D; Heron J; Gartner H
BC	Prince George	2013	90	no	Copley C; Copley D; Heron J; Gartner H
BC	Prince George	2013	140	no	Copley C; Copley D; Heron J; Gartner H
BC	Prince George	2013	99	no	Copley C; Copley D; Heron J; Gartner H
BC	Princeton	2014	30	no	Heron J
BC	Quesnel	2013	180	no	Copley C; Copley D; Heron J; Gartner H

Prov.	Place	Year	Min	TLB*	Surveyor
BC	Quesnel	2013	70	no	Copley C; Copley D; Heron J; Gartner H
BC	Russel Prov. Park	2014	15	no	Copley C; Copley D
BC	Russel Prov. Park	2014	15	no	Copley C; Copley D
BC	Russel Prov. Park	2014	15	no	Bennett R; Copley C; Copley D
BC	Russel Prov. Park	2014	15	no	Bennett R; Copley C; Copley D
BC	Sage Sparrow Grasslands	2013	360	no	Heron J; Sheffield C
BC	Similkameen	2013	80	no	Heron J; Sheffield C
BC	Smithers	2014	60	no	Westcott L
BC	Smithers	2014	60	no	Westcott L
BC	Smithers	2014	60	no	Westcott L
BC	Smithers	2014	60	no	Westcott L
BC	Smithers	2014	60	no	Westcott L
BC	Sooke	2014	15	no	Grant P
BC	South	2014	15	no	Heron J
BC	South Okanagan	2014	30	no	Heron J
BC	South Okanagan	2014	30	no	Heron J
BC	South Okanagan	2014	30	no	Heron J
BC	South Okanagan	2014	30	no	Heron J
BC	South Okanagan	2014	30	no	Heron J
BC	South Okanagan	2014	30	no	Heron J
BC	South Okanagan	2014	15	no	Heron J
BC	South Okanagan	2014	30	no	Heron J; Sandhu J
BC	South Okanagan	2014	30	no	Heron J; Sandhu J
BC	South Okanagan	2014	30	no	Heron J; Sandhu J
BC	South Okanagan	2014	30	no	Heron J; Weston W; Bunge S; Pope B
BC	South Okanagan	2014	15	no	Heron J; Sandhu J
BC	South Okanagan	2013	280	no	Sheffield C; Gardiner L; Dyer O; Heron J
BC	Strathcona Prov. Park	2014	15	no	Bennett R; Copley C; Copley D; Heron J; McClaren E
BC	Strathcona Prov. Park	2014	15	no	Bennett R; Copley C; Copley D; Heron J; McClaren E
BC	Sydney	2014	60	no	Heron J; Gelling L
BC	Tatton	2013	128	no	Copley C; Copley D; Heron J; Gartner H
BC	Taylor	2013	40	no	Copley C; Copley D; Heron J; Gartner H

Prov.	Place	Year	Min	TLB*	Surveyor
BC	Thompson Region	2014	30	no	Letay S
BC	Tranquille	2014	5	no	Howie R
BC	Tsay Keh	2014	15	no	Bennett R; Copley C; Copley D
BC	Tsay Keh	2014	15	no	Bennett R; Copley C; Copley D
BC	Tsay Keh	2014	15	no	Bennett R; Copley C; Copley D
BC	Tumbler Ridge	2013	70	no	Copley C; Copley D; Heron J; Gartner H
BC	Vancouver Island	2014	30	no	Casselli S; Turner S
BC	Vancouver Island	2014	15	no	Heron J
BC	Vancouver Island	2014	15	no	Heron J
BC	Vaseux Lake Prov. Park	2013	60	no	Heron J; Sheffield C
BC	Victoria	2014	15	no	Heron J; Gelling L
BC	Victoria	2014	15	no	Grant P
BC	Victoria	2014	15	no	Grant P
BC	Victoria	2015	30	no	Grant P
BC	Victoria	2015	30	no	Grant P
BC	Victoria	2015	30	no	Grant P
BC	Whiskers Point Prov. Park	2013	10	no	Copley C; Copley D; Heron J; Gartner H
BC	White Lake Prov. Park	2013	315	no	Sheffield C; Dyer O; Heron J
BC	Williams Lake	2014	30	no	Coot K
BC	Williams Lake	2014	60	no	Coot K; Foot T
BC	Williams Lake	2013	132	no	Copley C; Copley D; Heron J; Gartner H
BC	Williams Lake	2013	80	no	Copley C; Copley D; Heron J; Gartner H
AB	Calgary	2014	15	no	Grant P
AB	Calgary	2014	15	no	Grant P
AB	Calgary	2014	15	no	Grant P
AB	Calgary	2014	15	no	Grant P
AB	Calgary	2014	15	no	Grant P
AB	Calgary	2014	15	no	Grant P
AB	Calgary	2014	15	no	Grant P
AB	Calgary	2014	15	no	Grant P
AB	Calgary	2015	15	no	Grant P
AB	Calgary	2015	15	no	Grant P
AB	Calgary	2015	15	no	Grant P
AB	Cold Lake	2014	15	no	Grant P

Prov.	Place	Year	Min	TLB*	Surveyor
AB	Cold Lake	2014	15	no	Grant P
AB	Cold Lake	2014	15	no	Grant P
AB	Cold Lake	2014	15	no	Grant P
AB	Conklin	2014	15	no	Grant P
AB	Conklin	2014	15	no	Grant P
AB	Conklin	2014	15	no	Grant P
AB	Conklin	2014	15	no	Grant P
AB	Conklin	2014	15	no	Grant P
AB	Edmonton	2014	30	no	Anweiler G
AB	Grande Prairie	2014	15	no	Grant P
AB	Grande Prairie	2014	15	no	Grant P
AB	Grande Prairie	2014	15	no	Grant P
AB	Grande Prairie	2014	15	no	Grant P
AB	Grande Prairie	2014	15	no	Grant P
AB	McLean Creek	2014	15	no	Grant P
AB	Medicine Hat	2014	30	no	Leibel H
AB	Medicine Hat	2014	15	no	Buck M
AB	Sherwood Park	2014	30	no	Anweiler G
AB	Sherwood Park	2014	30	no	Anweiler G
AB	Vulcan County	2014	30	no	Leibel H
AB	Zama City	2014	15	no	Grant P
AB	Zama City	2014	15	no	Grant P
AB	Zama City	2014	15	no	Grant P
AB	Zama City	2014	15	no	Grant P
AB	Zama City	2014	15	no	Grant P
ON	Airport, Cockburn I.	2014	90	no	Foster R; Harris A; Jones C
ON	Batchawana Bay, Lake Superior	2014	60	no	Foster R; Harris A; Jones C
ON	Belanger Bay, Manitoulin I.	2014	105	no	Foster R; Harris A; Jones C
ON	Black's Point Beach, Lake Huron	2014	60	no	Foster R; Harris A; Jones C
ON	Burnt I. Harbour, Manitoulin I.	2014	210	no	Foster R; Harris A; Jones C
ON	Carroll Wood Bay, Manitoulin I.	2014	105	no	Foster R; Harris A; Jones C
ON	Carter Bay, Manitoulin I.	2014	300	no	Foster R; Harris A; Jones C
ON	Dean's Bay, Manitoulin I.	2014	270	no	Foster R; Harris A; Jones C
ON	Dominion Bay, Manitoulin I.	2014	120	no	Foster R; Harris A; Jones C
ON	Great Duck I.	2014	180	no	Foster R; Harris A; Jones C
ON	Kitchener	2014	5	no	Day M
ON	Lonely Bay, Manitoulin I.	2014	150	no	Foster R; Harris A; Jones C

Prov.	Place	Year	Min	TLB*	Surveyor
ON	Misery Bay, Manitoulin I.	2014	180	no	Foster R; Harris A; Jones C
ON	Mississagi River mouth	2014	102	no	Foster R; Harris A; Jones C
ON	Murphy Harbour, Manitoulin I.	2014	30	no	Foster R; Harris A; Jones C
ON	Pancake Bay, Lake Superior	2014	210	no	Foster R; Harris A; Jones C
ON	Pic River Dunes, Lake Superior	2014	48	no	Foster R; Harris A; Jones C
ON	Pinery Prov. Park, Lake Huron	2014	36	no	Foster R; Harris A; Jones C
ON	Point Farms Prov. Park, Lake Huron	2014	180	no	Foster R; Harris A; Jones C
ON	Portage Bay, Manitoulin I.	2014	180	no	Foster R; Harris A; Jones C
ON	Providence Bay, Manitoulin I.	2014	240	no	Foster R; Harris A; Jones C
ON	Sand (Hensly) Bay, Manitoulin I.	2014	96	no	Foster R; Harris A; Jones C
ON	Sand Bay, Cockburn I.	2014	300	no	Foster R; Harris A; Jones C
ON	Shrigley Bay, Manitoulin I.	2014	165	no	Foster R; Harris A; Jones C
ON	Square Bay, Manitoulin I.	2014	105	no	Foster R; Harris A; Jones C
ON	Taskerville, Manitoulin I.	2014	105	no	Foster R; Harris A; Jones C
QC	Chemin Choinière	2014	60	no	Bereczky V
QC	Chemin Magenta	2014	60	no	Bereczky V
QC	Lac Gale GR11	2014	60	no	Bereczky V
QC	Mont St-Hilaire	2014	120	no	Bereczky V
QC	Prairie Mt Aki	2014	120	no	Bereczky V
QC	Magdalen Islands	2015	85	no	Heron J; Sheffield C
QC	Magdalen Islands	2015	45	no	Heron J; Sheffield C
QC	Magdalen Islands	2015	135	no	Heron J; Sheffield C
QC	Magdalen Islands	2015	110	no	Heron J; Sheffield C
QC	Magdalen Islands	2015	15	no	Heron J; Sheffield C
QC	Magdalen Islands	2015	45	no	Heron J; Sheffield C
QC	Magdalen Islands	2015	35	no	Heron J; Sheffield C
QC	Magdalen Islands	2015	10	no	Heron J; Sheffield C
QC	Magdalen Islands	2015	35	no	Heron J; Sheffield C
QC	Magdalen Islands	2015	105	no	Heron J; Sheffield C
QC	Magdalen Islands	2015	45	no	Heron J; Sheffield C
QC	Magdalen Islands	2015	60	no	Heron J; Sheffield C
QC	Magdalen Islands	2015	54	no	Heron J; Sheffield C
QC	Magdalen Islands	2015	60	no	Heron J; Sheffield C
QC	Magdalen Islands	2015	30	no	Heron J; Sheffield C
QC	Magdalen Islands	2015	21	no	Heron J; Sheffield C
QC	Magdalen Islands	2015	39	no	Heron J; Sheffield C
QC	Magdalen Islands	2015	47	no	Heron J; Sheffield C

Prov.	Place	Year	Min	TLB*	Surveyor
QC	Magdalen Islands	2015	60	no	Heron J; Sheffield C
NB	Highway 15, Cap Pele exit	2015	35	no	Heron J; Sheffield C
NS	Eagle Head	2014	5	no	Durovich K
PE	Souris	2015	45	no	Heron J; Sheffield C
PE	Souris	2015	90	no	Heron J; Sheffield C
NL	Happy Valley-Goose Bay	2014	5	1	Elson L
NL	Black Tickle	2014	5	1	Elson L

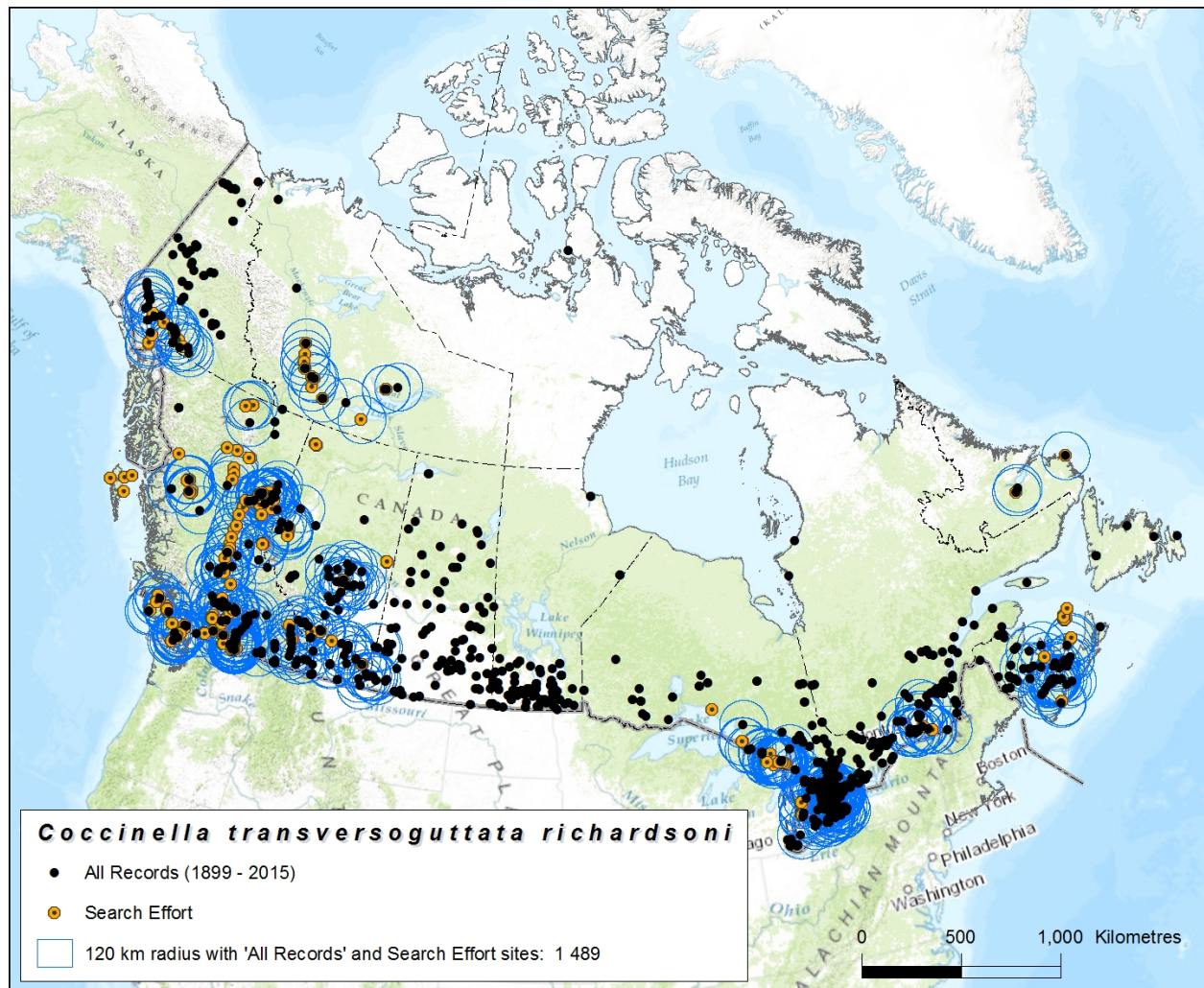


Figure 5. Search effort sites (orange) (2013 – 2015) and known sites (black) for the Transverse Lady Beetle (*Coccinella transversoguttata*). Search effort (within 120 km) overlapped with 1,489 (57%) known sites.

The dispersal ability of Transverse Lady Beetle is unknown. However, based on potential dispersal ability (under ideal conditions) of other closely related (*Coccinella*) lady beetle species (see Dispersal and Migration) the species could fly 18 – 120 km in a single flight (Jeffries *et al.* 2013). These potential dispersal distances were used to estimate overlap between search effort and known databased sites of Transverse Lady Beetles. An 18 km radius around search effort sites overlapped with 497 known databased sites. A 120 km radius around search effort sites overlapped with 1,489 known databased sites (Figure 5). For such a broadly distributed, mobile species, this search effort represents relatively good search effort coverage of known sites for Transverse Lady Beetles.

HABITAT

Habitat Requirements

The Transverse Lady Beetle is a habitat generalist and known to occur within agricultural areas, suburban gardens, parks, coniferous forests, deciduous forests, prairie grasslands, meadows, and riparian areas. It was also one of the more dominant lady beetles found on agricultural crops including alfalfa, potatoes, corn, soybean, and cotton (Wheeler and Hoebeke 1995; Harmon *et al.* 2007; Losey *et al.* 2007; Gardiner *et al.* 2011; Hodek *et al.* 2012). The Transverse Lady Beetle can also be found in a wide variety of non-agricultural vegetation including birch (*Betula spp.*), pine (*Pinus spp.*), spruce (*Picea spp.*), maple (*Acer spp.*), mountain ash (*Sorbus spp.*), poplar (*Populus spp.*), willow (*Salix spp.*), sage (*Salvia spp.*), cherry (*Prunus spp.*), alder (*Alnus spp.*), thistles (Family Asteraceae), grasslands, and scruff pea (Family Fabaceae) plants along the edge of sand dunes (Wheeler and Hoebeke 1995; Acorn 2007; Harmon *et al.* 2007; Losey *et al.* 2007).

Transverse Lady Beetles move across these 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 tussocks, in leaf litter, or in tree bark (Hodek and Honěk 1996; Hodek *et al.* 2012). Larvae tend to be located in habitat with an abundance of prey.

Habitat Trends

The Transverse Lady Beetle has a large range in Canada spanning numerous ecozones and habitat types (Gordon 1985; Grant pers. data). 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 Transverse Lady Beetle subpopulations. It is therefore unknown if specific habitat trends have caused this particular lady beetle, with its wide diet and habitat range, to decline historically over much of its known range across Canada.

However, 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 cause for this is more intensive use of agricultural land. This includes heavier reliance on chemicals for pest control (see Threats), which presumably negatively affect Transverse Lady Beetles directly, or indirectly by impacting their prey.

Conversion of managed lands and farms resulting in regrowth of forest could also result in less favourable foraging for the Transverse Lady Beetle (Harmon *et al.* 2007; Bucknell and Pearson 2007). This slow natural succession has mainly occurred in areas of Eastern Canada (see Threats).

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

In general, little is known on the biology of Transverse Lady Beetles. Information below is compiled from general lady beetle references from closely related species (*Coccinella*) (Acorn 2007; Hodek *et al.* 2012). Where applicable, references are provided specifically for Transverse Lady Beetles.

Life Cycle and Reproduction

Lady beetles are holometabolous, meaning they have a complete metamorphosis and pass through egg, larva, pupa and adult stages. No studies have been conducted regarding the lifespans of adult Transverse Lady Beetles, but closely related species generally have a lifespan of 20 to 60 days (McMullen 1967). The Transverse Lady Beetle can have two generations per year depending on regional climatic conditions (Hodek *et al.* 2012). Adults of the spring generation can undergo aestivation, a type of dormancy, to avoid high summer temperatures, and lay eggs in early autumn (Hodek *et al.* 2012). Adults of the autumn generation congregate overwinter and undergo another type of dormancy known as diapause, and only become active and reproduce when temperatures warm in the early spring (McMullen 1967; Hodek *et al.* 2012; Losey *et al.* 2012).

The eggs of lady beetles are typically tightly packed in an upright position in clusters of 20 to 30 eggs, on a range of plants that are likely to support subpopulations of aphids (Acorn 2007; Hodek *et al.* 2012). Over 14 days female Transverse Lady Beetles can lay approximately 267 eggs (Kajita *et al.* 2009). Many females also lay unfertilized eggs, along with the fertile eggs, as another food source for young larvae (Acorn 2007).

There is no information regarding the length of time it takes to develop from egg to adult for the Transverse Lady Beetle and development times are likely highly affected by prey availability and temperature. In closely related lady beetles, development from egg to adult typically takes 20 days (Ugine and Losey 2014). Larvae hatch from eggs after approximately 3 days followed by approximately 13 more days before reaching their fourth instar to pupate (Losey *et al.* 2012; Ugine and Losey 2014). After approximately 5 more days as a pupa, lady beetles emerge as adults (Ugine and Losey 2014). Typically, 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). Elytra harden one day after emerging and adults are then able to disperse. Female Transverse Lady Beetles secrete pheromones to attract males, and at close distances males rely on both chemical and visual cues (Losey *et al.* 2012). The Transverse Lady Beetle is polygynandrous, with both sexes mating with multiple partners (Omkar and Srivastava 2002; Srivastava and Omkar 2004; Acorn 2007). As in other lady beetles, the sex ratio is likely close to 1:1 and adults do not show exaggerated sexual dimorphism (Stellwag and Losey 2014). However, there can be variability in body size and weight, depending on food availability and regional climatic conditions. When food is scarce lady beetles will have smaller body sizes and weights, correlating to decreased survivorship over winter (Smith 1966).

Physiology and Adaptability

Transverse Lady Beetles display aposematism, or bright warning colours to deter predators (Acorn 2007). Although undocumented, this species (similar to other lady beetles) is likely 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).

Transverse Lady Beetles also occupy a wide ecological niche across a variety of temperature regimes in Canada; they are cold-tolerant and 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).

Dispersal and Migration

Little is known on the natural dispersal rates specifically for the Transverse Lady Beetle. In general lady beetles are very mobile, display low site fidelity, and readily engage in short (few hundred metres) and long (18 – 120 km) 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 long distances has generally been problematic due to the difficulty of tracking insects in the field. One study used vertical-looking entomological radars to determine dispersal distance of non-native Seven-spotted Lady Beetles (*Coccinella septempunctata*) and Multicolored Asian Lady Beetle (*Harmonia axyridis*). This study determined that the majority of these 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 these 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 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). As these non-native lady beetles are of similar size and in the case of the Seven-spotted Lady Beetle closely related, it is likely these dispersal distances are comparable for other native lady beetles.

Interspecific Interactions

Both adult and larval stages of the Transverse Lady Beetle prey primarily on a wide variety of aphids (Acorn 2007; Hodek *et al.* 2012). Typically, lady beetles 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). Transverse Lady Beetles, like other lady beetle species, are generalists in food and habitat use, often responding to changes in aphid abundance across many types of habitats (Hagen 1962; Hodek and Honěk 1996; Sloggett and Majerus 2000). Lady beetles can also 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 Transverse Lady Beetle is subject to intraguild competition and predation by other introduced lady beetles (Turnipseed *et al.* 2014). There is a broad coincidence between shrinkage of geographic range and subpopulation declines for native lady beetles with the introduction and spread of the Seven-spotted Lady Beetle and the Multicolored Asian Lady Beetle. 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 is also suspected to have led to declines in the body size of other native lady beetles (Losey *et al.* 2012), likely reducing their survivorship over winter (Smith 1966) (see Threats).

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 are parasitized by various tachinid flies, phorid flies, chalcidoid wasps, parasitic mites, nematodes, sporozoans, 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 Multicolored Asian Lady Beetle, and can likely cause substantial reductions in subpopulations of the Transverse Lady Beetle (Ceryngier and Hodek 1996; Abassi *et al.* 2001; Acorn 2007; Hodek *et al.* 2012). This braconid wasp currently has a cosmopolitan distribution covering all continents except Antarctica, and many islands (Hodek *et al.* 2012). The natural geographic range of *D. coccinellae* is difficult to reconstruct as it is believed this species arrived in some parts of its present distribution with ladybirds 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 survivorship 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

Multiple datasets from museum and private collections across Canada (see Collections Examined) were used to assess overall patterns of change in geographic distribution and relative abundance of the Transverse Lady Beetle. The collated dataset contains over 23,000 records of Coccinellidae from 1889 to 2015, including 2,606 Transverse Lady Beetle specimens. Numerous collections were also visited by McCorquodale *et al.* (2011) to identify and verify Coccinellidae specimens, before specimen label information was databased. Subsequently, additional museum and specimen data were compiled from surveys and collections for the preparation of this status report (Grant pers. data). Localities were georeferenced so that species could be mapped using geographic information systems (GIS) software. Latitude and longitude were taken from labels when available, but for other specimens, the generalized latitude and longitude of the town centre on the label was used, unless a more specific locality could be determined. In

addition, from 2013 to 2015 there were over 296 hours of field surveys conducted across 285 sites incorporated within this database (Table 2).

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 combination 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 can help delineate geographic ranges of lady beetles and assess temporal changes in distribution and abundance if the strengths and weaknesses of collection data are understood and considered. One weakness for broadly distributed insects across Canada is that collections have not been consistent throughout time or geographic range. In addition, there are a number of collections across the country which do not have specimen information databased, resulting in further information gaps. Collections can also 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. Conversely, newly introduced and invasive species might be collected out of proportion to the actual relative abundance of the Transverse Lady Beetle (McCorquodale *et al.* 2011).

Due to associated biases, accurately documenting changes in the geographic distribution of a species over time is a difficult task (Fortin *et al.* 2005; Elith *et al.* 2006; Koch and Strange 2009). Maps of geographic distribution over time may show a decrease in geographic range when in fact they reflect a decrease in subpopulation size, because with reduced subpopulations there is a decrease in probability of collection (McCorquodale *et al.* 2011). Conversely, an increase in geographic range can also reflect greater search effort, rather than an increase in subpopulation size. Trends in extent of occurrence (EOO) and index of area of occupancy (IAO) are therefore biased by search effort, which has not been consistent over time or over the range of this species.

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 Transverse 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.

Abundance

Estimating abundance of total number of mature individuals for a wide-ranging species, such as the Transverse Lady Beetle, is not possible with current available data. Extent of occurrence (EOO), index of area of occupancy (IAO), and relative abundance were therefore used to measure trends. In addition, these data were supplemented by published research and expert opinion documenting subpopulations and range declines of the Transverse Lady Beetle in North America.

Fluctuations and Trends

Natural population fluctuations in lady beetle subpopulations are related to dispersal, prey availability, climatic conditions and overwinter survivorship. Lady beetles, including the Transverse Lady Beetle, do not experience extreme fluctuations.

Based on all databased records and surveys (1889 – 2015), the Transverse Lady Beetle has a total EOO of 10.6 million km² and IAO of 2,884 km² (Figure 3). During 1996 – 2005 the EOO was calculated as 5.3 million km² with an IAO of 76 km² (Figure 4). During the last decade (2006 – 2015) the EOO increased to 6.9 million km² with a concurrent increase in IAO of 144 km² (Figure 4). This is an estimated 30% change in EOO and 89% change in IAO from the previous decade.

As this is a broadly distributed species across Canada, and surveys have not been spatially or temporally complete, trends in this species' geographic distribution therefore reflect issues with survey coverage or detection rather than expansion or contraction of its range. The increase in EOO and IAO are therefore directly related to recent search effort for this species. Search effort for this status report resulted in 75 of the 105 (71%) of recorded specimens for the 2006 – 2015 time period. Without this recent search effort IAO would have been similar to the previous decade (32 records in 1996 – 2006 vs. 30 records in 2006 – 2015). Correspondingly, it is also reasonable to assume that EOO has not changed significantly over the last two decades. Recent search effort has resulted in this species being detected in Labrador, where little search effort had been conducted in the previous decade. This significantly contributed toward an artificially low EOO for (1996 – 2005) and a false increase in EOO during the last ten years (2006 – 2015). Trends in EOO and IAO for this species are therefore biased by search effort, and are not reliable to assess trends across its entire Canadian range.

Historically the Transverse Lady Beetle was widely distributed, occurring across all Canadian provinces and territories. Nationally, it was also one of the more common lady beetles collected before 1985 (Brown 1940; Gordon 1985). From 1916 to 1975 the relative abundance of the Transverse Lady Beetle gradually increased each decade, dropping marginally in 1976 to 1985, corresponding to the same time period the non-native Seven-spotted Lady Beetle increased in abundance (Figure 6, 7; Table 3). During subsequent decades the Transverse Lady Beetle declined significantly, concurrent with significant increases in abundance of non-native lady beetles, such as the Seven-spotted Lady Beetle and the Multicolored Asian Lady Beetle (Figure 6, 7; Table 3).

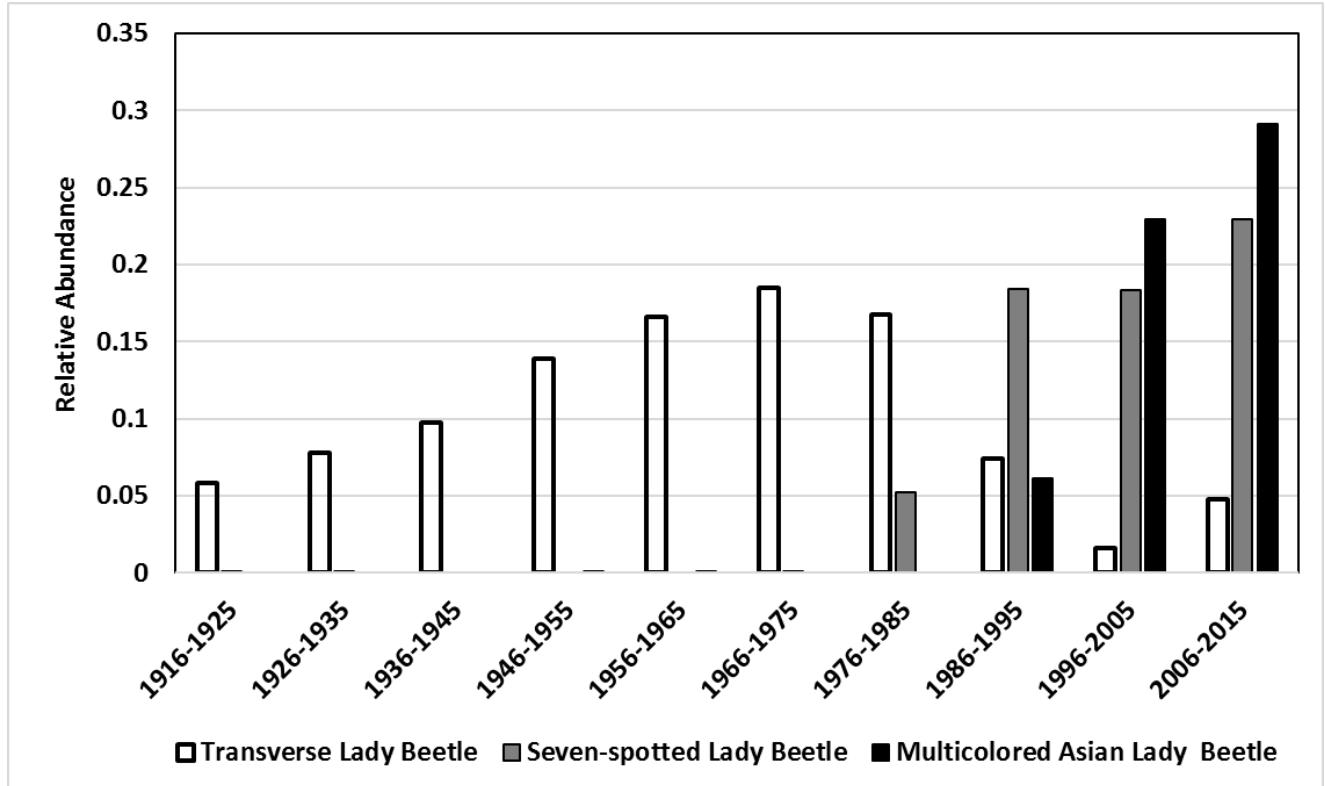


Figure 6. Changes in relative abundance of the native Transverse Lady Beetle (*Coccinella transversoguttata*), non-native Seven-spotted Lady Beetle (*Coccinella septempunctata*) and Multicolored Asian Lady Beetle (*Harmonia axyridis*) compared to all databased Coccinellidae in Canada from 1916 - 2015.

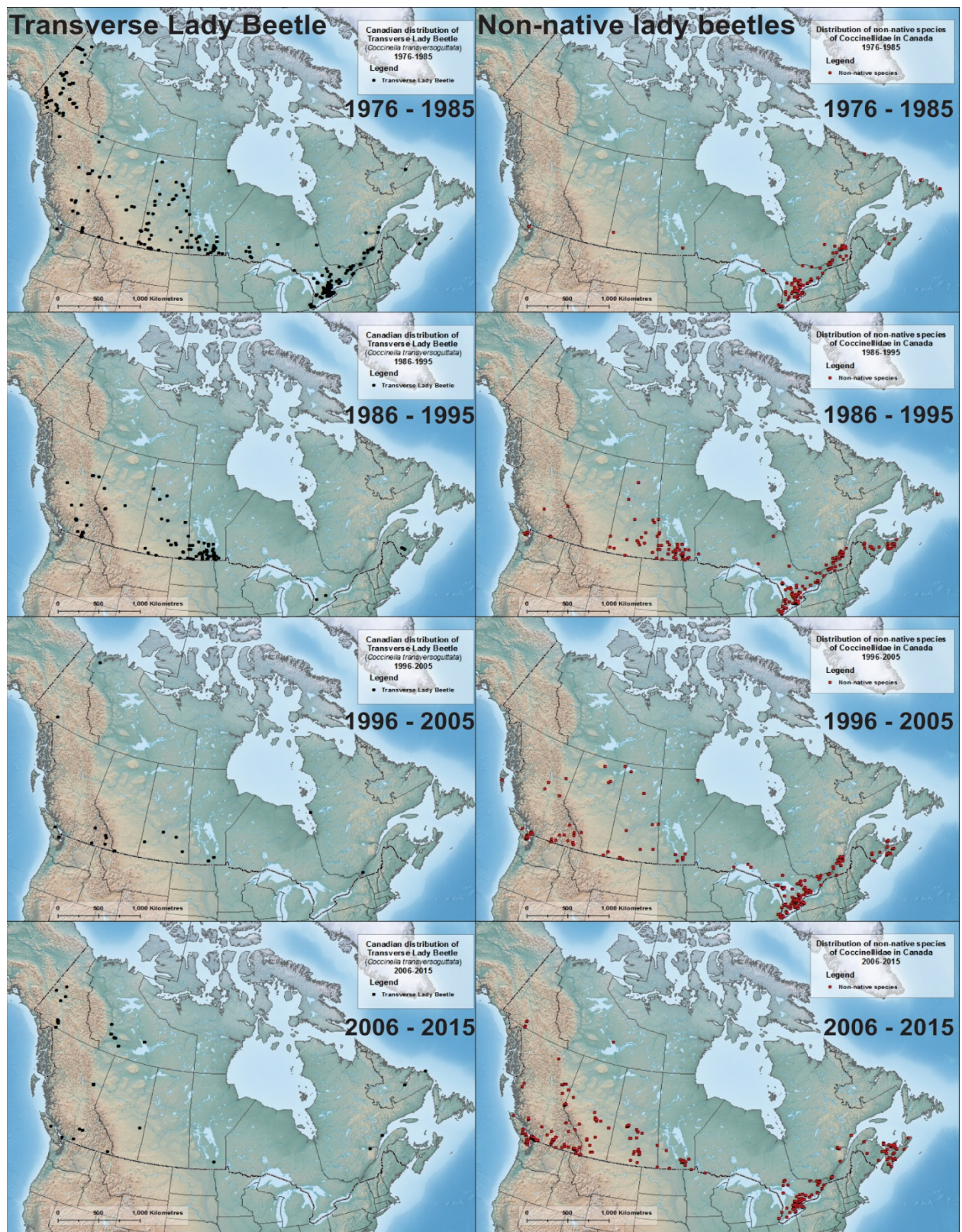


Figure 7. Canadian distribution of the Transverse Lady Beetle (black dots) and non-native lady beetles (red dots) over time.

Table 3. Numbers of Lady Beetle specimens recorded over ten-year periods. Results for Transverse Lady Beetles (TLB), all lady beetles (All) and non-native (NN). Lady Beetles were used to calculate relative abundance (see Table 4). Specimens with known date of collection but unrecorded location are listed as unknown (?)

Time		YT	NT	NU	BC	AB	SK	MB	ON	QC	NB	NS	PE	NL	?	Total
1896-1905	TLB				2		2	2	6							12
	All	1			86	2	15	46	69	3					5	227
	NN															
1906-1915	TLB				7	9		2	8			11				37
	All	1			104	32	1	15	47	8	1	23			2	234
	NN															
1916-1925	TLB				33	6		4	17			4				64
	All		1		758	42	1	134	121	16	7	9			3	1092
	NN							1								1
1926-1935	TLB				41	13	6	4	35	22	16					137
	All				1160	75	8	67	173	221	46	5			3	1758
	NN							1								1
1936-1945	TLB				15	8	12	12	18	8	6				36	115
	All				383	48	131	43	170	100	46	12	2	2	243	1180
	NN								1	1						2
1946-1955	TLB	4			15	30	16	38	136	37	17	60		1	10	364
	All	8			824	51	88	376	720	202	98	210		3	42	2622
	NN											1				
1956-1965	TLB	2	1		22	64	19	2	247	37	49	9		7	5	464
	All	14	7		722	123	91	108	1130	170	260	136	14	16	13	2804
	NN								16	3		1				20
1966-1975	TLB	1	2		13	27	42	5	154	88	17	15	2	2	6	374
	All	1	3		211	79	373	33	726	394	76	82	5	25	14	2022
	NN								36	84						120
1976-1985	TLB	102			43	13	64	103	311	22	1	5		1	4	669
	All	480	7		570	69	533	499	1549	231	6	25		19	8	3996
	NN				1		1	1	213	84		3		3	4	310
1986-1995	TLB				40	5	37	144	2		3			1		232
	All	7	1		1018	16	281	707	822	204	34	35	2	12	3	3142
	NN				89		45	128	434	106	12	24		3		841
AVRG: 1976-2005	TLB	35	0		31	8	35	84	104	8	1	2		1	1	311
	All	164	3		679	45	327	497	1102	187	21	42	1	11	4	3083
	NN				71	4	17	52	339	86	5	21	1	2	1	597
1996-2005	TLB	2	1		10	6	5	6		2						32
	All	5	1		448	49	168	285	935	127	22	65	2	3		2110
	NN				195	14	20	80	671	68	8	57	2			1115
2006-2015	TLB	22	44		31	1		1		3				3		105
	All	66	70		733	192	103	56	226	273	62	84	40	7		1912
	NN	6	1		334	96	72	42	154	220	22	57	37			1041

In the last decade (2006 – 2015) 54% of lady beetles collected in Canada were non-native and 82% of these non-native species were the Seven-spotted Lady Beetle and the Multicolored Asian Lady Beetle (Table 4). The abundance of non-native lady beetles varies across Canada (Figure 6, Table 4). Northern regions tend to have a lower proportion of non-native to native species (e.g., YT 9%, NT 1%). In Western Canada, BC (46%) and AB (50%) have a fairly even proportion of native to non-native lady beetles, compared to SK (70%) and MB (75%). Eastern Canada also has much higher proportions of non-native species (e.g., ON 68%, QC 81%, NS 68%, PE 93%). This trend was reflected in recent search effort in the Yukon, where collection at five sites resulted in 5 non-native lady beetles out of 55 native lady beetles (9%) (Leung 2016). In Quebec search effort collection at four sites resulted in over 280 lady beetles, of which 99% were non-native (86% Multicolored Asian Lady Beetles, 13% Seven-spotted Lady Beetles), demonstrating a continued dominance of non-native lady beetles in this region.

Table 4. Percent change in relative abundance (RA) over two decades, of the Transverse Lady Beetle (TLB) to all lady beetles (Coccinellidae) (native and non-native species) collected in Canada.

Prov	1976-2005		1996-2005		2006-2015		% Change 1976- 2015 All	% Change 1976- 2015 Native	% Change 1996- 2015 All	% Change 1996- 2015 Native	% Non- Native/ Native 2006- 2015
	RA All	RA Native	RA All	RA Native	RA All	RA Native					
YT	0.21	0.21	0.40	0.40	0.33	0.37	58	73	-17	-8	9
NT	0.11	0.11	1.00	1.00	0.63	0.64	466	474	-37	-36	1
NU											
BC	0.05	0.05	0.02	0.04	0.04	0.08	-7	46	89	97	46
AB	0.18	0.20	0.12	0.17	0.01	0.01	-97	-95	-96	-94	50
SK	0.11	0.12	0.03	0.03	0.00	0.00	-100	-100	-100	-100	70
MB	0.17	0.20	0.02	0.03	0.02	0.07	-89	-64	-15	144	75
ON	0.09	0.16					-100	-100			68
QC	0.04	0.08	0.02	0.03	0.01	0.06	-74	-28	-30	67	81
NB	0.06	0.10					-100	-100			35
NS	0.04	0.12					-100	-100			68
PE	0.00	0.00									93
NL	0.06	0.07	0.00	0.00	0.43	0.43	629	500			
Total	0.10	0.13	0.02	0.03	0.05	0.12	-46	-10	262	275	54

In the last decade (2006 – 2015) there were 105 specimens of the Transverse Lady Beetle collected, compared to 32 specimens from the previous decade. This increase is due directly to increased search effort for this species (especially in the west and north), and does not reflect an actual increase in the Canadian population size.

Following increased search effort, relative abundance of Transverse Lady Beetles over the last decade increased nationally from 0.02 (1996 – 2005) to 0.05 (2006 – 2015) (compared to native and non-native lady beetles collected) and 0.03 (1996 – 2005) to 0.12 (2006 – 2015) (compared to native lady beetles collected). This is a positive change of 262% and 275% respectively. However, this national trend is largely driven by an increase in Transverse Lady Beetles collected in the YT and NT, where relatively little search effort for lady beetles had been conducted in the previous decade (1996 – 2005) and where relative abundance of this species appears to be substantially higher than in other parts of Canada.

Due to large variation in survey coverage, relative abundance of Transverse Lady Beetles over the last decade (2006 – 2015) was also compared to an average of the previous three decades (1976 – 2005). This resulted in relative abundance decreasing nationally by 46% (compared to native and non-native lady beetles collected) and 10% (compared to native lady beetles collected). The only regions in Canada that had higher percent relative abundances were YT, NT and BC (Table 4).

Looking at the number of specimens recorded across Canada from a historical context, out of the 13 provinces and territories where this species was historically abundant, it is no longer detected in 5 provinces (SK, ON, NB, NS and PE [although only two specimens have been databased for PE]). This species was last recorded in SK in 2001, ON in 1987, NB in 1994, NS in 1984, and PE in 1969. Furthermore, over the last ten years this species has only been recorded in low numbers in 4 other provinces (AB, MB, QC, and NL). In AB one specimen was recorded in 2012, in MB one specimen was recorded in 2015, in QC two specimens were recorded in 2006 and one in 2012, in NF and LB three specimens were recorded in 2014. Comparatively, 22 specimens were collected in YT, mainly in 2015, 44 specimens were collected in the NT in 2014, and 31 specimens were collected in BC, mainly in 2013. While no records exist in NU, given the prevalence of this species in YT and NT, it is also possible this species occurs here.

The consensus of expert opinion from the COSEWIC Arthropod Species Subcommittee is that the Transverse Lady Beetle has declined significantly historically, especially in regions where there is a high proportion of non-native lady beetles present (Figure 7). In the last decade, this species has remained undetected where it was formerly common (SK, ON, NB, NS, and likely PE) and is in decline or persisting in low numbers across the majority of its range (AB, MB, QC, NL). However, in BC, YT, NT and likely NU, this species remains common and these regions also seem to have a lower proportion of non-native species, which are considered a potential threat to the Transverse Lady Beetle.

McCorquodale *et al.* (2011) also reviewed evidence from literature and collection data from QC and ON to look at relative abundance and geographic ranges of a subset of 10 species of native and non-native lady beetles over time (<1960 – 2009). This study focused on regions with high quality data, complete over the time period non-natives arrived in Canada. Within this study McCorquodale *et al.* (2011) also showed that Transverse Lady Beetles declined in geographic range and in relative abundance by 72% from prior to 1960 to after 1980, concurrent with an increase in collection of non-native species.

Trends of decline in subpopulations of Transverse Lady Beetles and other native lady beetles after the arrival and establishment of non-native lady beetles are not restricted to Canada. In the United States, the Transverse Lady Beetle has also significantly declined, along with other lady beetles, which has been well documented by Wheeler and Hoebeke (1995). They highlighted studies that showed native species were common in many areas from the 1950s through 1970s, yet rarely encountered after 1985. Intensive surveys of lady beetles in Iowa, South Dakota, Minnesota, Michigan, Virginia and Maine all show that Transverse Lady Beetles and other native lady beetles were common and widespread prior to 1980, but are now very rare or extirpated (Elliott *et al.* 1996; Brown 2003; Alyokhin and Sewell 2003; Harmon *et al.* 2007; Hesler 2008; Hesler 2009; Koch 2011; Hodek *et al.* 2012; Bahlai *et al.* 2013; Bahlai *et al.* 2015).

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 1985 (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 Multicolored 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 native lady beetles 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 Transverse Lady Beetle.

In summary, this once historically common lady beetle now appears to be rare and with a more restricted range. Declines in relative abundance and geographic range have been documented in numerous studies throughout the Transverse Lady Beetle's range across Canada and the United States (Staines *et al.* 1990; Wheeler and Hoebeke 1995; Elliott *et al.* 1996; Marshall 1999; Stephans 2002; Brown 2003; 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). Within Canada, the relative abundance of the Transverse Lady Beetle has been significantly reduced compared to historical levels and extent. Over the last ten years, the Transverse Lady Beetle has continued to decline or is managing to persist in low numbers across the majority of its range, with the exception of BC, YT, NT and likely NU, where this species appears common and somewhat isolated from the impact of non-native species.

Rescue Effect

The Transverse 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 Transverse 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 (see Salafsky *et al.* 2008; Master *et al.* 2009) was used to classify and list threats to the Transverse Lady Beetle (Appendix 1). Overall threat impact for the Transverse Lady Beetle is *High – Medium*. Potential or suspected threats below are listed on order of highest to lowest threat.

Threat 8. Invasive and Other Problematic Species and Genes (high to medium impact)

8.1 Invasive non-native/alien species

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; Mack *et al.* 2000; 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 Multicolored 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 Multicolored Asian Lady Beetle into North America has been implicated in an overall reduction in the Transverse 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:

In support of scramble competition, where a finite resource is accessible to all competitors, it has been shown that Seven-spotted Lady Beetles were more voracious, had a higher aphid attack rate and lower aphid handling time, under a wide variety of conditions, compared with other native lady beetles (Hodek and Michaud 2008; Hoki *et al.* 2014). Tumminello *et al.* (2015) also investigated scramble competition and intraguild predation, concluding that the displacement of lady beetles from their 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.

Competition with Seven-spotted Lady Beetles has resulted in limited prey availability and decreased body size of other native lady beetles (Evans 2004; Losey *et al.* 2012). Furthermore, other studies have shown Seven-spotted Lady Beetles and Multicolored Asian Lady Beetles reduce survivorship of Transverse Lady Beetles and other native lady beetles, as a result of higher predation rates on their eggs and larvae (Obrycki *et al.* 1998; Michaud 2002; Alyokhin and Sewell 2004; Evans 2004; 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; Turnipseed *et al.* 2014). Intraguild predation also plays a major role in preventing recolonization by native lady beetles and females avoid oviposition sites where intraguild predators are present (Ruzicka 1997; Hodek *et al.* 2012).

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 Multicolored Asian Lady Beetles negatively impact Transverse 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 exotic parasites and pathogens (Bjornson 2008). These include parasitoids (*i.e.*, braconid wasp *D. coccinellae*), parasitic mites (*i.e.*, *Coccipolipus hippodamiae*), nematodes, protozoans, fungal pathogens (*i.e.*, *Beauveria bassiana*), microsporidia (Nosematidae), and bacteria. All can negatively impact lady beetle fitness and reduce survivorship over winter (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 exotic parasites and pathogens on the Transverse Lady Beetle is uncertain, native species typically have a greater susceptibility (Cottrell and Shapiro-Ilan 2003). Obrycki (1989) reported greater susceptibility of native lady beetles to the exotic braconid wasp *D. coccinellae*, compared to non-native species, such as the Multicolored Asian Lady Beetle. Cottrell and Shapiro-Ilan (2003) also reported greater susceptibility of native lady beetles to an exotic fungal pathogen (*Beauveria bassiana*) compared to the Multicolored 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 Transverse Lady Beetles.

Threat 9. Pollution (low impact)

9.3 Agricultural and forestry effluents

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 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 (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 Multicolored Asian Lady Beetle larvae 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.

Threat 7. Natural System Modifications (low impact)

7.3 Other ecosystem modifications

Conversion of managed lands and farms resulting in forest regrowth, specifically in eastern ON, could potentially be a factor in the decline of the Transverse Lady Beetle and other native lady beetles (Bucknell and Pearson 2007; Harmon *et al.* 2007). Urban expansion and abandonment of farmland may mean less favourable foraging (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).

Threat 2. Agriculture and Aquaculture (negligible impact)

2.1 Annual and perennial non-timber crops

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 (Threat 9).

Planting of genetically modified (GM) insect-resistant crops, *e.g.*, GM corn 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).

Threat 1. Residential and Commercial Development (negligible impact)

1.1 Housing and urban areas; 1.2 Commercial and industrial areas

Habitat loss and declines in habitat quality from expansion of residential and commercial developments may be contributing to local declines of this species in some parts of its range, particularly southern ON. Green areas and local gardens within smaller urbanized areas, however, may also still provide habitat for the Transverse 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 broad geographic range and is highly mobile, the threats to it remain unclear and variable across its range, and the number of location is not applicable.

PROTECTION, STATUS AND RANKS

Legal Protection and Status

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

Non-Legal Status and Ranks

This species has not yet been ranked globally or nationally. The conservation data centres across Canada have assigned status ranks as follows: ON: S1, YT: S4; NT: S4S5; BC: S5; AB, SK, MB: S4S5; ON: S1; QC: S4; NB, NS, PE: SH; NF: SU; NF (Labrador only): S5.

The Canada National Status Ranks (Canadian Endangered Species Conservation Council [CESCC 2015]) assessed this species in 2010 as Sensitive.

The IUCN Red list (2015): Not assessed

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

Habitat Protection and Ownership

Given the expansive range and broad habitat niche of the Transverse 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 Transverse Lady Beetle spans numerous provincial and national parks and protected areas.

ACKNOWLEDGEMENTS AND AUTHORITIES CONTACTED

The authors wish to thank Jennifer Heron for supervising this report, as well Angèle Cyr, Jenny Wu and Alain Fillion (COSEWIC Secretariat), in addition to David McCorquodale (Cape Breton University); John Acorn (University of Alberta); John Losey (Cornell University); Cory Sheffield (Royal Saskatchewan Museum); Suzanne Carrière, Danny Allaire, Nicholas Larter (Northwest Territories Government); Mary Sabine (New Brunswick Government); Barb Sharanowski (University of Manitoba); Gilles Boiteau (Agriculture Canada); Isabelle Gauthier, Nathalie Desrosiers (Ministère des Forêts, de la Faune et des Parcs); Ken Millard, Lisa Ott (Galiano Conservancy Association); Claudia Copley, Darren Copley, Heidi Gartner and Rob Cannings (Royal British Columbia Museum); Syd Cannings, Amy Ganton and Ruben Boles (Canadian Wildlife Service, Environment and Climate Change Canada); J. Grant Pryznyk (Wek'ëezhii Renewable Resources Board); Kaytlin Cooper (Gwich'in Renewable Resources Board), Gary Anweiler, Heather Leibel, Matthias Buck, Robb Bennett, Erica McClaren, Berry Wijdeven, Mark Weston, Lynn Westcott, Sandy Cessellie, Bill Ramey, Bev Ramey, Michael Dunn, Geoff Lynch, Nick Burdock, Jeevan Sandu, Sylvia Letay, Rick Howie, Lea Gelling, Kathy Coot, Tom Foot, Karen Durovich, Sara Kalnay-Watson, Al Harris, Rob Foster, Vincent Bereczki, Bruce Bennett, and the Lost Ladybug Project. Photographs of the Transverse Lady Beetle courtesy Steve Marshall.

INFORMATION SOURCES

- Abassi, S., M.A. Birkett, J. Pettersson, J.A. Pickett, L.J. Wadhams, and C.M. Woodcock. 2001. Response of the ladybird parasitoid *Dinocampus coccinellae* to toxic alkaloids from the seven-spot ladybird, *Coccinella septempunctata*. *Journal of Chemical Ecology* 27:33-43.
- Acorn, J. 2007. *Ladybugs of Alberta: Finding the spots and connecting the dots*. The University of Alberta Press, Edmonton, Alberta.
- Alyohin, A., and G. Sewell. 2004. Changes in a lady beetle community following the establishment of three alien species. *Biological Invasions* 6:463-471.

- Bahli, C.A., M. Colunga-Garcia, S.H. Gage, and D.A. Landis. 2015. The role of exotic ladybeetles in the decline of native ladybeetle populations: evidence from long term monitoring. *Biological Invasions* 17:1005-1024.
- Bahlai, C.A., M. Colunga-Garcia, S.H. Gage, and D.A. Landis. 2013. Long-term functional dynamics of an aphidophagous coccinellid community remain unchanged despite repeated invasions. *PLoS ONE* 8:1-11.
- Bahlai, C.A., W. van der Werf, M. O'Neal, L. Hemerik, and D.A. Landis 2015. Shifts in dynamic regime of an invasive lady beetle are linked to the invasion and insecticidal management of its prey. *Ecological Applications* 25:1807-1818.
- Barrn, A., and K. Wilson. 1998. Overwintering survival in the seven spot ladybird, *Coccinella septempunctata* (Coleoptera: Coccinellidae). *European Journal of Entomology* 95:639-642.
- Belicek, J. 1976. Coccinellidae of western Canada and Alaska with analyses of the transmontane zoogeographic relationships between the fauna of British Columbia and Alberta (Insecta: Coleoptera: Coccinellidae). *Quaestiones Entomologicae* 12:283-409.
- Bianchi, F.J., A., Honěk, and W. van der Werf. 2007. Changes in agricultural land use can explain population decline in a ladybeetle species in the Czech Republic: evidence from a process-based spatially explicit model. *Landscape Ecology* 22:1541-1554.
- Bjornson, S. 2008. Natural enemies of the convergent lady beetle, *Hippodamia convergens* Guérin-Ménéville: their inadvertent importation and potential significance for augmentative biological control. *Biological Control* 44:305-311.
- Bjornson, S., J. Le, T. Saito, and H. Wang. 2011. Ultrastructure and molecular characterization of a microsporidium, *Tubulinosema hippodamiae*, from the convergent lady beetle, *Hippodamia convergens* Guérin-Ménéville. *Journal of Invertebrate Pathology* 106:280 – 288.
- Bousquet, Y., P. Bouchard, A.E. Davies, and D.S. Sikes. 2013. Checklist of beetles (Coleoptera) of Canada and Alaska. Second edition. *ZooKeys* 360:1-44.
- Brown, M.W. 2003. Intraguild responses of aphid predators on apple to the invasion of an exotic species, *Harmonia axyridis*. *BioControl* 48:141-153.
- Brown, W.J. 1940. Notes on the American distribution of some species of Coleoptera common to the European and North American continents. *The Canadian Entomologist* 72:65-78.
- Brown, W.J. 1962. A revision of the forms of *Coccinella* L., occurring in America north of Mexico (Coleoptera: Coccinellidae). *The Canadian Entomologist* 94:785-808.
- Brown, W.J., and R. de Ruelle. 1962. An annotated list of the Hippodamiini of Northern America, with a key to the genera (Coleoptera: Coccinellidae). *The Canadian Entomologist* 94:643-652.

- Bucknell, D., and C.J. Pearson. 2007. A spatial analysis of land-use change and agriculture in eastern Canada. *International Journal of Agricultural Sustainability* 4:22-38.
- Burgio, G., F. Santi, and S. Maini. 2002. On intra-guild predation and cannibalism in *Harmonia axyridis* (Pallas) and *Adalia bipunctata* L. (Coleoptera: Coccinellidae). *Biological Control* 24:110-116.
- Cali, A., and J.D. Briggs. 1967. The biology and life history of *Nosema tracheophila* sp. n. (Protozoa: Cnidospora: Microsporidea) found in *Coccinella septempunctata* Linnaeus (Coleoptera: Coccinellidae). *Journal of Invertebrate Pathology* 9:515-522.
- Cardinale, B.J., J.J. Weis, A.E. Forbes, K.J. Tilmon, and A.R. Ives. 2006. Biodiversity as both a cause and consequence of resource availability: a study of reciprocal causality in a predator-prey system. *Journal of Animal Ecology* 75:497-505.
- Ceryngier, P., and I. Hodek. 1996. Enemies of the Coccinellidae. Pp. 319-350. in Hodek, I., and A. Honěk. (eds). *Ecology of Coccinellidae*. Kluwer Academic, Dordrecht.
- Coll, M., M. Guershon. 2002. Omnivory in terrestrial arthropods: mixing plant and prey diets. *Annual Review of Entomology* 47:267 – 297.
- Comont, R.F., H.E. Roy, R. Harrington, C.R. Shortall, and B.V. Purse. 2013. Ecological correlates of local extinction and colonisation in the British ladybird beetles (Coleoptera: Coccinellidae). *Biological Invasions* 16:1805-1817.
- Cottrell, T.E., and D.I. Shapiro-Ilan. 2003. Susceptibility of a native and an exotic lady beetle (Coleoptera: Coccinellidae) to *Beauveria bassiana*. *Journal of Invertebrate Pathology* 84:137-144.
- Crowder, D.W., and W.E. Snyder. 2010. Eating their way to the top? Mechanisms underlying the success of invasive insect generalist predators. *Biological Invasions* 12:2857 – 2876.
- Dobzhansky, T. 1935. A list of Coccinellidae of British Columbia. *Journal of the New York Entomological Society* 43:331-336.
- Duan, J.J., Head, G., McKee M.J. *et al.* 2002. Evaluation of dietary effects of transgenic corn pollen expressing Cry3Bb1 protein on a non-target ladybird beetle, *Coleomegilla maculata*. *Entomologia Experimentalis et Applicata* 104:271 – 280.
- Ehler, L.E. 1990. Introduction strategies in biological control of insects. Pp 111-134. in Mackauer, M., L.E. Ehler, and J. Roland. (eds) *Critical issues in biological control*. Intercept Ltd, Andover.
- Eisenback, B.M., S.M. Salom, L.T. Kok, and A.F. Lagalante. 2010. Lethal and sublethal effects of imidacloprid on hemlock woolly adelgid (Hemiptera: Adelgidae) and two introduced predator species. *Journal of Economic Entomology* 103:1222-1234.
- Elith, J., C.H. Graham, R.P. Anderson, M. Dudik, S. Ferrier, *et al.* 2006. Novel methods improve prediction of species' distributions from occurrence data. *Ecography* 29:129-151.

- Elliott, N.C., and R.W. Kieckheffer. 1990. A 13-year study of the aphidophagous insects of alfalfa. *Prairie Naturalist* 22:87-96.
- Elliott, N. 2000. Adult coccinellid activity and predation on aphids in spring cereals. *Biological Control* 17:218 – 226.
- Elliott, N.C., R.W. Kieckheffer, J.H. Lee, and B.W. French. 1999. Influence of within-field and landscape factors on aphid predator populations in wheat. *Landscape Ecology* 14:239 – 252.
- Elliott, N.C., R.W. Kieckheffer, and W.C. Kauffman. 1996. Effects of an invading coccinellid on native coccinellids in an agricultural landscape. *Oecologia* 105:537-544.
- Ellis, D.R., D.E. Prokrym, and R.G. Adams. 1999. Exotic lady beetle survey in northeastern United States: *Hippodamia variegata* and *Propylea quatuordecimpunctata* (Coleoptera: Coccinellidae). *Entomological News* 111:73-84.
- Evans, E.W., and T.R. Toler. 2007. Aggregation of polyphagous predators in response to multiple prey: ladybirds (Coleoptera: Coccinellidae) foraging in alfalfa. *Population Ecology* 49:29-36.
- Evans, E.W., A.O. Soares, and H. Yasuda. 2011. Invasions by ladybugs, ladybirds, and other predatory beetles. *BioControl* 56:597-611.
- Evans, E.W. 2004. Habitat displacement of North American ladybirds by an introduced species. *Ecology* 85:637-647.
- Federal, Provincial and Territorial Governments of Canada. 2010. Canadian Biodiversity: Ecosystem Status and Trends 2010. Canadian Councils of Resource Ministers. Ottawa, ON. vi + 142 pp.
- Finlayson, C.J., K.M. Landry, and A.V. Alyokhin. 2008. Abundance of native and non-native lady beetles (Coleoptera: Coccinellidae) in different habitats in Maine. *Annals of the Entomological Society of America* 101:1078-1087.
- Fortin, M.J., T.H. Keitt, B.A. Maurer, M.L. Taper, D.M. Kaufman, and T.M. Blackburn. 2005. Species' geographic ranges and distributional limits: pattern analysis and statistical issues. *Oikos* 108:7-17.
- Fothergill, K., and K.V. Tindall. 2010. Lady beetle (Coleoptera: Coccinellidae: Coccinellinae) occurrences in southeastern Missouri agricultural systems: differences between 1966 and present. *The Coleopterists Bulletin* 64:379-382.
- Gardiner, M.M., L.L. Allee, P.M.J. Brown, J.E. Losey, H.E. Roy. *et al.* 2012. Lessons from lady beetles: accuracy of monitoring data from US and UK citizen-science programs. *Frontiers in Ecology and the Environment*: Online Preprint. doi:10.1890/110185.
- Gardiner, M.M., Landis, D.A., Gratton, C., Schmidt, N., O'Neal, M., Mueller, E., Chacon, J., Heimpel, G.E., and DiFonzo, C.D. 2009. Landscape composition influences patterns of native and exotic lady beetle abundance. *Diversity and Distributions* 15:554–564.

- Gardiner, M.M., M.E. O'Neal, and D.A. Landis. 2011. Intraguild predation and native lady beetle decline. *PloS ONE* 6:e23576.
- Gesraha, M.A. 2007. Impact of some insecticides on the Coccinellid predator, *Coccinella undecimpunctata* L. and its aphid prey, *Brevicoryne brassicae* L. *Egyptian Journal of Biological Pest Control* 17:65-69.
- Giorgi, A., and J. Vandenberg. 2009. Coccinellidae. Lady beetles, ladybird beetles, ladybugs. Version 09 November 2009 (under construction). <http://tolweb.org/Coccinellidae/9170/2009.11.09> in The Tree of Life Web Project, <http://tolweb.org/>.
- Gordon, R.D. 1985. The Coccinellidae (Coleoptera) of America north of Mexico. *Journal of New York Entomological Society* 95:1-912.
- Gordon, R.D., and N. Vandenberg. 1991. Field guide to recently introduced species of Coccinellidae (Coleoptera) in North America, with revised key to North America genera of Coccinellini. *Proceedings of the Entomological Society of Washington* 93:845-864.
- Gordon, R., N. Vandenberg. 1995. Larval systematics of North American *Coccinella* L. (Coleoptera: Coccinellidae). *Entomologica Scandinavica*, 26:67-86.
- Grant, P. pers. data.
- Hagen, K.S. 1962. Biology and ecology of predaceous Coccinellidae. *Annual Review of Entomology* 7:289-326.
- Harmon, J.P., E. Stephens, and J. Losey. 2007. The decline of native coccinellids (Coleoptera: Coccinellidae) in the United States and Canada. *Journal of Insect Conservation* 11:85-94.
- Harwood, J.D., R.A. Samson, and J.J. Obrycki. 2007. Temporal detection of Cry1Ab-endotoxins in coccinellid predators from fields of *Bacillus thuringiensis* corn. *Bulletin of Entomological Research* 97:643-648.
- Hesler, L.S. 2009. An annotated checklist of the lady beetles (Coleoptera: Coccinellidae) of Iowa, U.S.A. *Insecta Mundi* 91:1-10.
- Hesler, L.S., and R.W. Kieckhefer. 2008. Status of exotic and previously common native coccinellids (Coleoptera) in south Dakota landscapes. *Journal of the Kansas Entomological Society* 81:29-49.
- Hesler, L.S., G. McNickle, M. Catangui, J. Losey, E. Beckendorf, L. Stellwag, D. Brandt, and P. Bartlett. 2012. Method for continuously rearing coccinella lady beetles (Coleoptera: Coccinellidae). *The Open Entomology Journal* 6:42-48.
- Hesler, L.S., R.W. Kieckhefer, and M.A. Catangui. 2004. Surveys and field observations of *Harmonia axyridis* and other Coccinellidae (Coleoptera) in eastern and central South Dakota. *Transactions of the American Entomological Society* 130:113-133.
- Hodek I, H.F. van Emden, and A. Honěk. 2012. Ecology and behaviour of the ladybird beetles (Coccinellidae). Wiley-Blackwell. Kindle Edition.

- Hodek, I., and A. Honěk. 1996. Ecology of Coccinellidae. Kluwer Academic Publishers, Dordrecht, The Netherlands.
- Hodek, I., and J.P. Michaud. 2008. Why is *Coccinella septempunctata* so successful? (A point-of-view). European Journal of Entomology 105:1-12.
- Hoki, E., J.E. Losey, and T.A. Ugone. 2014. Comparing the consumptive and non-consumptive effects of a native and introduced lady beetle on pea aphids (*Acyrtosiphon pisum*). Biological Control 70:78-84.
- Hurst, G.D.D., R.G. Sharpe, A.H. Broomfield. *et al.* 1995. Sexually transmitted disease in a promiscuous insect, *Adalia bipunctata*. Ecological Entomology 20:230 – 236.
- ITIS (Integrated Taxonomic Information System). 2015. Retrieved [November 2015], from the on-line database (<http://www.itis.gov>).
- Ives, A.R., P. Kareiva, and R. Perry. 1993. Response of a predator to variation in prey density at three hierarchical scales lady beetles feeding on aphids. Ecology 74:1929-1938.
- Ives, P.M. 1981. Estimation of coccinellid numbers and movement in the field. The Canadian Entomologist 113:981-997.
- Javorek, S.K., and M.C. Grant. 2011. Trends in wildlife habitat capacity on agricultural land in Canada, 1986 – 2006. Canadian Biodiversity: Ecosystem Status and Trends 2010, Technical Thematic Report No. 14. Canadian Councils of Resource Ministers. Ottawa, ON. vi + 46 pp.
<http://www.biodivcanada.ca/default.asp?lang=En&idn=137E1147-1>
- Jeffries, D.L., J. Chapman, H.E. Roy, S. Humphries, R. Harrington, P.M.J. Brown, and L.J. Handley. 2013. Characteristics and drivers of high-altitude ladybird flight: insights from vertical-looking entomological radar. PLoS ONE 8:e82278.
- Kajita, Y., and E.W. Evans. 2010. Alfalfa fields promote high reproductive rate of an invasive predatory lady beetle. Biological Invasions 12:2293 – 2302.
- Kajita, Y., E.W. Evans, and H. Yasuda. 2009. Reproductive responses of invasive and native predatory lady beetles (Coleoptera: Coccinellidae) to varying prey availability. Physiological Ecology 38(4):1283-1292.
- Kenis, M., M.A. Auger-Rozenberg, A. Roques, L. Timms, C. Pere, M.J.W. Cock, J. Settele, S. Augustin, and C. Lopez-Vaamonde. 2008. Ecological effects of invasive alien insects. Biological Invasions 11:21-45.
- Koch, J.B., and J.P. Strange. 2009. Constructing a species database and historic range maps for North American bumblebees (*Bombus sensu stricto* Latreille) to inform conservation decisions. Uludag Bee Journal 9:97-108.
- Koch, R.L. 2011. Recent detections of a rare native lady beetle, *Coccinella novemnotata* (Coleoptera : Coccinellidae), in Minnesota. Great Lakes Entomologist 44:196-199.

- Kovář, I. 2005. Revision of the Palaearctic species of the *Coccinella transversoguttata* species group with note on some other species of the genus (Coleoptera: Coccinellidae). *Acta Entomologica Musei Nationalis Pragae* 45:129-164.
- Krafsur, E.S., J.J. Obrycki, and J.D. Harwood. 2005. Comparative genetic studies of native and introduced Coccinellidae in North America. *European Journal of Entomology* 102:469-474.
- Krivan, K. 2008. Dispersal dynamics: Distribution of lady beetles (Coleoptera: Coccinellidae). *European Journal of Entomology* 105:405-409.
- Kumar, S., and R.I. Bhatt. 2002. Pyrethroid-induced resurgence of sucking pests in the mango ecosystem. *Journal of Applied Zoological Research* 13:107-111.
- Larochelle, A. 1979. Les Coléoptères Coccinellidae du Québec. *Cordulia* (Supplement) 10:1-111.
- Laurent, P., J.C. Braekman, and D. Daloze. 2005. Insect chemical defense. *Topics in Current Chemistry* 240:167 – 229.
- Leung, M. 2016. Baseline inventory and monitoring of the Transverse Lady Beetle in southern Yukon. Canadian Wildlife Service. January 2016.
- Losey, J., J. Perlman, and E.R. Hoebeke. 2007. Citizen scientist rediscovers rare Nine-spotted Lady Beetle, *Coccinella novemnotata*, in eastern North America. *Journal of Insect Conservation* 11:415-417.
- Losey, J., J. Perlman, J. Kopco, S. Ramsey, L. Hesler, E. Evans, L. Allee, and R. Smyth. 2012. Potential causes and consequences of decreased body size in field populations of *Coccinella novemnotata*. *Biological Control* 61:98-103.
- Louda, S.M., R.W. Pemberton, M.T. Johnson, and P.A. Follett. 2003. Non-target effects - the achilles' heel of biological control? Retrospective analyses to reduce risk associated with biocontrol introductions. *Annual Review of Entomology* 48:365-396.
- Lucas, E. 2005. Intraguild predation among aphidophagous predators. *European Journal of Entomology* 102:351-364.
- Lucas, E., C. Vincent, G. Labrie, G. Chouinard, F. Fournier, F. Pelletier, N.J. Bostanian, D. Coderre, M.P. Mignault, and P. Lafontaine. 2007. The multicolored Asian ladybeetle *Harmonia axyridis* (Coleoptera: Coccinellidae) in Québec agroecosystems ten years after its arrival. *European Journal of Entomology* 104:737-743.
- Lundgren, J.G., and R.N. Wiedenmann. 2002. Coleopteran-specific Cry3Bb toxin from transgenic corn pollen does not affect the fitness of a nontarget species, *Coleomegilla maculata* DeGeer (Coleoptera, Coccinellidae). *Environmental Entomology* 31:1213-1218.
- Mack R.N., D. Simberloff, W.M. Lonsdale, H. Evans, M. Clout and F.A. Bazzaz. 2000. Biotic invasions: causes, epidemiology, global consequences, and control. *Ecological Applications* 10:689-710.

- Majka, C.G., and D.B. McCorquodale. 2006. The Coccinellidae (Coleoptera) of the maritime provinces of Canada: new records, biogeographical notes, and conservation concerns. *Zootaxa* 1154:49-68.
- Majka, C.G., and D.B. McCorquodale. 2010. Ladybird beetles (Coleoptera: Coccinellidae) of the Atlantic Maritime Ecozone. Chapter 21. Pp. 439-452. in McAlpine, D.F., and I.M. Smith. (eds). *Assessment of species diversity in the Atlantic Maritime Ecozone*. NRC Research Press, Ottawa, Canada.
- Marletto, F., A. Patetta, and A. Manino 2003. Laboratory assessment of pesticide toxicity to bumble bees. *Bulletin of Insectology* 56:155-158.
- Marples, N.M., P.M. Brakefield, and R.J. Cowie. 1989. Differences between the 7-spot and 2-spot ladybird beetles (Coccinellidae) in their toxic effects on a bird predator. *Ecological Entomology* 14:79-84.
- Marriott, S.M, D.J. Giberson, and D.B. McCorquodale. 2009. Changes in the status and geographic ranges of Canadian lady beetles (Coccinellidae) and the selection of candidates for risk assessment. Part I Foundation Report. Report to COSEWIC Arthropods Species Specialist Committee. 53 pp.
- Marshall, S. 1999. Alien invasions, Ontario's ever changing bug landscape. *Seasons*. Spring 1999:26 – 29.
- Master, L., D. Faber-Langendoen, R. Bittman, G.A. Hammerson, B. Heidel, J. Nichols, L. Ramsay, and A. Tomaino. 2009. NatureServe conservation status assessments: factors for assessing extinction risk. NatureServe, Arlington, VA.
- McCorquodale, D.B., D.J. Giberson, and S.M. Marriott. 2011. Changes in the status and geographic ranges of Canadian lady beetles (Coleoptera: Coccinellidae: Coccinellinae) and the selection of candidate species for risk assessment. Part 3: Final Report. Committee on the Status of Endangered Wildlife in Canada, Ottawa.
- McMullen, R.D. 1967. The effects of photoperiod, temperature and food supply on rate of development and diapause in *Coccinella novemnotata*. *The Canadian Entomologist* 99:578-586.
- Michaud, J.P. 2002. Invasion of the Florida citrus ecosystem by *Harmonia axyridis* (Coleoptera: Coccinellidae) and asymmetric competition with a native species, *Cycloneda sanguinea*. *Environmental Entomology* 31:827-835.
- Moser, S.E., J.D. Harwood, and J.J. Obrycki. 2008. Larval feeding on Bt-hybrid and non-Bt corn seedlings by *Harmonia axyridis* (Coleoptera, Coccinellidae) and *Coleomegilla maculata* (Coleoptera, Coccinellidae). *Environmental Entomology* 37:525-533.
- Moser, S.E., and J.J. Obrycki. 2009. Non-target effects of neonicotinoid seed treatments; mortality of coccinellid larvae related to zoophytophagy. *Biological Control* 51:487-492.
- Natureserve. 2014. Natureserve Explorer: An online encyclopedia of life [web application]. Version 7.1. Natureserve, Arlington, Virginia. Available <http://www.natureserve.org/explorer>. (Accessed: December 15, 2014).

- Nentwig, W. 1983. The prey of web-building spiders compared with feeding experiments (Araneae: Aranelidae, Linyphiidae, Pholcidae, Agelenidae). *Oecologia* 56:132-139.
- New, T.R. 1995. *Introduction to Invertebrate Conservation Biology*. Oxford University Press, New York. 194 pp.
- Obrycki, J.J. 1989. Parasitization of native and exotic coccinellids by *Dinocampus coccinellae* (Schrank) (Hymenoptera: Braconidae). *Journal of Kansas Entomological Society* 62:211 – 218.
- Obrycki, J.J., K.L. Giles, and A.M. Ormord. 1998. Interactions between an introduced and indigenous coccinellid species at different prey densities. *Oecologia* 117:279 – 285.
- Obrycki, J.J., and T.J. Kring. 1998. Predaceous Coccinellidae in biological control. *Annual Review of Entomology* 43:295-321.
- Olszak, R.W., B. Pawlik, and R.Z. Zajac. 1994. The influence of some insect growth-regulators on mortality and fecundity of the aphidophagous coccinellids *Adalia bipunctata* L. and *Coccinella septempunctata* L. (Col-Coccinellidae). *Journal of Applied Entomology* 117:58-63.
- Omkar, and S. Srivastava, 2002. The reproductive behaviour of an aphidophagous ladybeetle, *Coccinella septempunctata* (Coleoptera: Coccinellidae). *European Journal of Entomology* 99:465-470.
- Osawa, N. 2000. Population field studies on the aphidophagous ladybird beetle *Harmonia axyridis* (Coleoptera:Coccinellidae): resource tracking and population characteristics. *Population Ecology* 42:115-127.
- Patt, J.M., S.C. Wainright, G.C. Hamilton, D. Whittinghill, K. Bosley, J. Dietrick, J.H. Lashomb. 2003. Assimilation of carbon and nitrogen from pollen and nectar by a predaceous larva and its effects on growth and development. *Ecological Entomology* 28:717-728.
- Pell, J.K., J. Baverstock, H.E. Roy, R.L. Ware, and M.E.N. Majerus. 2008. Intraguild predation involving *Harmonia axyridis*: a review of current knowledge and future perspectives. *BioControl* 53:147-168.
- Petersen, L.S. 1993. Effects of 45 insecticides, acaricides and molluscicides on the rove beetle *Aleochara bilineata* (Col.: Staphylinidae) in the laboratory. *Entomophaga* 38:371-382.
- Porcar, M., I. Garcia-Robles, L. Dominguez-Escriba, and A. Latorre. 2010. Effects of *Bacillus thuringiensis* Cry1Ab and Cry3Aa endotoxins on predatory Coleoptera tested through artificial diet-incorporation bioassays. *Bulletin of Entomological Research* 100:297-302.
- Rees, B.E., D.M. Anderson, R.D. Gordon, and D. Bouk. 1994. Larval key to genera and selected species of North American Coccinellidae (Coleoptera). *Proceedings of the Entomological Society of Washington* 96:387-412.
- Richardson, M.L., and L.M. Hanks. 2009. Partitioning of niches among four species of orb-weaving spiders in a grassland habitat. *Environmental Entomology* 38:651-656.

- Riddick, E.W., T.E. Cottrell, and K.A. Kidd. 2009. Natural enemies of the Coccinellidae: Parasites, pathogens, and parasitoids. *Biological Control* 51:306-312.
- Roy, H.E., and T. Cottrell. 2008. Forgotten natural enemies: interactions between coccinellids and insect-parasitic fungi. *European Journal of Entomology* 105:391-398.
- Ruzicka, Z. 1997. Recognition of oviposition-detering allomones by aphidophagous predators (Neuroptera: Chrysopidae, Coleoptera: Coccinellidae). *European Journal of Entomology* 94:431-434.
- Salafsky, N., D. Salzer, A.J. Stattersfield, C. Hilton-Taylor, R. Neugarten, S.H.M. Butchart, B. Collen, N. Cox, L.L. Master, S. O'Connor, and D. Wilkie. 2008. A standard lexicon for biodiversity conservation: unified classifications of threats and actions. *Conservation Biology* 22:897-911. Web site: <http://conservationmeasures.org/CMP/IUCN/browse.cfm?TaxID=DirectThreats>
- Sato, S., and A.F.G. Dixon. 2004. Effect of intraguild predation on the survival and development of three species of aphidophagous ladybirds: Consequences for invasive species. *Agricultural and Forest Entomology* 6:21 – 24.
- Schaeffer, P.W., R.J. Dysart, and H.B. Specht. 1987. North American distribution of *Coccinella septempunctata* (Coleoptera: Coccinellidae) and its mass appearance in coastal Delaware. *Environmental Entomology* 16:368-373.
- Singh, S.R., K.F.A. Walters, G.R. Port, and P. Northing. 2004. Consumption rates and predatory activity of adult and fourth instar larvae of the seven spot ladybird, *Coccinella septempunctata* (L.), following contact with dimethoate residue and contaminated prey in laboratory arenas. *Biological Control* 30:127-133.
- Skinner, B., and E. Domaine. 2010. Rapport sur la situation de la cocinelle à neuf points (*Coccinella novemnotata*) au Québec. Ministère des Ressources naturelles et de la Faune du Québec. Faune Québec. 37 pp.
- Sloggett, J.J. 2010. Predation of ladybird beetles by the orb-web spider *Araneus diadematus*. *BioControl* 55:631-638.
- Sloggett, J.J., and M.E.N. Majerus. 2000. Habitat preferences and diet in the predatory Coccinellidae (Coleoptera): An evolutionary perspective. *Biological Journal of the Linnean Society* 70:63-88.
- Smith, B.C. 1966. Variation in weight, size, and sex ratio of Coccinellid adults (Coleoptera: Coccinellidae). *The Canadian Entomologist* 98:639-644.
- Smith, C.A., and M.M. Gardiner. 2013. Biodiversity loss following the introduction of exotic competitors: does intraguild predation explain the decline of native lady beetles? *PLoS ONE* 8:e84448.
- Smith, S.F., and V.A. Krischik. 1999. Effects of systemic imidacloprid on *Coleomegilla maculata* (Coleoptera, Coccinellidae). *Environmental Entomology* 28:1189-1195.
- Snyder, W.E., and E.W. Evans. 2006. Ecological effects of invasive arthropod generalist predators. *Annual Review of Ecology, Evolution and Systematics* 37:95-122.

- Snyder, W.E., G.M. Clevenger, and S.D. Eigenbrode. 2004. Intraguild predation and successful invasion by introduced ladybird beetles. *Oecologia* 140:559-565.
- Srivastava, S., and Omkar. 2004. Age-specific mating and reproductive senescence in the seven-spotted ladybird, *Coccinella septempunctata*. *Journal of Applied Entomology* 128:452-458.
- Staines, C.L., M.J. Rothchild, and R.B. Trumble. 1990. A survey of the Coccinellidae (Coleoptera) associated with nursery stock in Maryland. *Proceedings of the Entomological Society of Washington* 92:310-313.
- Stellwag, L., and E. Losey. 2014. Sexual dimorphism in North American coccinellids: sexing methods for species of *Coccinella* L. (Coleoptera: Coccinellidae) and implications for conservation research. *The Coleopterists Bulletin* 68:271 – 281.
- Stephens, E.J. 2002. Apparent extirpation of *Coccinella novemnotata* in New York State: Optimizing sampling methods and evaluating explanations for decline. MSc Thesis. Cornell University, Ithaca NY USA.
- Theiling, K.M., and B.A. Croft. 1988. Pesticide side effects on arthropod natural enemies: a database summary. *Agriculture, Ecosystems and Environment* 21:191 – 218.
- Tumminello, G., T.A. Ugine, and J.E. Losey. 2015. Intraguild interactions of native and introduced coccinellids: The decline of a flagship species. *Environmental Entomology* 44:64-72.
- Turchin, P., and P. Kareiva. 1989. Aggregation in *Aphis varians* - an effective strategy for reducing predation risk. *Ecology* 70:1008-1016.
- Turnipseed, R.K., T.A. Ugine, and J.E. Losey. 2014. Effect of prey limitation on competitive interactions between a native lady beetle, *Coccinella novemnotata*, and an invasive lady beetle, *Coccinella septempunctata* (Coleoptera: Coccinellidae). *Environmental Entomology* 43:969-976.
- Turnock, W.J., I.L. Wise, and F.O. Matheson. 2003. Abundance of some native coccinellines (Coleoptera: Coccinellidae) before and after the appearance of *Coccinella septempunctata*. *The Canadian Entomologist* 135:391-404.
- Ugine, T.A., and J.E. Losey. 2014. Development times and age-specific life table parameters of the native lady beetle species *Coccinella novemnotata* (Coleoptera: Coccinellidae) and its invasive congener *Coccinella septempunctata* (Coleoptera: Coccinellidae). *Physiological Ecology* 43:1067-1075.
- van der Werf, W., E.W. Evans, and J. Powell. 2000. Measuring and modelling the dispersal of *Coccinella septempunctata* (Coleoptera: Coccinellidae) in alfalfa fields. *European Journal of Entomology* 97:487-493.
- Vandenberg, N.J. 2002. Coccinellidae Latreille 1807. Pp. 371-389. in Arnett, R.H., M.C. Thomas, P.E. Skelley, and J.H. Frank. (eds) *American Beetles, Volume 2 Polyphaga: Scarabaeoidea through Curculionoidea*, CRC Press, Boca Raton, FL.

- Watson, W.Y. 1956. A study of the phylogeny of the genera of the tribe Coccinellini (Coleoptera). Contributions of the Royal Ontario Museum Life Sciences Division 42:1-52.
- Watson, W.Y. 1976. A review of the genus *Anatis* Mulsant (Coleoptera: Coccinellidae). The Canadian Entomologist 108:935-944.
- Webberley, K.M., G.D.D. Hurst, R.W. Husband. *et al.* 2004. Host reproduction and an STD: causes and consequences of *Coccipolipus hippodamiae* distribution on coccinellids. Journal of Animal Ecology 73:1-10.
- Webberley, K. M., and G.D.D. Hurst. 2002. The effect of aggregative overwintering on an insect sexually transmitted parasite system. Journal of Parasitology 88:707-712.
- Wheeler, A.G., and E.R. Hoebeke. 1995. *Coccinella novemnotata* in northeastern North America: historical occurrence and current status (Coleoptera: Coccinellidae). Proceedings of the Entomological Society of Washington 97:701-716.
- Wheeler, A.G., and C.A. Stoops. 1996. Status and spread of the Palaearctic lady beetles *Hippodamia variegata* and *Propylea quatuordecimpunctata* (Coleoptera: Coccinellidae) in Pennsylvania, 1993-1995. Entomological News 107:291 – 298.
- Wiggins, G.B., S.A. Marshall, and J.A. Downes. 1991. The importance of research collections of terrestrial arthropods. Brief for the Biological Survey of Canada (Terrestrial Arthropods). <http://www.biology.ualberta.ca/bsc/briefs/brimportance.htm>
- Youn, Y.N., M.J. Seo, J.G. Shin, C. Jang, and Y.M. Yu. 2003. Toxicity of greenhouse pesticides to multicolored Asian lady beetles, *Harmonia axyridis* (Coleoptera: Coccinellidae) Biological Control 28:164-170.

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).

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

Appendix 1. IUCN Threats calculation on the Transverse Lady Beetle.

Assessment Date: 13/02/2015			
Assessors: Jenny Heron (Co-chair and facilitator), Paul Grant (Co-chair and author), David McCorquodale (SSC member), John Klymko (SSC member), Syd Cannings (SSC and COSEWIC member), Shelley Pardy (COSEWIC member for NL), Nathalie Desrosiers (COSEWIC member for QC), Michael Svoboda (CWS-QC), and Angèle Cyr (COSEWIC Secretariat and comment recorder)			
		Level 1 Threat Impact Counts	
Threat Impact		high range	low range
A	Very High	0	0
B	High	1	0
C	Medium	0	1
D	Low	2	2
Calculated Overall Threat Impact:		High	Medium
Assigned Overall Threat Impact:		BC = High - Medium	

Threat		Impact (calculated)		Scope (next 10 Yrs)	Severity (10 Yrs or 3 Gen.)	Timing	Comments
1	Residential & commercial development		Negligible	Negligible (<1%)	Negligible (<1%)	High (Continuing)	
1.1	Housing & urban areas		Negligible	Negligible (<1%)	Negligible (<1%)	High (Continuing)	Habitat loss and declines in habitat quality from expansion of residential developments may contribute to local declines of this species. However, green areas and local gardens within smaller urbanized areas may provide habitat for the Transverse 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 contribute to local declines of this species.
1.3	Tourism & recreation areas						Habitat loss and declines in habitat quality from recreation and tourism is minimal or potentially beneficial. Most recreation areas have open areas that provide suitable habitat for Lady Beetles, or contribute to maintaining open habitat.
2	Agriculture & aquaculture	D	Negligible	Negligible (<1%)	Negligible (<1%)	High (Continuing)	

Threat		Impact (calculated)		Scope (next 10 Yrs)	Severity (10 Yrs or 3 Gen.)	Timing	Comments
2.1	Annual & perennial non-timber crops	D	Not a Threat	Small (1-10%)	Neutral or Potential Benefit	High (Continuing)	Agricultural land and crops are beneficial for this species and its prey. However, homogenization of agricultural landscapes, and changing agricultural practices such as intensive reliance on fertilizers and pesticides contribute to local declines in native species (Wheeler and Hoebeke 1995; Bianchi et al. 2007; Evans et al. 2011). Homogenization of agricultural landscapes is discussed under other ecosystem modifications (Threat 7). Pesticides are discussed in the pollution section below (Threat 9).
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. Some areas in its range are intensively managed for pulp and paper.
2.3	Livestock farming & ranching		Not a Threat	Small (1-10%)	Neutral or Potential Benefit	High (Continuing)	Transverse Lady Beetles are known to occur in heavily grazed areas in Alberta, and direct impact from grazers is unlikely. Grazing is also beneficial, and maintains open habitat.
2.4	Marine & freshwater aquaculture						Not applicable.
3	Energy production & mining						
3.1	Oil & gas drilling						Roads, seismic lines and other linear features create new open habitat and help with dispersal. Overall it is beneficial.
3.2	Mining & quarrying						Sand quarrying can be beneficial to this species in habitat creation.
3.3	Renewable energy						Wind turbines (e.g., ON): Access roads may be a potential benefit. Lady beetle mortality from wind turbines are undocumented and unlikely a threat.
4	Transportation & service corridors						
4.1	Roads & railroads						Not a threat due to preference for open habitat and linear features help with dispersal.
4.2	Utility & service lines						Potential benefit (see Threat 3). Pipe lines and power lines occur throughout this species range and are considered a benefit as they create new open habitat and help with dispersal.
4.3	Shipping lanes						Not applicable.
4.4	Flight paths						Not applicable.

Threat		Impact (calculated)		Scope (next 10 Yrs)	Severity (10 Yrs or 3 Gen.)	Timing	Comments
5	Biological resource use						
5.1	Hunting & collecting terrestrial animals						This species is not collected in the wild for biological control. Insects for biological control are reared from culture, mainly in the United States.
5.2	Gathering terrestrial plants						Not applicable.
5.3	Logging & wood harvesting						Not applicable. Clearcutting is beneficial for this species as it creates ideal open habitat.
5.4	Fishing & harvesting aquatic resources						Not applicable.
6	Human intrusions & disturbance						
6.1	Recreational activities						Not applicable. Neutral or potentially beneficial through creating high quality habitat or maintaining open habitat (e.g., recreational use of all-terrain vehicles).
6.2	War, civil unrest & military exercises						Not applicable.
6.3	Work & other activities						Not applicable. The number of specimens collected for research is considered to have a negligible impact on the overall population.
7	Natural system modifications		Low	Small (1-10%)	Slight (1-10%)	High (Continuing)	
7.1	Fire & fire suppression						Neutral or not a threat. Fire typically creates open habitat and allows for the succession of flowering plants which would be beneficial. Fire suppression prevents creation of open habitat. 30% of grasslands in the prairies have vanished due to fire suppression. In the Northern boreal forest, fire suppression has resulted in build up fuel loads, creating fires that burn too hot and potentially impact succession of flowering plants.
7.2	Dams & water management/use						Not applicable. Within the next 15 years a large hydro reservoir will be built in the YT. Some habitat will be lost due to flooding, but overall this is not considered an applicable threat.

Threat		Impact (calculated)		Scope (next 10 Yrs)	Severity (10 Yrs or 3 Gen.)	Timing	Comments
7.3	Other ecosystem modifications		Low	Small (1-10%)	Slight (1-10%)	High (Continuing)	Abandonment of managed lands and farms, primarily in Eastern Canada, could potentially be a factor in the decline of the Transverse Lady Beetle. This results in less favorable foraging for the Transverse Lady Beetle, as succession occurs and ideal habitat is lost. In addition homogenization of agricultural landscapes reduces habitat quality and foraging for this species.
8	Invasive & other problematic species & genes	BC	High - Medium	Pervasive (71-100%)	Serious - Moderate (11-70%)	High (Continuing)	
8.1	Invasive non-native/alien species	BC	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 19th century. Significant declines in geographic range and abundance of native insects are frequently due to changes in habitat or interactions with non-native species. Establishment of non-native lady beetles (e.g., Seven-spotted Lady Beetle), in North America has been implicated in an overall reduction in Transverse Lady Beetle and other native lady beetle subpopulations. Most explanations focus on direct effects through competition and intraguild predation or indirect effects through introduction of pathogens. Pathogens are potentially a large threat to this species.
8.2	Problematic native species						Not applicable. No known native species that is problematic.
8.3	Introduced genetic material						Not applicable.
9	Pollution	D	Low	Restricted (11-30%)	Moderate (11-30%)	High (Continuing)	
9.1	Household sewage & urban waste water						Not applicable.
9.2	Industrial & military effluents						Not applicable.
9.3	Agricultural & forestry effluents	D	Low	Restricted (11-30%)	Moderate (11-30%)	High (Continuing)	Pesticides used in agricultural areas have potential to impact lady beetles directly, and indirectly by reducing aphid densities (food source) on crops.
9.4	Garbage & solid waste						Not applicable.
9.5	Air-borne pollutants						Not applicable.
9.6	Excess energy						Not applicable.
10	Geological events						
10	Volcanoes						Not applicable.
10	Earthquakes/tsunamis						Not applicable.

Threat		Impact (calculated)		Scope (next 10 Yrs)	Severity (10 Yrs or 3 Gen.)	Timing	Comments
10	Avalanches/landslides						Not applicable.
11	Climate change & severe weather						
11	Habitat shifting & alteration						Unknown. This is a widely distributed species in North America, which occurs across ecozones and habitats.
11	Droughts						Unknown. When plants get stressed, they become more vulnerable to aphids and other insect pests, which could be a benefit.
11	Temperature extremes						Unknown. This species occurs across a wide variety of temperature regimes in North America. However, late season frosts may affect plants, aphids and lady beetles. Some stressors increase aphid densities and others may be a detriment.
11	Storms & flooding						Not applicable.
Classification of Threats adopted from IUCN-CMP, Salafsky <i>et al.</i> (2008).							