COSEWIC
Assessment and Status Report

on the

Four-leaved Milkweed
Asclepias quadrifolia

in Canada

ENDANGERED
2010

COSEWIC
Committee on the Status
of Endangered Wildlife
in Canada

COSEPAC
Comité sur la situation
des espèces en péril
au Canada

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

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Four-leaved Milkweed — Photo by Sean Blaney.

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COSEWIC
Assessment Summary

Assessment Summary – April 2010

Common name
Four-leaved Milkweed

Scientific name
Asclepias quadrifolia

Status
Endangered

Reason for designation
Only two small extant populations are known in Canada at the eastern end of Lake Ontario, each with very low numbers of individuals. Historic populations within the Niagara Falls region are believed extirpated. Extant populations are in very rare limestone deciduous woodland communities where plants are at risk from shading by invasive Common Buckthorn shrubs and from native shrubs and trees expanding in the absence of ground fires. Residential development is a potential threat at the largest site. Future development on this site remains a reasonable possibility.

Occurrence
Ontario

Status history
Designated Endangered in April 2010.

COSEWIC
Executive Summary

Four-leaved Milkweed
Asclepias quadrifolia

Species information

Four-leaved Milkweed (*Asclepias quadrifolia*) is an erect herbaceous perennial of the milkweed family (Asclepiadaceae). A single unbranched stem, 30 to 80 cm tall, arises from a tough, perennial root crown. Two pairs of the opposite leaves near the top of mature plants appear four-whorled, giving the species its name. Flowers are in one to four clusters of 10 to 25 pinkish-white flowers. The species is insect-pollinated and probably self-incompatible. The fruit develops into a long, narrow, erect seed pod. Seeds have a dense tuft of long, silky, white hairs at the top to create buoyancy in aid of wind dispersal.

Distribution

Four-leaved Milkweed occurs in the eastern United States in two disjunct regions, separated by a 150 to 400 km wide zone of almost complete absence in the Mississippi River Valley. The western region of occurrence extends from eastern Oklahoma and western Arkansas north to western Illinois and eastern Iowa. The eastern region extends from the southern Appalachian Mountains north to eastern Indiana and southern New Hampshire. The species just extends into Canada in southern Ontario at the eastern end of Lake Ontario in Prince Edward County, and the western end in the vicinity of Niagara Falls, where it is believed extirpated.

Habitat

Four-leaved Milkweed occurs in dry to mesic, relatively open deciduous forest often on rocky soils and steep slopes. It has a tendency to occur on calcareous soils, especially over limestone bedrock, but soil pH tolerance over the North American range is from slightly acidic to strongly basic. Four-leaved Milkweed in Missouri grows and reproduces better at forest edges than forest interiors due to energy limitation in deep shade. In Ontario, it occurs in open, dry-mesic woodland on fairly shallow soils on the plateau, rim or slopes of steep limestone escarpments. Prince Edward County sites are dominated by Bur Oak, Shagbark Hickory and Ironwood, with Eastern Red-Cedar, Chinquapin Oak, Sugar Maple, Basswood and White Ash. Niagara region occurrences would have been in similar habitats dominated by Red, White, Black and Chinquapin Oaks with Pignut and Shagbark Hickories and other deciduous trees.

Biology

Four-leaved Milkweed reproduces only from seed. Soil seed banking is likely only short-term (1-5 years). Field experiments indicate at least 5 to 10 years are required to reach maturity, with younger or resource-poor plants functioning as unisexual males. Flowering occurs from late May through June. As with most milkweeds, the species is likely largely or entirely self-incompatible. Milkweeds have a remarkably complex, insect-mediated pollination system and flowers produce copious nectar. Known pollinators include certain bees and butterflies such as skippers and the Pearl Crescent butterfly. Pollen dispersal distances are unusually high, with pollination over distances exceeding 1 km common in North Carolina. Plants develop only one, two or rarely three seed pods, averaging 35 seeds each. Mature seed pods open in autumn to release their seeds. Seed dispersal beyond 50-150 m is likely rare. The energetic requirements for flower and seed production have been extensively studied in Four-leaved Milkweed and the related forest species Poke Milkweed.

Population sizes and trends

Between 96 and 178 mature individuals are known from two extant populations: 1) between 80 and 136 mature plants over about 20 ha at McMahon Bluff and 2) between 16 and 42 mature plants over about 0.25 ha at Macauley Mountain. Seedlings are present at both sites.

Along the Niagara River, populations have declined since 1956 to the point where they are probably extirpated, based on repeated surveys of former occurrences. Historic Bay of Quinte area sites are probably also extirpated. Other undocumented population losses probably occurred with habitat loss since European settlement. There is no information on recent trends in extant Canadian populations, although limited observations do not suggest any declines since 2006-2007. Continued encroachment of the exotic Common Buckthorn and native shrubs seems likely to reduce the population at both sites over time.

Limiting factors and threats

Four-leaved Milkweed was likely always rare and local in Ontario, but massive habitat loss and fragmentation since European settlement now limits the species' future prospects. The habitat in which the species occurs falls into the Bur Oak – Shagbark Hickory – Big Bluestem community ranked critically imperiled for Ontario.

Major threats to Four-leaved Milkweed are: 1) habitat conversion – a developer proposing development on over 73% of the Canadian population has now (August 2009) sold the McMahon Bluff property, but future development of the site remains a threat; 2) habitat degradation (excessive shading) caused by the exotic Common Buckthorn and by native shrubs and trees, associated with loss of pre-settlement fire regime; 3) the invasive exotic herb Pale Swallow-wort, although not yet at known sites, is rapidly expanding in the vicinity of known sites and presents a significant threat within the next 10 to 30 years. Potential threats of unknown or lesser magnitude are: the small, isolated population and small area of occupancy at the Macauley Mountain site leading to inbreeding and risk of stochastic loss and ATV use at the McMahon Bluff site, which is presently not a problem but could become problematic if intensified.

Special significance of the species

Four-leaved Milkweed is biogeographically interesting as one of a small suite of species with a strong southern affiliation occurring at both the eastern and western ends of Lake Ontario. It occurs in a critically imperiled habitat with two other nationally imperiled species [the sedges *Carex mesochorea* and *Carex bicknellii*]. As a disjunct at its northern limit, it may harbour unusual genetic variation for the species.

Existing protection

Four-leaved Milkweed is globally secure but critically imperiled in Canada and Ontario. The species is potentially extirpated in Delaware, critically imperiled in Rhode Island and Kansas, imperiled in New Hampshire and sensitive in Iowa and Vermont. It has a state-level Threatened status in New Hampshire and Rhode Island and is not ranked or secure in 20 other American states.

TECHNICAL SUMMARY

Asclepias quadrifolia
Four-leaved Milkweed asclépiade à quatre feuilles
Range of Occurrence in Canada: Ontario

Demographic Information

Generation time (usually average age of parents in the population; indicate if another method of estimating generation time indicated in the IUCN guidelines(2008) is being used)	~ 7 to 10+ years, based on 5-10 years to first reproduction in published report
Is there an [observed, inferred, or projected] continuing decline in number of mature individuals? This is inferred based on suspected ongoing canopy closure.	Yes
Estimated percent of continuing decline in total number of mature individuals within [5 years or 2 generations]	% historic decline unknown; % recent decline unknown but likely due to canopy closure
[Observed, estimated, inferred, or suspected] percent [reduction or increase] in total number of mature individuals over the last [10 years, or 3 generations].	% historic decline unknown; % recent decline unknown but likely due to canopy closure
[Projected or suspected] percent [reduction or increase] in total number of mature individuals over the next [10 years, or 3 generations].	Future declines likely from canopy closure by exotic & native shrubs
[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 but recent and ongoing decline likely from canopy closure
Are the causes of the decline clearly reversible and understood and ceased?	Canopy closure understood, ongoing and reversible only with intensive management
Are there extreme fluctuations in number of mature individuals?	No

Extent and Occupancy Information

Estimated extent of occurrence	8 km²
Index of area of occupancy (IAO) (Always report 2x2 grid value; other values may also be listed if they are clearly indicated (e.g., 1x1 grid, biological AO)).	8 km² (2x2 km grid)
Is the total population severely fragmented? The two populations are separated by about 9 km which is likely greater than the dispersal distance of pollen or seeds within one generation. The two small populations are questionably viable.	Likely
Number of "locations*"	2
Is there an [observed, inferred, or projected] continuing decline in extent of occurrence?	Historic decline; may now be stable

* See definition of location.

Is there an [observed, inferred, or projected] continuing decline in index of area of occupancy?	Unknown but possible if site development does occur at the McMahon Bluff location
Is there an [observed, inferred, or projected] continuing decline in number of populations?	Unknown
Is there an [observed, inferred, or projected] continuing decline in number of locations?	Historic decline; may now be stable
Is there an [observed, inferred, or projected] continuing decline in [area, extent and/or quality] of habitat? Decline in quality is inferred based on suspected ongoing shrub encroachment.	Decline in quality
Are there extreme fluctuations in number of populations?	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 population)

Population	N Mature Individuals
McMahon Bluff – 80 flowering, 52 vegetative (some likely mature), 4 unknown	80-136
Macauley Mountain – 16 flowering, 26 vegetative (some likely mature)	16-42
Total	96-178

Quantitative Analysis

Probability of extinction in the wild is at least [20% within 20 years or 5 generations, or 10% within 100 years].	None available

Threats (actual or imminent, to populations or habitats)

1. Habitat degradation and loss from residential, quarry, winery or other development.
2. Reduced light levels caused by shrub encroachment and canopy closure associated with lack of wildfire and the exotic Common Buckthorn.
3. Competition from exotic herbs, especially Pale Swallow-wort and Garlic Mustard. Exotics are a potential future threat at extant sites, and a contributing factor to extirpation in Niagara area.
4. Small population size and area potentially causing inbreeding depression and increasing the threat of stochastic loss.

Rescue Effect (immigration from outside Canada)

Status of outside population(s)? USA: Globally secure (G5), nearest populations (New York) are secure statewide (S5) but uncommon to rare near Canadian border.	
Is immigration known or possible?	Not known and unlikely
Would immigrants be adapted to survive in Canada?	Likely yes
Is there sufficient habitat for immigrants in Canada?	Yes
Is rescue from outside populations likely?	No – very unlikely

* See definition of location.

Current Status

COSEWIC: Endangered (April 2010)

Status and Reasons for Designation

Status:	**Alpha-numeric code:**
Endangered	B1ab(iii,v)+2ab(iii,v); C2a(i); D1
Reasons for designation: Only two small extant populations are known in Canada at the eastern end of Lake Ontario, each with very low numbers of individuals. Historic populations within the Niagara Falls region are believed extirpated. Extant populations are in very rare limestone deciduous woodland communities where plants are at risk from shading by invasive Common Buckthorn shrubs and from native shrubs and trees expanding in the absence of ground fires. Residential development is a potential threat at the largest site. Future development on this site remains a reasonable possibility.	

Applicability of Criteria

Criterion A (Decline in Total Number of Mature Individuals): Not applicable.
Criterion B (Small Distribution Range and Decline or Fluctuation): Meets Endangered B1ab(iii,v)+2ab(iii,v) based on very small EO and IAO and presence at only two locations with a continuing decline inferred in the quality of habitat due to the spread of invasive species, especially Common Buckthorn, and an inferred decline in the number of mature individuals.
Criterion C (Small and Declining Number of Mature Individuals): Meets Endangered under C2a(i) based on an inferred future decline in mature individuals that will continue with the spread of major invasive exotics at the sites; neither of the two populations has >250 mature individuals.
Criterion D (Very Small Population or Restricted Distribution): Meets Endangered D1 with a total of <250 mature individuals.
Criterion E (Quantitative Analysis): None available.

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 (2010)

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 Canada / Environnement Canada
Canadian Wildlife Service / Service canadien de la faune
Canada

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

COSEWIC Status Report

on the

Four-leaved Milkweed

Asclepias quadrifolia

in Canada

2010

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SPECIES INFORMATION

Name and classification

Scientific name:	*Asclepias quadrifolia* Jacq.
Synonyms:	none
English vernacular names:	Four-Leaved Milkweed
French vernacular names:	asclépiade à quatre feuilles
Family:	Asclepiadaceae, milkweed family
Major plant group:	Eudicot flowering plant

Four-Leaved Milkweed (*Asclepias quadrifolia*) is a member of the milkweed family Asclepiadaceae and one of 72 native *Asclepias* species in the United States and Canada (Kartesz 2008) and about 150 species in the New World (Agrawal *et al*. 2008). There has never been any dispute regarding the status of Four-Leaved Milkweed as a distinct species. The species is named for its leaves, in which the internodes between two pairs of opposite leaves in the middle of the stem are reduced to the point that leaves appear to be in a whorl of four (Woodson 1954).

Woodson (1954) placed Four-leaved Milkweed in the large (50 species) subgenus Asclepias which he divided into six series. He placed Four-leaved Milkweed in the series Syriacae that included the Canadian species Common Milkweed (*A. syriaca*) and Oval-leaved Milkweed (*A. ovalifolia*) along with eight others. Recent analysis of chloroplast DNA (Agrawal *et al*. 2008) for 51 *Asclepias* species produced a phylogenetic tree differing somewhat from Woodson's (1954) series, placing Four-leaved Milkweed as most closely related to Poke Milkweed (*A. exaltata*) within a clade of three species including the Canadian *A. syriaca* and *A. tuberosa*.

Morphological description

Four-leaved Milkweed (Figure 1) is an erect herbaceous perennial that is one of the smaller North American milkweeds. Typically a single unbranched stem arises 30 to 80 cm tall (average flowering plant about 40 cm, Chaplin and Walker 1982) from a tough, perennial root crown. The leaves are 4 to 12 cm long by 2 to 5 cm wide, elliptic, untoothed and have an opposite, decussate arrangement (alternating pairs oriented at 90 degrees to one another). Two pairs of leaves near the top of mature plants are separated by a short internode and appear four-whorled. Flowers are arranged in one to four umbels of 3 to 5 cm across, arising from the upper nodes. Umbels are composed of (3) 10 to 25 (33), mean 15.9, white to pinkish-white flowers (Chaplin and Walker 1982). Individual flowers of Four-leaved Milkweed are similar to other *Asclepias* species in size (about 1.2 cm long) and structure, being composed of five reflexed petals united with highly modified stamens that largely hide the female structures. The complex and highly specialized morphology and pollination biology of *Asclepias* are described in Wyatt and Broyles (1994), and in less detail for Four-leaved Milkweed in Chaplin and Walker (1982). Only one or two (rarely three) flowers per plant mature into follicles (seed pods)

which are erect, long and thin (8 to 11 cm long and about 1 cm wide), containing 20 to 35 or seeds (Chaplin and Walker 1982). Seeds are brown, flattened and winged, about 6 mm by 4 mm and tear-drop shaped, with a dense coma of long, silky white hairs at the top that create buoyancy to aid in wind dispersal.

Figure 1. Four-leaved Milkweed (*Asclepias quadrifolia*) in flower at McMahon Bluff, Prince Edward County, Ontario (photo by Sean Blaney).

The false four-whorled leaf arrangement of Four-leaved Milkweed distinguishes it from all other Ontario *Asclepias*, but small, immature plants lacking this feature could be easily confused with *A. exaltata*, the only other milkweed sharing the upland forest habitat of Four-leaved Milkweed within its Ontario range. The abundant and widespread Common Milkweed (*A. syriaca*) typically occurs in more open areas but could share forest edge or semi-open woodland habitats with Four-leaved Milkweed. Common Milkweed is typically taller, with broader, more blunt-ended leaves, stouter stems, larger umbels of around 100 pink flowers and shorter, stouter seed pods with a warty, not smooth, outer surface.

Population spatial structure and variability

No chromosome count for Four-leaved Milkweed has been published, but Moore (1946) reported all milkweeds to have an isoploid chromosome count of n=11. Mark Fishbein has analyzed three non-coding regions of chloroplast DNA for almost all New World *Asclepias* to create a complete phylogeny that is not yet completely published. The most complete published phylogeny from this work is in Agrawal *et al*. (2008), which involves 51 *Asclepias* species. It places Four-leaved Milkweed as most closely related to Poke Milkweed (*A. exaltata*) and to a clade including *A. syriaca*, *A. tuberosa* and *A. obovata*. The chloroplast DNA sequences from a single individual of Four-leaved Milkweed are documented in GenBank (Agrawal *et al*. 2008, GenBank 2009).

Broyles *et al*. (1994) reported levels of gene flow between adjacent populations significantly higher than is typical for forest herbs in an allozyme study of *Asclepias exaltata* in the southern Appalachians, where it is common and populations are typically separated by 500 to 1000 m. They attributed this to the wind-dispersed seeds and durable insect-dispersed pollinia. Broyles (1998) also found that allozyme variation in *A. exaltata* was significantly reduced in northern parts of the range colonized post-glacially compared to populations within the Pleistocene refugium in the southern Appalachians. Northern populations, however, still had relatively high allozyme diversity and low population differentiation for a long-lived herbaceous perennial. *A. exaltata* is closely related and ecologically similar to Four-leaved Milkweed, and potential gene flow and patterns of genetic diversity could be expected to be similar in Four-leaved Milkweed.

The only documented hybrid involving Four-leaved Milkweed is an *A. exaltata* x *quadrifolia* cross, confirmed by flavonoid analysis, from Clay County, North Carolina (Wyatt and Hunt 1991). Although hybridization is generally rare in milkweeds (Kephart *et al*. 1988, Wyatt and Hunt 1991), *Asclepias syriaca* would likely also be capable of crossing with *A. quadrifolia* given that it is closely related, widespread and also hybridizes with *A. exaltata* (Wyatt and Hunt 1991). The later flowering time and more open habitats of *A. syriaca* would, however, generally provide barriers to *A. quadrifolia* x *syriaca* hybridization.

Designatable units

The Niagara and Prince Edward County areas of occurrence are separated by 190 km but there is no genetic information on Canadian or New York populations available to either justify or argue against separating the Canadian occurrences into two designatable units. The discontinuous distribution along the south shore of Lake Ontario between the Niagara and Prince Edward County occurrences (New York Flora Atlas 2008) and the 70 km disjunction across Lake Ontario between New York and Prince Edward County records both suggest thorough isolation of Prince Edward County and former Niagara populations. The two areas of occurrence are, however, considered a single designatable unit in this report because they are both within the Great Lakes Plains COSEWIC National Ecological Area.

DISTRIBUTION

Global range

In North America, Four-Leaved Milkweed is almost completely restricted to the eastern United States, where it occurs in two disjunct regions, separated by a 150 km to 400 km wide zone of almost complete absence in the Mississippi River valley (Figure 2). Woodson (1954) attributes this near absence to colonization from separate glacial refugia and to generally unsuitable prairie and lowland soils where dry, rocky woodland does not occur. The western (Ozarkian – Woodson 1954) region of occurrence extends from eastern Oklahoma and western Arkansas northward through Missouri, extreme southeast Kansas, western Illinois and eastern Iowa. The southern boundary of the larger eastern (Appalachian – Woodson 1954) region of occurrence is in the northern parts of Alabama, Georgia and South Carolina in the Appalachian Mountains. From there, Four-leaved Milkweed extends north to eastern Indiana, to Lake Erie and Lake Ontario in Ohio, Pennsylvania and New York, to the Champlain Valley of New York and Vermont and to southern New Hampshire. Four-leaved Milkweed just extends into Canada in southern Ontario at the eastern and western ends of Lake Ontario. Four-leaved Milkweed has been reported for Mississippi (McCook and Kartesz 2000, Kartesz 2008), but the record on which both reports are based is considered unconfirmed (L. McCook pers. comm. 2008 and H. Sullivan pers. comm. 2008). Table 1 gives the conservation status in each jurisdiction in which Four-leaved Milkweed is known.

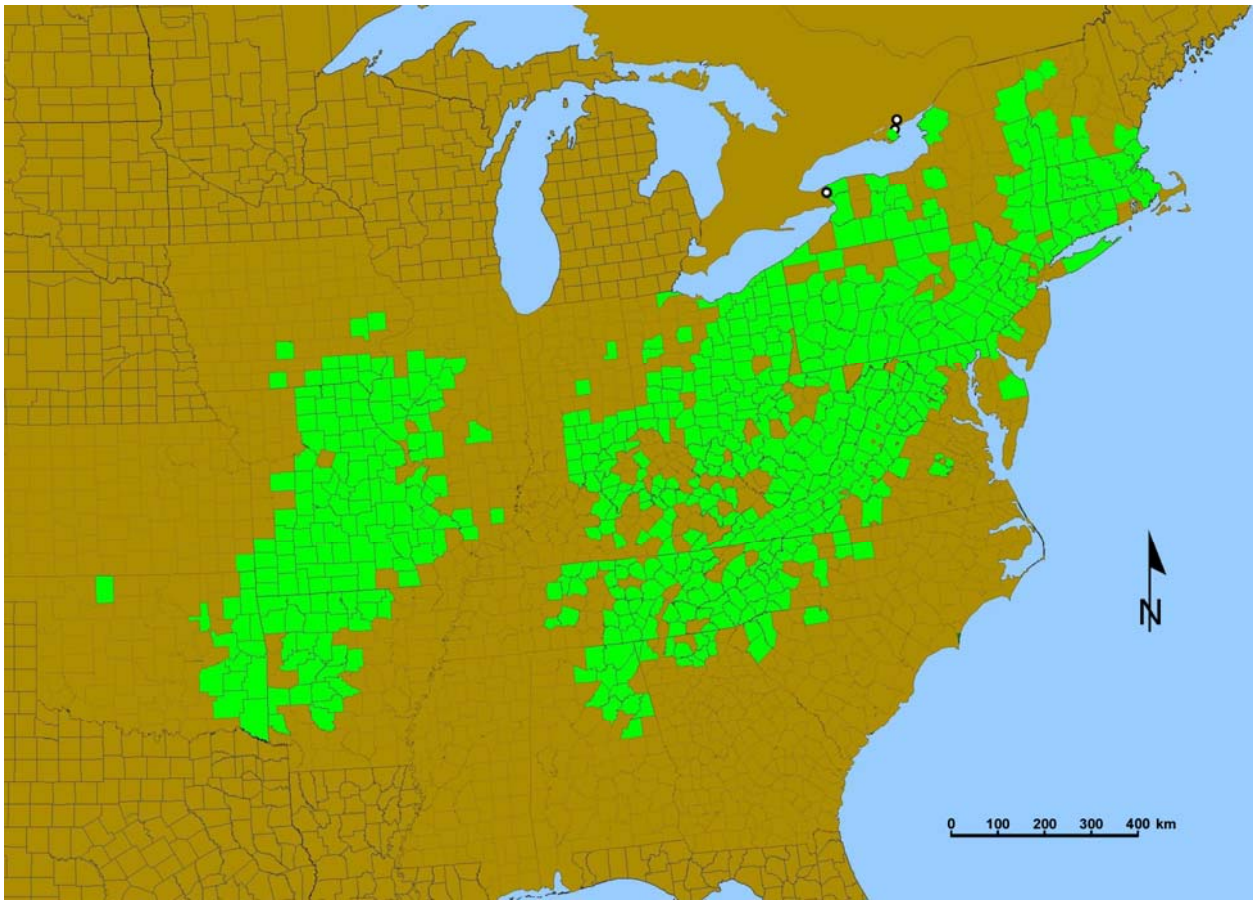

Figure 2. Range of Four-Leaved Milkweed (*Asclepias quadrifolia*) by county for the United States (modified from Kartesz 2008, used with permission), with Canadian occurrences indicated by dots. Thick-bordered dots are historic occurrences and unbordered dots are extant occurrences, with the two extant occurrences appearing as a single dot because of their proximity.

Table 1. Four-leaved Milkweed (*Asclepias quadrifolia*) state and provincial S-ranks (NatureServe Explorer 2008 and verified on each jurisdictional heritage program website) with state and provincial status designations (from jurisdictional heritage program websites, May 2008).

Country	State / Province	S-rank	State / Province Designation
Canada	Ontario	S1	
United States	Arkansas	SNR	
	Connecticut	SNR	
	Delaware	SH	
	Georgia	SNR	
	Illinois	SNR	
	Indiana	SNR	
	Iowa	S3	
	Kansas	S1	
	Kentucky	S4	
	Maryland	SNR	
	Massachusetts	SNR	

Country	State / Province	S-rank	State / Province Designation
	Minnesota	SNR	
	Missouri	SNR	
	New Hampshire	S2	Threatened
	New Jersey	S4	
	New York	S5	
	North Carolina	S4	
	Ohio	SNR	
	Oklahoma	SNR	
	Pennsylvania	S5	
	Rhode Island	S1	Threatened
	South Carolina	SNR	
	Tennessee	SNR	
	Vermont	S3	
	Virginia	S5	
	West Virginia	S5	

Canadian range

In Canada, Four-Leaved Milkweed has been found only at the eastern end of Lake Ontario around the Bay of Quinte and the western end of Lake Ontario along the Niagara River Gorge just downstream of Niagara Falls. The species is probably extirpated from the Niagara region, where no records have been documented since 1956 despite substantial survey effort at the original collection sites and elsewhere. Until 2006, Four-Leaved Milkweed was reported in southeastern Ontario only from two or three records no more recent than 1890: Adolphustown and “near Napanee” in Lennox and Addington County (Macoun 1883-1890; no specimens supporting these records are known) and from an 1868 John Macoun collection labelled “Bay of Quinte”, which may have been from one of these sites. In 2006 a population was found in southeastern Prince Edward County at McMahon Bluff, where it is scattered over an area of 1 km by 0.2 km (20 ha). In 2007, another smaller population was found 9 km northeast of McMahon Bluff near the town of Picton in the Macauley Mountain Conservation Area, where it occupies about 0.25 ha.

Canadian occurrences are mapped in Figure 3. Extent of occurrence in Prince Edward County is given as a nominal 8 km². Area of occupancy in Prince Edward County is 8 km² using a 2x2 km grid. Actual area occupied is much less than 1 km^2.

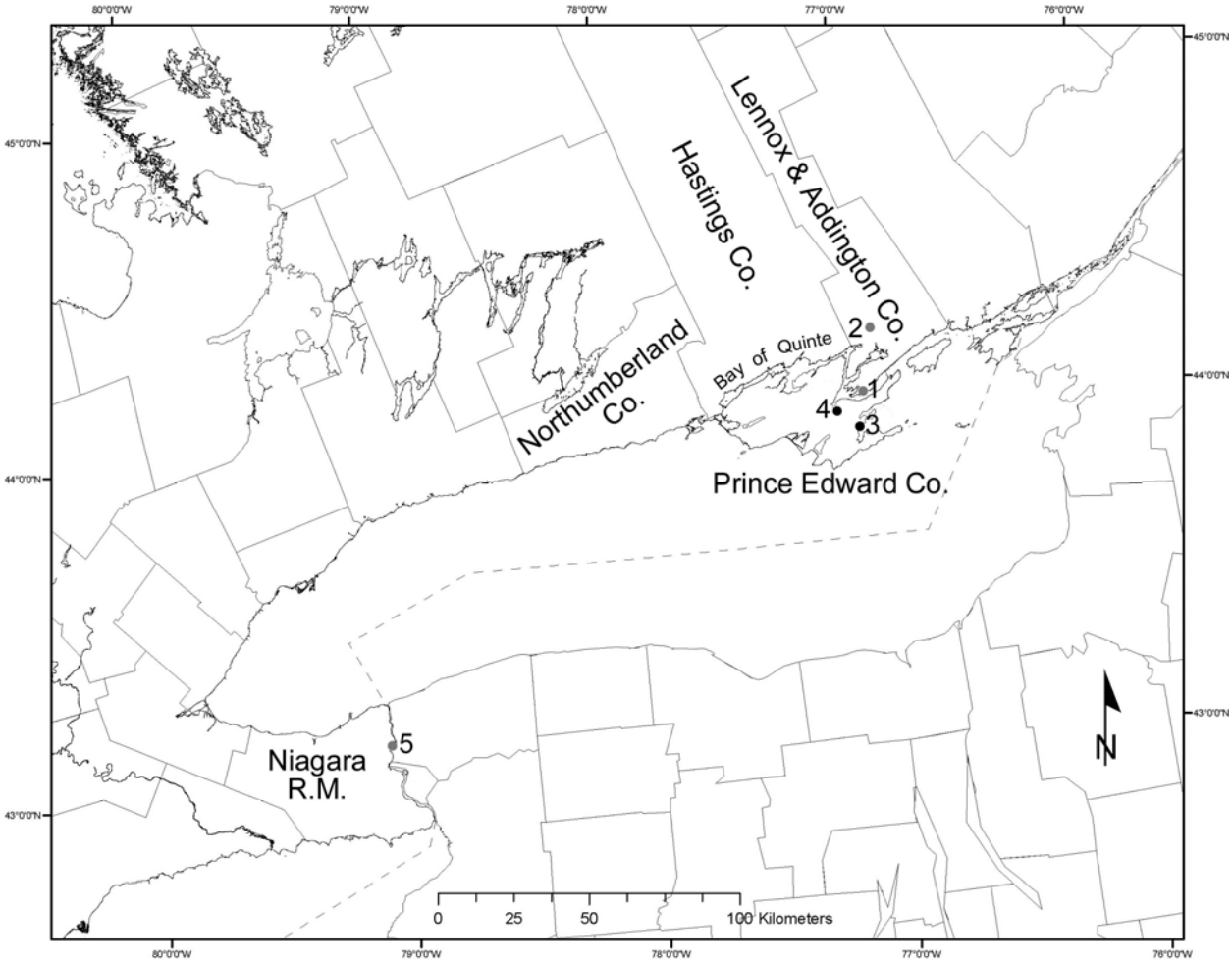

Figure 3. Canadian occurrences of Four-leaved Milkweed (*Asclepias quadrifolia*). Numbers correspond to populations in Table 3. Grey dots (1, 2, 5) are historic locations and black dots (3, 4) are extant locations. John Macoun's 1868 collection labelled "Bay of Quinte", which may have been from site 1 or 2 or another location in the area, is not mapped.

HABITAT

Habitat requirements

There are no detailed analyses of Four-leaved Milkweed habitat, but the many references available and discussion with natural heritage program botanists (summarized in Table 2) within the species' range provide consistent indication that Four-leaved Milkweed is a species of dry to mesic, relatively open, deciduous forest that is often found on rocky soils and steep slopes. The North Carolina Natural Heritage Program provided plot data for 26 plant community plots in which Four-leaved Milkweed was reported, in all cases at a trace or less than 1% cover level. Among 54 tree species recorded having at least 2% cover in one plot, the most frequent were: Tulip-Tree (*Liriodendron tulipifera*, 20 plots), Red Oak (*Quercus rubra*, 19 plots), Red Maple (*Acer rubrum*, 17 plots), Pignut Hickory (*Carya glabra*, 12 plots), White Oak (*Quercus alba*, 10

plots), Mockernut Hickory (*Carya alba*, 9 plots), White Ash (*Fraxinus americana*, 9 plots), Cucumber Magnolia (*Magnolia acuminata*, 8 plots), and Chestnut Oak (*Quercus montana*, 8 plots). At the generic level, oak species (45 records), hickory species (31 records) and maple species (27 records) were most frequently recorded. American Chestnut (*Castanea dentata*) was recorded in six plots, but would have been a much more important component of these habitats historically (S. Broyles pers. comm. 2008).

Table 2. Summary of Four-leaved Milkweed habitat information communicated to Sean Blaney from American botanists, plus that of Chaplin and Walker (1982). Geographic notes and habitat columns are paraphrased directly from emails received. Authorities are natural heritage program botanists unless otherwise noted.

State	Geographic Notes	Authority	Habitat / Notes
Delaware	Piedmont Province of New Castle County	William McEvoy	Historic records only
Indiana	SE Indiana	Michael Homoya	Mostly on calcareous soils, although not necessarily associated with outcrops of limestone. Typically on steep, well drained forested slopes, mostly on calcareous soils. Chinquapin Oak (*Quercus muehlenbergii*) and White Oak are common among various canopy trees
Iowa	South-central & southeast Iowa	John Pearson	Dry to mesic, upland woods
Kansas	Restricted to Ozark Plateau physiographic province in extreme SE Kansas	Craig Freeman	Oak-hickory forest or woodlands on slopes with cherty, rocky soils mostly on dolomite or limestone but potentially on sandstone as well
Missouri		Tim Smith	Dry-mesic forest or woodlands on dolomite, typically where bedrock has weathered away leaving a chert-rich, somewhat acidic or circumneutral soil
Missouri	University of Missouri, Columbia	Chaplin and Walker (1982)	Mature oak – hickory woods, soils thin and rocky overlying limestone; White Oak, with Shagbark Hickory, Sugar Maple and White Ash dominant
New York		New York herbarium label info supplied by Steve Young	Dry, open, often rocky woods (mention of rocky exposed ridge, rock ledges, above cliffs and on sandstone pavement) on limestone, shale or sandstone
North Carolina	Mountain and Piedmont regions	Suzanne Mason, citing Weakley (2008)	Moist to dryish forests and forest margins, most common on mafic and calcareous substrates
Vermont	Champlain & Connecticut River valleys	Bob Popp	Dry oak - hickory – hophornbeam (*Ostrya virginiana*) forest, mostly on calcareous areas in forest openings or near the edge of cliffs where it receives more light
Virginia	Shenandoah National Park, Virginia	Steve Broyles, State University of New York, Cortland	Often on shaded roadside embankments at margins of American Beech and Red Oak-dominated forest; historically dominated by American Chestnut

There seems to be a tendency toward occurrence on calcareous soils, especially in areas over limestone bedrock, but soil pH tolerance over the whole range is from slightly acidic to strongly basic (Table 2). Chaplin and Walker (1982) demonstrated that Four-leaved Milkweed plants at forest edges were larger and produced more seeds than those in forest interiors due to greater energy limitation in fully forested habitat, rather than to pollinator limitation. Thus light levels are important and are perhaps one reason for the noted tendency to occur on or at the top of steep slopes.

In Ontario, Prince Edward County records are on fairly shallow soils on flat or gently sloped plateau near steep limestone escarpment slopes. The sites are in open, dry-mesic forest dominated by Bur Oak (*Quercus macrocarpa*), Shagbark Hickory (*Carya ovata*) and Ironwood (*Ostrya virginiana*), with Eastern Red-Cedar (*Juniperus virginiana*), Chinquapin Oak (*Quercus muhlenbergii*), Sugar Maple (*Acer saccharum*), Basswood (*Tilia americana*) and White Ash. The sites have a shrubby understory, though Four-leaved Milkweed occurrence tends to be in areas with reduced shrub cover. Dominant tall shrubs are Prickly-Ash (*Zanthoxylem americanum*), Gray Dogwood (*Cornus racemosa*) and Downy Arrow-wood (*Viburnum rafinesquianum*), and dominant lower shrubs are Common Juniper (*Juniperus communis*), Snowberry (*Symphoricarpos albus*) and Fragrant Sumac (*Rhus aromatica*). Woodland Sunflower (*Helianthus divaricatus*) is a characteristic herbaceous associate and other abundant herbs include Blue-stemmed Goldenrod (*Solidago caesia*), Pennsylvania Sedge (*Carex pensylvanica*), Early Meadow-Rue (*Thalictrum dioicum*), Large-leaved Aster (*Eurybia macrophylla*) and Barren Strawberry (*Waldsteinia fragarioides*). Characteristic but less dominant species in the community include Blue Phlox (*Phlox divaricata*), Hairy Brome (*Bromus pubescens*), Seneca Snakeroot (*Polygala senega*) and Bastard Toadflax (*Comanda umbellata*).

Habitat information was given for two Niagara River collections as “dry woods” and “shallow soil on limestone” suggesting similar habitats to those in Prince Edward County, except that occurrence was noted on the escarpment slope as well as the rim and plateau at Queenston by Macoun (1893, cited in Eckel 2001). Based on Niagara Gorge forests today and Eckel’s (1986) description of the former Four-leaved Milkweed site on the American side of the Niagara River, dominants would have been Red Oak, White Oak, Black Oak (*Q. velutina*) and Chinquapin Oak with Pignut Hickory and Shagbark Hickory and other deciduous trees. Bakowsky (2007) described a remnant Niagara Gorge Chinquapin Oak savannah on shallow soils over limestone bedrock that seems like ideal Four-leaved Milkweed habitat. He noted that large, open grown trees in developed parkland nearby indicate that this habitat, now largely limited to the rim of the escarpment, was once much more extensive.

Habitat trends

The dry, open, rocky, oak - hickory woodland most ideal for Four-leaved Milkweed would have been locally extensive prior to European settlement within the Napanee Limestone Plain (Chapman and Putnam 1984) in southeastern Ontario. Habitat similar to the extant sites would likely have been fairly continuous along the crest of the roughly 110 km of steep limestone escarpment running through Prince Edward County. Other potentially suitable habitat would have been found on shallow soils over limestone elsewhere in Prince Edward County and locally over the 90 km between the city of Kingston and the southern Trent River near Lake Ontario's Bay of Quinte. Smaller areas of suitable habitat would also have been scattered along the southern Niagara Escarpment at least from Niagara Falls to the Hamilton region, where shallow soils over limestone are mostly limited to the immediate area of the escarpment, with the exception of a small region on the Flamborough Limestone Plain (Catling and Brownell 1999) northwest of Hamilton. All these regions are now extensively agricultural, with uplands having deeper soils generally converted to cropland and shallow-soiled areas extensively cleared for pasture. The Niagara-Hamilton region has also subsequently become extensively urbanized. The level of alteration in the region is indicated by the fact that 20 of 26 Species at Risk formerly known from the Niagara River area are potentially or likely extirpated (Oldham 2007). Forest cover is presently 14.2% in Prince Edward County and 15.5% in Niagara Regional Municipality (Riley and Mohr 1994), little of which is suitable for Four-leaved Milkweed. The habitat in which the species occurs at McMahon Bluff and Macauley Mountain is now rare and threatened in Ontario, probably falling into the Bur Oak – Shagbark Hickory – Big Bluestem community listed as S1 (critically imperiled) by the Ontario Natural Heritage Information Centre (W. Bakowsky pers. comm. 2008; see Bakowsky 2007).

The factors that have apparently extirpated the Niagara River population continue to act on extant sites and on suitable habitat that could support undiscovered sites. The largely privately held nature of known and potential habitat makes it susceptible to conversion for residential, quarry and winery development or for other uses. The exotic shrub Common Buckthorn (*Rhamnus cathartica*) is abundant in Prince Edward County and surrounding areas and frequently forms a dense subcanopy in formerly open woodlands (S. Blaney pers. obs. 1990-2009). Common Buckthorn is common at both extant Four-leaved Milkweed sites and is contributing to an unnaturally high level of shading in those communities (S. Blaney pers. obs. 2006-2009), but it is not yet nearly as dense as at some other sites in the region. It is likely that this bird-dispersed species, with massive populations in the areas surrounding Four-leaved Milkweed sites, will continue to increase at those sites. Exotic herbs, especially Garlic Mustard (*Alliaria petiolata*), are extremely dense at Niagara River sites and probably contributed to Four-leaved Milkweed's extirpation there (Oldham 2007). This and other invasive exotic herbs are not yet problematic at the Prince Edward County sites, but invasive exotics, especially Pale Swallow-wort (*Cynanchum rossicum*), are known from within 8 km and probably closer (S. Blaney pers. obs. 2006-2009), and can be expected to spread in the future. Pale Swallow-wort is rapidly spreading in eastern Ontario and has had devasting effects, largely eliminating other understory herbs, on habitat at Prince Edward Point

(12 km east of McMahon Bluff) similar to the known milkweed sites (S. Blaney pers. obs. 1990-2009). Excessive shading caused by native shrub encroachment and increased tree canopy closure associated with the loss of pre-settlement fire regimes is also an ongoing issue at known and potential sites.

On the positive side, reductions in cattle and dairy farming in the past 30 years have resulted in fairly extensive reversion of formerly open or semi-open pasture to woodland on shallow limestone soils in Prince Edward and south Hastings Counties, producing potentially suitable Four-leaved Milkweed habitat in some areas (S. Blaney pers. obs. 1990-2009). There is no evidence, however, that the small extant milkweed populations are able to colonize such areas and ongoing invasion by exotic Common Buckthorn and native shrubs and trees may reduce their suitability over time.

Habitat protection/ownership

Until July 2009, the McMahon Bluff site was fully owned by a development company that produced a “preliminary concept plan” in 2006 to develop 19 one to four hectare luxury estate properties over two thirds of the site (J. Blaney pers. comm. 2009), including most of the area occupied by Four-leaved Milkweed. This area supported 98% of plants at McMahon Bluff and 73% of plants known in Canada. Under this plan, the remainder of the site was proposed as a conservation reserve. The Hastings-Prince Edward Land Trust was fund-raising with the intent to purchase the property from the developer as a protected area but the developer sold the property to an unknown party in July 2009. The current intentions for the property are not known (J. Blaney pers. comm. 2009), but the threat of some type of development on the site is still likely. McMahon Bluff is classified by the Ontario Ministry of Natural Resources as a provincially significant earth science and life science Area of Natural and Scientific Interest (MacDonald 1987), which provides tax relief to landowners if they conserve the site, and requires any development to proceed with regard for natural features of the site.

The Macauley Mountain site is within Macauley Mountain Conservation Area on land owned by the Quinte Conservation Authority. Their mandate includes ownership and management of conservation and public recreation land among other areas of responsibility. Quinte Conservation has been contacted about the presence of Four-leaved Milkweed at Macauley Mountain and will be taking its presence into account in their management of the site (T. Trustham pers. comm. 2008). Almost all the potential habitat where additional populations of Four-leaved Milkweed might occur around the eastern end of Lake Ontario is on private land owned by small landowners.

Remaining potential habitat along the Niagara Gorge (from The Whirlpool to Queenston) is largely owned by the Niagara Parks Commission. The Niagara Parks Commission is a provincial government agency mandated to protect, enhance and manage both cultivated and environmentally sensitive lands along the Niagara River corridor. Historically, it has focused on creating and maintaining manicured parkland along the river, which likely reduced Four-leaved Milkweed habitat and populations. Today, the commission is managing remaining natural areas to maintain rare species and communities (Niagara Parks 2008).

BIOLOGY

Life cycle and reproduction

Four-leaved Milkweed is a perennial herb that reproduces only from seed (Chaplin and Walker 1982). The lack of references to milkweed seed longevity in the soil suggests they do not form a long-term soil seed bank, as would be expected given the forest habitat of the species in combination with the seeds' relatively large size and soft seed coat (Thompson *et al*. 1998). The relatively short-lived nature of milkweed seeds is supported by Bowles *et al.* (2006) who studied seeds from herbarium specimens and found *Asclepias meadii* seed germination rates were reduced to 45% at 3 years and 0% after 4 to 5 years. They found that twelve-year-old *A. lanuginosa* seeds from herbarium specimens failed to germinate.

Plants in the field are slow to mature, as is typical of milkweeds (Wilber 1976, Shannon and Wyatt 1986a). Chaplin and Walker (1982) found that field-planted seeds reached 5.0 cm, 9.5 cm and 13.5 cm in their first 3 years. Flowering was occasionally initiated by plants as small as 19 cm, but seed pod production was not usually found until stems reached 33 to 34 cm, and pod production in two subsequent years was only possible at about 42 cm height. Smaller plants are thus functionally unisexual males until they have sufficient energy reserves to produce fruit. Chaplin and Walker (1982) extrapolated these results, in combination with reproductive data on plants of known size but unknown age, to say that at least 5 to 10 years (depending on conditions such as soil depth and moisture and solar exposure) are required for plants to reach reproductive maturity. This makes 7 to 10 years a conservative estimate for generation time as defined by the average age of reproductive individuals.

In Missouri, almost all growth occurred in the short period prior to canopy closure (Chaplin and Walker 1982). Four-leaved Milkweed flowers in mid-June in Canada, earlier than most other milkweed species. For plants with multiple umbels, umbels mature from the bottom upwards. There is an interval of 2 to 5 days between flowering of successive umbels and flowering within an umbel is fairly synchronized (Pleasants and Chaplin 1983). Nectar production per flower peaks over the first 2 days of the flower's lifespan and then slowly declines until the flower reaches senescence at day eight to ten (Pleasants and Chaplin 1983). Milkweeds have an unusual pollination system rivalling the orchids in specialization and complexity (Woodson 1954, Macior

1965, Wyatt 1976, Wyatt and Broyles 1994). Wyatt and Broyles (1994) provided a detailed diagram of *Asclepias* flower structure showing Four-leaved Milkweed flowers to consist of five reflexed and unmodified petals and five highly modified stamens tightly abutting the two superior ovaries to form five stigmatic chambers. The stamens have extensions from their base (hoods) containing arching structures (horns) that retain large quantities of nectar secreted by the stigmatic head, making the flowers very attractive to insects. Each flower has five pollinaria made up of two pollinia (masses of pollen packaged in a waxy matrix) connected by two translator arms joined by a grooved gland (the corpusculum). Pollinaria are removed when insects' body parts (typically legs) catch on the groove on the corpusculum, forcing the insect to pull the whole pollinarium free. The force required to pull the pollinarium from the flower restricts pollination to larger insects. The pollinaria can remain on insects for several days (Morse 1982, though pollen viability is reduced 50% after one day in *A. exaltata*, Shannon and Wyatt 1986b) resulting in potential for long-distance pollen dispersal (Broyles *et al.* 1994). Upon removal, pollinia dry and rotate 90 degrees on the translator arms so that they are in position for insertion on another flower. The fact that several minutes are required for this rotation is probably an adaptation to reduce self-pollination (Chaplin and Walker 1982). Pollination is achieved when the pollinator visits another flower and inserts a pollinium (usually only one of the pair) back into the stigmatic chamber against the stigmatic surface, where pollen germinates immersed in a nectar solution. A single pollinium contains sufficient pollen to fertilize all the ovules in a flower (Wyatt 1976, Kephart 1981). The fact that both male and female function (pollen removal and reception) can be determined by visual inspection of flowers is the reason milkweeds have been favoured subjects in studies of plant reproductive biology.

The level of self-compatibility in Four-leaved Milkweed is not yet known (Chaplin and Walker 1982), but it is likely low. Milkweeds are largely or entirely self-incompatible, including three of the most closely related species to Four-leaved Milkweed (*A. exaltata, A. syriaca, A. tuberosa*; Wyatt and Broyles 1994). In *A. exaltata*, Lipow and Wyatt (2000) showed that self-incompatibility acted only after fertilization and was likely controlled by a single gene, with rare individuals having an altered version of that gene being self-compatible.

Chaplin and Walker (1982) observed 80 to 90% abortion of developing Four-leaved Milkweed seed pods within three to four weeks of flowering, leaving 84% of fruiting plants with one seed pod, 16% with two, and only rare individuals with three seed pods. This and other evidence strongly suggested that energy reserves rather than levels of successful pollination control number of seed pods matured. Wyatt and Broyles (1994) suggest that late-acting self-incompatibility could also play a role in high rates of seed pod abortion and that seed production in milkweeds (including the closely related *A. exaltata*) can be limited by pollination under certain conditions.

Seed pods remain on the plant through the summer, opening upon drying in late summer or early fall to release the wind dispersed seeds. The only mature seed pod observed during a mid-September visit to the McMahon Bluff site had not opened (S. Blaney, pers. obs. 2006-2009).

Pollinating insects

Chaplin and Walker (1982) investigated pollinators of Four-leaved Milkweed with window traps in milkweed habitat to intercept flying insects, which were checked for pollinaria. Almost all pollinaria removal (99%) involved Hymenoptera (bees and wasps) and Lepidoptera (butterflies, moths and skippers). Only bees 8 to 12 mm long carried pollinaria, with smaller bees lacking strength to remove pollinaria and larger species feeding from below the flowers. The most significant pollinator, accounting for 52% of pollinaria removal was the bee *Melissoides desponsa* (Anthophoridae). The remaining five major pollinators were skippers (family Hesperiidae – Zabulon Skipper - *Poanes zabulon*, Hobomok Skipper - *Poanes hobomok*, Tawny-edged Skipper - *Polites themistocles* and Peck's Skipper - *Polites coras,=P. peckius*) and a Nymphalid butterfly (Pearl Crescent - *Phyciodes tharos*) in the 12 to 20 mm size range. Pollinaria were primarily attached to tarsal claws, with 4% attached to mouthparts, predominantly in *Melissoides desponsa*. Pollinators carried an average of 2.2 pollinaria at the start of the flowering period, 2.9 pollinaria during the 8 days surrounding peak flowering and 1.0 pollinaria at the end of the flowering period. Pollinator numbers were also highest in the peak flowering period, suggesting insects were drawn into Four-leaved milkweed habitat at that time. Bumblebees (*Bombus* spp.), Honey Bee (*Apis mellifera*) and fritillary (*Speyeria cybele* and *S. aphrodite*), Monarch (*Danaus plexippus*) and Painted Lady (*Vanessa cardui*) butterflies were recorded as major pollinators of *Asclepias exaltata* in Queller (1985, in Michigan) and Broyles and Wyatt (1991, in Virginia) and might be important for Four-leaved Milkweed as well.

Among the above insects, all but *Poanes zabulon* occur in Ontario within Four-leaved Milkweed range. Other congeneric species in the genera *Poanes* (one species), *Polites* (three species), *Phyciodes* (two species) and *Melissoides* (at least two species) also occur within the same areas (Layberry *et al.* 1998, Harder and Barratt 1992, Paiero and Marshall 2008), along with many other equivalent-sized butterflies, skippers and bees that could act as Four-leaved Milkweed pollinators.

Herbivory

Monarch butterfly (*Danaus plexippus*, Danaidae) and the Milkweed Stem Weevil (*Rhyssomatus lineaticollis*, Curculionidae) were the two principal herbivores reported in a study of Four-leaved Milkweed in Missouri (Chaplin and Walker 1982). Chaplin and Walker found that herbivory was a major influence on reproduction and survival. In their two-year study, they found 6.8% and 11% of plants were damaged by Monarch larvae, which generally consumed most of the aboveground biomass and prevented seed formation. The Milkweed Stem Weevils damaged 15.9% and 29.4% of flowering plant stems, chewing holes in stems and laying eggs that hatched into pith-feeding larvae, weakening stems and causing many to fall over and die back early. An additional 9.1% and 10.0% of plants were damaged by unknown herbivores. Survival and reproductive success of herbivore-damaged plants was significantly reduced in the year following damage.

Milkweeds produce toxic cardiac glycosides (also called cardenolides) in all their tissues. These chemicals are bitter, emetic, cytotoxic, inhibit the activity of sodium-potassium-ATPase (a key enzyme for regulating cell volume and facilitating nerve and muscle activity) and affect heart function in mammals (Nelson *et al*. 1981). These chemicals largely limit milkweed herbivory to specialist insects (Nelson *et al*. 1981, Agrawal *et al*. 2008), although herbivory by deer has been reported for *Asclepias exaltata* (Shannon and Wyatt 1986a*)* and *A. tuberosa* (Ritchie *et al.* 1998). The milky latex exuded by broken tissue acts both as a mechanical deterrent to herbivory through gumming up insect mouthparts and as a toxin, having higher concentrations of cardenolides than plant tissue (Nelson *et al.* 1981; Zalucki *et al.* 2001). In all 34 *Asclepias* species tested by Agrawal *et al*. (2008) latex also contained cysteine proteases that digest insect peritrophic membranes (Pechan *et al.* 2002; Konno *et al.* 2004). Quantity and toxicity of latex are correlated with reduction in number and performance of insect herbivores, even in the specialist insects that are relatively tolerant of them (Zalucki & Malcolm 1999; Zalucki *et al*. 2001, Agrawal 2005). Caterpillars and beetles will sever veins to bleed the latex out of leaf tissue and make it more palatable (Dussourd & Eisner 1987, Agrawal 2005), but many milkweed insects will also sequester cardenolides for their own defence and advertise their resultant toxicity to predators through bright coloration (*i.e*. Dobler *et al.* 1998, Scudder and Meredith 2004).

The community of milkweed specialist insects in Ontario includes about ten species (van Zandt and Agrawal 2004, Agrawal 2008): Monarch butterfly (*Danaus plexippus*, Danaidae), Milkweed Tiger Moth (*Euchaetes egle*, Arctiidae), Milkweed Longhorn Beetle (*Tetraopes tetropthalmus*, Cerambycidae), Swamp Milkweed Beetle (*Labidomera clivicollis*, Chrysomelidae), Milkweed Stem Weevil (*Rhyssomatus lineaticollis*, Curculionidae), Oleander and Milkweed Aphids (*Aphis nerii, Aphis asclepiadis*), the aphid *Myzocallis asclepiadis* (Drepanosiphidae), Small Milkweed Bug (*Lygaeus kalmii*, Lygaeidae), Large Milkweed Bug (*Oncopeltus fasciatus*, Lygaeidae), and Milkweed Leaf Miner Fly (*Liriomyza asclepiadis*, Agromyzidae). These species generally occur on a number of different *Asclepias* species across their range (Price and Willson 1979, Farell 2001 and references therein, Hilty 2008) and thus could occur on Four-leaved Milkweed.

Chaplin and Chaplin (1981) compared the success of Large Milkweed Bug on laboratory diets of seeds from seven Missouri milkweeds including two frequent, three occasional and three non-host species, one of which was Four-leaved Milkweed. Growth rate and efficiency, developmental time, nymphal mortality, size at teneral moult, adult size of female milkweed bugs and brood female to male biomass ratio were all significantly poorer on Four-leaved Milkweed seeds versus the regular host species (*A. syriaca* and *A. verticillata*) despite greater biomass ingestion. There is no other literature evidence available on which of the milkweed specialist insects beyond Monarch and Milkweed Stem Weevil might occur on Four-leaved Milkweed either in Canada or more broadly across its range, although the Swamp Milkweed Beetle is known from the closely related and ecologically similar *A. exaltata* (Queller 1985). No observations on herbivory at the Prince Edward County sites have been made. Anurag

Agrawal (Cornell University, widely published on milkweed herbivory) has noted no herbivory on a single population of Four-leaved Milkweed near Ithaca, New York over several visits and speculated that Monarchs and Milkweed Longhorn Beetles may be inhibited by the species' shaded habitat (A. Agrawal pers. comm. 2008). The single-stemmed nature of Four-leaved Milkweed and its low density relative to *A. syriaca* probably also make it less suitable for insects that occur at high density and consume most of plant's biomass as a single plant might not support a whole cohort to maturity and neighbour plants might be beyond larval dispersal distance.

Dispersal

As with other milkweeds, Four-leaved Milkweed seeds have a coma of long, silky hairs that aid in wind-dispersal. Morse and Schmitt (1985) and Sacchi (1987) found that coma length and seed size varied extensively within Common Milkweed (*A. syriaca*), with coma length associated with seed position in the pod. Longer coma (more strongly) and lighter seed mass were correlated with longer potential seed dispersal in the lab and the field, and wind speed was strongly correlated with seed dispersal distance. In a controlled field study, Morse and Schmitt (1985) found that *A. syriaca* seed dispersal from a 1 m release height varied by clone from 1.5 m +/- 1.0m to 31 m +/- 41m, with some seeds traveling more than 150 m. In a similar field experiment, Sacchi (1987) found seeds with long comas travelled 57.9 m +/- 17.0 m on a moderately windy day. Average dispersal distances in Four-leaved Milkweed are probably less than in *A. syriaca* because of lower plant height, and the reduced wind speed and greater number of obstacles within its forested, rather than open, habitat, but occasional long-distance seed dispersal likely occurs.

Broyles *et al*. (1994) studied pollen dispersal in the closely related and ecologically similar *Asclepias exaltata* in North Carolina and, based on allozyme paternity analysis of seeds, found that it had among the highest rates of pollen-mediated gene dispersal of any insect-pollinated plant (Broyles *et al.* 1994), with pollination over distances of 1000+ m common. At the population isolated from others by 1000 m, 50% of pollination was from immigrant pollen and all populations showed at least 29% pollination by immigrant pollen. Potential pollen dispersal is likely similar in Four-leaved Milkweed, but pollen dispersal between known populations in Canada would still be unlikely because of the minimum 9 km distance between them and because of their small population sizes. Assuming Four-leaved Milkweed also has effective pollen interchange over 1000+ m, this would enable isolated plants at a newly established site within the range of pollen dispersal to produce seeds despite self-incompatibility. It could also make the minimum population size required to avoid inbreeding effects smaller in Four-leaved Milkweed than in species with lower rates of genetic interchange.

Interspecific interactions

Smith *et al*. (2008) documented an arbuscular mycorrhizal association with the fungus *Glomus intradices* under greenhouse cultivation of *Asclepias syriaca*, and such associations are probably significant for that and other milkweeds in the wild as well. Aside from the insect pollinators described in detail above under *Life Cycle* and *Pollinating Insects* and the herbivores described in detail under *Herbivory*, nothing further is known about interspecific interactions involving Four-leaved Milkweed.

Physiology/Adaptability

Chaplin and Walker (1982) found that energy reserves available from the previous year and stored in the roots were the primary determinant of total flower number, and root mass was strongly correlated with and could be calculated from plant height. Chaplin and Walker documented a series of thresholds that represented the minimum energy content and plant size required for plants to: a) produce flowers (20.6 kJ and 19 to 20 cm, requiring a minimum of 5 years from seed germination), b) to mature seed pods (32.7 kJ and 30 cm, requiring about 10 years) and to c) mature seed pods in successive years (42.9 kJ and 42 cm, time undetermined). Smaller plants between 19 and 33 cm are thus functionally unisexual males until gaining sufficient energy reserves to produce mature fruit since during that period they abort all seed pods initiated. Four-leaved Milkweed seeds, due to fat content, are the most energetically expensive part of the plant by mass. Seed pods, which contain an average of 35 seeds, are thus energetically expensive with a single pod representing more than 21% of the total energy content of the plant on average. Plants maturing seed pods in one year decreased in size the following year by an amount equivalent to slightly less than the energetic costs of the seed pod (indicating that a portion of the cost is compensated for by photosynthesis during pod formation), while those plants that did not produce seed pods increased in size. For plants near the above thresholds, seed production thus set them back to a previous level. The cost of seed pod production was also demonstrated by the increased mortality in smaller plants (having smaller energy reserves) that matured seed pods, with 40% of such plants failing to emerge the following year.

Another notable aspect of Four-leaved Milkweed energetics is the amount of energy devoted to nectar production, which amounts to 30% of the total energy devoted to the flower (Pleasants and Chaplin 1983) and is unusually high for flowering plants (Harder and Barratt 1992), though not exceptional among milkweed (Willson and Bertin 1979, Wilson *et al*. 1979). The allocation of a relatively large amount of energy to attracting pollinators makes sense in an obligate out-crossing species requiring moderately large, nectar-feeding insects for pollination. Nectar production per flower was positively correlated with root mass (associated with a plant's energetic status) and negatively correlated with number of flowers in an umbel, perhaps because of constraints in the single peduncle in carbohydrate delivery to the umbel or because insects are more attracted to larger umbels independent of amount of nectar, allowing the plant to "cut costs" in per flower nectar production (Pleasants and Chaplin 1983). Pleasants and Chaplin (1983) found that male but not female fitness was positively correlated with nectar production.

Chaplin and Walker (1982) and numerous subsequent papers for *Asclepias exaltata* (Broyles and Wyatt 1990a, 1990b, 1995, 1997, Queller 1983, 1985, 1997, among others) addressed the question of the purpose of allocating the energy required to produce a large number of flowers when only one or two pods per plant are matured. Chaplin and Walker felt that the best explanation was that it increased the male contribution to genetic fitness by providing more pollinia to sire more seeds. Broyles and Wyatt (1997) concluded that although increasing number of flowers does increase fruits sired, the benefits were not large enough for this to be the only factor explaining flower numbers.

The only other physiological data specific to Four-leaved Milkweed are from Agrawal *et al.* (2008), who found that Four-leaved Milkweed had an intermediate level of latex production, ranking 29th out of 49 *Aclepias* species sampled.

POPULATION SIZES AND TRENDS

Search effort

Surveys have been extensive within the Ontario range of Four-leaved Milkweed, probably amounting to several hundred botanist days in potentially suitable habitat. This effort includes surveys for the International Biological Program (Archives of the National Academies 2009) in the late 1960s and early 1970s, Ontario Ministry of Natural Resources fieldwork from the late 1970s onward to establish and document Life Science Areas of Natural and Scientific Interest (Lindsay 1986, MacDonald 1987), especially along the Niagara Escarpment (Cuddy *et al.* 1976, Riley *et al.* 1996), and fieldwork focused on alvars and associated communities (Catling *et al*. 1975, Catling and Catling 1993, Catling and Brownell 1995 and 1999, Brownell and Riley 2000), among others.

Four-leaved Milkweed is likely extirpated along the Niagara River having not been found in a series of fieldwork surveys by qualified botanists (Cuddy *et al.* 1976, Varga 1979-82, Varga 1989, Varga 1995, Varga and Kor 1993, Oldham 1994, Oldham 2007) has failed to locate it at the original sites, and little unsurveyed habitat exists along the river or northward toward Hamilton. If the species persists along the Niagara River Gorge, it would likely only be in small numbers on the more extreme slopes where access by botanists is limited. Although Four-leaved Milkweed has never been found there, the small and threatened limestone savannahs on the Flamborough Limestone Plain near Hamilton (Catling and Brownell 1999) have been less intensively surveyed than the Niagara Gorge sites and would be another potential area of occurrence.

The Ontario Natural Heritage Information Centre's Natural Areas database (ONHIC 2008) lists at least 21 botanically surveyed natural areas on limestone escarpments or limestone plains that could contain suitable habitat for Four-leaved Milkweed within Prince Edward County and the adjacent townships of Hastings and Lennox and Addington Counties. Specific efforts to find Four-leaved Milkweed in Prince Edward County have included one day by Sutherland, Oldham and Gould in 1986 (M. Oldham pers. comm. 2008), one day by Oldham, Sutherland and Jalava in 1994 (M. Oldham pers. comm. 2008) and two days by Blaney in 2008. ONHIC botanists also conducted 10 person days of fieldwork in 2008 in and around Prince Edward County without finding the species (Mike Oldham pers. comm. 2008). This region does, however, still support local pockets of suitable habitat that have not been examined by botanists, especially in east-central Prince Edward County. There is thus reasonable potential for discovery of a small number of new Four-leaved Milkweed sites in this region. The limited populations at known sites, limited area of unsurveyed suitable habitat and the number of apparently suitable sites lacking the species all suggest, however, that Four-leaved Milkweed is truly rare.

Number of populations

The first Canadian record of Four-leaved Milkweed was John Macoun's 1868 collection from "Bay of Quinte" in 1868 (specimen at DAO, ONHIC data). Macoun (1883-1890) reported the species from Adolphustown (citing R.M. Stark) and "vicinity of Napanee" (citing Rev. John Scott). Both of these communities are in Lennox and Addington County on the Bay of Quinte, and Macoun's 1868 record may have been collected at one of those sites, or could have been at a separate location. These populations are most likely extirpated since suitable habitat around the Bay of Quinte has undoubtedly been substantially reduced through agriculture and expansion of development since 1868 and the species has not been found in remaining suitable habitat at numerous surveyed sites around the Bay of Quinte.

Four-leaved Milkweed was collected or reported along the Canadian side of the Niagara River eight times from at least four separate locations between 1898 and 1956 (Table 3). All records but two can be placed within a 6 km stretch of the Niagara River Gorge between 5 km and 11 km downstream from Niagara Falls. These records probably originally represented a single, more or less continuous population, and are treated as a single population here because there is no break of 1 km of permanently unsuitable habitat (NatureServe 2004) between them, habitat would have been more continuous at the time of the records, and because pollen dispersal of one to several kilometres is plausible in milkweeds (Broyles *et al*. 1994). The remaining Niagara records are from "Niagara Falls" and the vicinity of Niagara Falls (based on the geographic scope of the record's source) and would represent a separate population if they were truly from at or near the falls. It is quite possible that "Niagara Falls" was used more generally and that the records in question were actually downstream from the falls near the other records, or that the Voaden record from 1902 might have been from the Goat Island area on the American side of the falls. Even in 1902, little suitable habitat likely remained at the falls on the Canadian side. No Niagara area records have been found since 1956 despite multiple searches in and near the original sites and the species is considered probably extirpated there (M. Oldham pers. comm. 2008).

Table 3. Canadian records of Four-leaved Milkweed (*Asclepias quadrifolia*).

Population#	Sub-population#	County	Location	Directions / Notes	Observers + Collection #	Date	Evidence	Institution & Accession#	# in flower	# non-flowering	# unkn. fertility
1		Lennox and Addington	Adolphustown		R.M. Stark	Pre-1890	literature report (Macoun 1883-1890)			unknown; likely extirpated	
2		Lennox and Addington	Napanee	"near Napanee"	Rev. J. Scott	Pre-1890	literature report (Macoun 1883-1890)			unknown; likely extirpated	
1 or 2; or possibly separate		Lennox and Addington, or Hastings or Prince Edward	Bay of Quinte	Could be from either #1 or #2 above or a separate location	J.M. Macoun	1868 07 14	specimen	DAO D 680714A; MTMG 1127		unknown; likely extirpated	
3		Prince Edward	McMahon Bluff	[4 GPS locations]	C.S. Blaney; R.J. Blaney	2006 06 13	photograph		10	14	
3		Prince Edward	McMahon Bluff	[3 GPS locations]	M.J. Oldham; T. Norris	2006 06 19	specimen; photograph	DAO	23	34	
3		Prince Edward	McMahon Bluff	[9 GPS locations]	M.J. Oldham; T. Norris; B. Van Sleeuwen	2006 06 22	sight record		43		
3		Prince Edward	McMahon Bluff	[2 GPS locations]	G. Poisson	2006 06 30	sight record				4
3		Prince Edward	McMahon Bluff	[1 GPS location]	D. Bree	2007 06 17	sight record		3		
3		Prince Edward	McMahon Bluff	[2 GPS locations]	C.S. Blaney	2008 09 29	photograph		1	4	
4		Prince Edward	MacAuley Mountain Conservation Area	[same plants as below]	D. Bree	2007 06 19	photograph		12		
4		Prince Edward	McCauley Mountain Conservation Area	[3 GPS locations]	M.J. Oldham 35726; S. Brinker	2008 07 08	specimen; photograph	DAO	16	26	

Population#	Sub-population#	County	Location	Directions / Notes	Observers + Collection #	Date	Evidence	Institution & Accession#	# in flower	# non-flowering	# unkn. fertility
5	A	Niagara Reg. Mun.	Niagara River	The Whirlpool	W. Scott	1898 06 21	specimen	DAO D 980621; TRT 716		extirpated	
5	B	Niagara Reg. Mun.	Niagara Glen	[1.0-2.4km northeast of sub-population A; 0.7-2.1km southwest of sub-population C]	"Field Club"	1888	literature report (Eckel 2001)			extirpated	
5	B	Niagara Reg. Mun.	Niagara Glen	“woods opposite the Glen”, probably around current Botanical Gardens	G.H. Hamilton	1943	Literature report (Hamilton 1943, in Eckel 2001)			“very abundant”; now extirpated	
5	C	Niagara Reg. Mun.	Queenston	Hydro woods south of Queenston power plant	J.H. Soper 5979	1954 06 16	specimen	CAN 257784; TRT 92105; MICH D 540616A		extirpated	
5	C	Niagara Reg. Mun.	Queenston	Hydro woods south of Queenston power plant	J.H. Soper 6339; G. Fleishmann 66	1956 06 20	specimen	CAN 258061; DAO D 560620A; TRT 96991		extirpated	
5	D	Niagara Reg. Mun.	Queenston	Woods on either side of the railway, leading up the face of the escarpment just south of Queenston (1.5-2.5km north of sub-population C); location was "near Niagara Falls" on the specimen and ONHIC data, and revised to above based on Macoun (1893) cited in Eckel (2001)	J.M. Macoun	1892 06 25	specimen	CAN 93161		extirpated	
5?		Niagara Reg. Mun.	Niagara Falls	["Niagara Falls" perhaps a generalized description referring to The Whirlpool to Queenston area of above records, rather than immediate area of falls]	J. Voaden	1902 06 23	specimen	QK 14616		extirpated	
5?		Niagara Reg. Mun.	vicinity of Niagara Falls	[vicinity of Niagara Falls is the scope of the Eckel (2001) publication, including area of above records]	either Miller or M. Landon	unknown; 1948-52	literature report (Heimburger 1955, cited in Eckel 2001)			extirpated	

There are only two extant populations of Four-leaved Milkweed known in Canada, both in Prince Edward County at the eastern end of Lake Ontario. These are McMahon Bluff, where it is sparsely scattered over roughly 20 ha (1 km x 0.2 km) and Macauley Mountain Conservation Area, where it is sparsely scattered over roughly 0.25 ha. The two extant populations are on the same limestone escarpment system and are separated by 9 km straight line distance and roughly 22 km following the escarpment. They are clearly separate populations under NatureServe guidelines (NatureServe 2004) because of the distance and presence of persistently unsuitable habitat between them.

Two other unconfirmed Canadian reports are indefinite enough to be excluded from consideration here. A “clump of seven plants” of Four-leaved Milkweed was reported to Michael Oldham in 1994 from a bird survey transect at Point Petre in southwest Prince Edward County (M. Oldham pers. comm. 2008). He and two other expert botanists searched this transect and failed to find any plants. The record was among only 13 other species noted, including some not fully identified, so it should be considered questionable at best. Expert southwestern Ontario botanist Gerry Waldron also reported seeing this species during International Biological Program surveys with Stuart Hay in 1969 but is unsure about the location (M. Oldham pers. comm. 2008). This record is likely correct but further information is needed before it could be considered confirmed. No specimen is present at the Marie-Victorin Herbarium (S. Hay pers. comm. 2009).

Abundance

Macauley Mountain

Twelve stems, in a loose colony, were found at the initial discovery of this site in 2007 (Table 3). Subsequently, 42 stems (16 developing fruit, 26 infertile) were found over a 50 m x 50 m area during a more thorough survey of the same area in 2008.

McMahon Bluff

Compilation of the field data of Sean Blaney, Michael Oldham, David Bree and Geri Poisson for the McMahon Bluff site gives a total of 136 plants, 80 flowering, 52 non-flowering and four of unknown fertility. The multiple observers over multiple visits and the limits of GPS precision make it difficult to eliminate the possibility of double counting at a few points; however, most records were clearly separate with potential double counting only an issue for about 15 to 20 plants. Non-flowering plants (many or most of which were likely not mature) were not recorded on one field day, so their numbers are somewhat under-recorded, by perhaps 20 to 50 plants. Some other undocumented plants are likely also present at the site although coverage of available habitat has been fairly thorough.

The total Canadian population counts are 96 flowering, 78 non-flowering, and 4 plants of unknown fertility (178 total plants). The number of *mature individuals* (COSEWIC 2006) is thus between 96 and 178 plants because some of the non-flowering plants were likely too small to produce flowers (20 cm, Chaplin and Walker 1982) and were not counted as mature individuals, whereas others may have been mature but lacking sufficient resources to produce flowers at the time of survey (Chaplin and Walker 1982). It is reasonable to expect that some other small populations might be found elsewhere in Prince Edward, southern Hastings or southern Lennox and Addington Counties in eastern Ontario, but the rarity of the habitat in which the extant populations occur coupled with the lack of records strongly suggest that Four-leaved Milkweed is a rare species and that it is unlikely that the Canadian population could exceed 1000 mature plants.

The Niagara River population is likely extirpated. It was once at least locally common on the Canadian side of the Niagara River. Macoun [1893, cited in Eckel (2001)] recorded it “on both sides of the railway just south of Queenstown”, and Hamilton [1943, cited in Eckel (2001)] noted it as “very abundant in the open woods opposite the [Niagara] Glen”, which probably refers to the plateau directly inland from the Niagara Glen on which woodland has since been almost completely eliminated by the Niagara Parks Commission Botanical Gardens and other developments (OMNR pers. comm. 2009).

Fluctuations and trends

No sizable population fluctuations are known in Four-leaved Milkweed, either in Canada or elsewhere in its range. Small and large plants were observed in both populations, indicating that seed production and seedling recruitment are occurring (S. Blaney pers. obs. 2006-2009, M. Oldham pers. comm. 2008) but no further quantification on this is available.

Populations of Four-leaved Milkweed have clearly declined since 1956 along the Niagara River, to the point where they are probably extirpated. Macoun’s 1868 “Bay of Quinte” site is probably also extirpated given the extent of habitat change in the Belleville area since that time and the absence of the species in recently surveyed potential habitat in that area. Other undocumented population losses probably occurred with the extensive deforestation and land conversion in Four-leaved Milkweed range in Ontario since European settlement. All of these losses are outside the 21 to 30 year period (estimated three times generation time) relevant to COSEWIC status assessment.

There is no information on more recent trends in Canadian populations, although the limited observations at McMahon Bluff and Macauley Mountain do not point to any declines since 2006-2007. As described under *Limiting Factors and Threats*, continued encroachment of the exotic Common Buckthorn and various native shrubs seems likely to reduce habitat quality and population at both sites over time. The proposed subdivision development at McMahon Bluff would also substantially reduce Four-leaved Milkweed numbers if it were to go ahead.

Rescue effect

The nearest American populations of Four-leaved Milkweed are in New York State at the east and west ends of Lake Ontario. At the eastern end of Lake Ontario, Four-leaved Milkweed is known from near Henderson, New York (Woodson 1954), 70 km across Lake Ontario from extant populations in Prince Edward County but it is quite rare and localized in upstate New York with no records known from other adjacent counties (New York Flora Atlas 2008). Rescue from this area would be very unlikely. Four-leaved Milkweed is also known from the American side of the Niagara River, but was not found in a 1985 inventory of the DeVeaux Woods (Eckel 1986) across the river from the Niagara Glen area of the Canadian population where it had been reported as “very abundant” in 1943 (Eckel 2001). If Four-leaved Milkweed still occurs at all in New York within 4 km of the Niagara Gorge, it is likely rare as deforestation in this area is almost complete (1:50,000 topographic map, Natural Resources Canada 1990). Rescue from American populations in Niagara is even less plausible due to habitat alteration and loss that have probably extirpated Canadian populations, making survival of potential colonists questionable.

LIMITING FACTORS AND THREATS

Limited and fragmented habitat

Four-leaved Milkweed was likely always a rare and local plant in Ontario, limited by climate, availability of rocky, open woodland and perhaps by incomplete post-glacial colonization of potential Canadian habitat, to the eastern and western ends of Lake Ontario in the Prince Edward County region and the southern Niagara Escarpment. On top of its natural rarity, the massive loss and fragmentation of habitat in Four-leaved Milkweed range since European settlement has probably reduced populations even beyond the documented losses on the Niagara River. The habitat in which the species occurs at McMahon Bluff and Macauley Mountain is now rare in Ontario, probably falling into Bur Oak – Shagbark Hickory – Big Bluestem community listed as S1 (critically imperiled) for Ontario by the Ontario Natural Heritage Information Centre (W. Bakowsky pers. comm. 2008, see Bakowsky 2007). Today, limited and fragmented habitat likely limits any potential for re-colonization and expansion of the species’ Canadian range and population.

Habitat conversion

The Macauley Mountain population is within the Macauley Mountain Conservation Area and is not threatened by development. Quinte Conservation Authority manages the land, is aware of the record and will avoid any further trail or other construction in the area (T. Trustham pers. comm. 2008). Until July 2009, the McMahon Bluff site was owned by a developer who produced a “preliminary concept plan” in 2006 to subdivide over half the land into 19 one to four hectare lots and build luxury homes (J. Blaney pers. comm. 2009). The potential subdivision area covered 98% of plants known at McMahon Bluff representing 73% of the Canadian population. The Hastings-Prince Edward Land Trust had been working to raise sufficient funds to purchase the property as a conservation reserve, but in July 2009 the site was sold to another individual whose intentions for the property are not known to the land trust (J. Blaney pers. comm. 2009). The development threat to the site is likely still high.

If any other sites exist in or near Prince Edward County, they are likely to be threatened by one or several factors. Potentially suitable habitat is in small patches, almost all under private ownership, and frequently isolated by surrounding unsuitable agricultural or former agricultural land. Private woodlots are frequently subject to forest harvesting or other potentially incompatible land use. Prince Edward County has experienced extensive growth as a recreational and retirement destination in the past decade because of its proximity to Toronto and its 800 km of lakeshore (Corporation of the County of Prince Edward 2008). Any potential Four-leaved Milkweed habitat near existing roads or having lakeshore views is at risk of housing development. Grape cultivation and winery development have been rapid and extensive since the late 1990s with at least 13 wineries (Wines of Canada 2008) and numerous additional grape growers now established in the county. Grape cultivation has thus far mostly been developed on land previously devoted to other agricultural use and therefore already unsuitable for Four-leaved Milkweed, but the limestone plateau habitats of the milkweed are potentially suitable sites for grape cultivation and winery development could impact undiscovered sites in the future. Four-leaved Milkweed habitat in Prince Edward County is also ideal for limestone quarrying, and quarry expansion could impact undiscovered sites. The species is currently not legally protected under federal or provincial legislation, meaning there is little mitigation of the threat of development impacts.

Exotic and native shrub encroachment and canopy closure

Habitat change that increases shading appears threaten to Four-leaved Milkweed. Chaplin and Walker (1982) demonstrated that Four-leaved Milkweed grew and reproduced best at forest edges rather than in forest interiors in Missouri, and there is extensive anecdotal evidence suggesting that it is a species of open forests, steep forested slopes and forest margins where light levels are greater than in closed-canopy forest. There is also good evidence that natural fires and those deliberately set by First Nations for habitat management kept southern Ontario’s dry upland habitats such as prairies, alvars and the limestone savannahs occupied by Four-leaved Milkweed more open than they are today (Catling and Catling 1993, Jones and Reschke 2005). At the

McMahon Bluff site, there seemed to be a concentration of plants along the margins of a lightly used ATV trail where light levels were slightly higher than in the surrounding woodland, further suggesting light availability is a limiting factor.

Limestone woodland habitats have been extensively invaded by Common Buckthorn (*Rhamnus cathartica*) throughout Prince Edward County and the Bay of Quinte region (S. Blaney pers. obs. 1990-2009), where the species frequently creates a dense subcanopy and deep shade in formerly fairly open forest. Common Buckthorn is common at both milkweed sites, forming 5 to 10% of canopy cover in some areas of McMahon Bluff (S. Blaney pers. obs. 2006-2009) and Macauley Mountain (S. Brinker pers. comm. 2008). It is already contributing to what is likely an unnaturally high level of shading at the sites, although it is not nearly as dense as in the worst affected areas in the region. Given large populations nearby and on-site and extensive bird dispersal of seeds, it is likely that Common Buckthorn will continue to increase and cause further shading at Four-leaved Milkweed sites.

Several native shrubs also form locally dense sub-canopy cover to an extent that is likely detrimental to Four-leaved Milkweed, with Gray Dogwood (*Cornus racemosa*), Prickly-Ash (*Zanthoxylem americanum*) and Downy Arrow-wood (*Viburnum rafinesquianum*) being most prominent. Loss of fire is likely also changing the tree cover at the sites, causing increases in fire-intolerant sugar maple, white ash and basswood abundance and promoting more canopy closure. If the ingrowth of Common Buckthorn and native shrubs and increases in canopy closure continue, the Four-leaved Milkweed population seems likely to decline over the next several generations.

Competition from exotic herbs

Exotic herbs, especially Garlic Mustard (*Alliaria petiolata*) are extremely dense at Niagara River sites and probably contributed to Four-leaved Milkweed's extirpation there (Oldham 2007, M. Oldham pers. comm. 2008). This and other invasive exotic herbs are not yet problematic at the Prince Edward County sites, but Pale Swallow-wort (*Cynanchum rossicum*) presents a serious threat. It is rapidly spreading in eastern Ontario, is known within 8 km of both Four-leaved Milkweed sites and is probably already closer than that (S. Blaney pers. obs. 2006-2009). It has had devastating effects, largely eliminating other understory herbs, on habitat at Prince Edward Point (12 km east of McMahon Bluff) similar to the known milkweed sites (S. Blaney pers. obs. 1990-2009). Given its rate of spread in eastern Ontario in the past 20 years it can be expected in the immediate vicinity of known Four-leaved Milkweed sites within the next 21 years (three times minimum estimated generation time) (S. Blaney pers. obs. 2006-2009). If it becomes well-established near Four-leaved Milkweed, extirpation would be possible.

Small population size and area

There is good evidence for effective genetic interchange between individuals isolated from others by 1000 m for the closely related and ecologically similar Poke Milkweed (*Asclepias exaltata*) (Broyles *et al*. 1994). Study of fixation indices (Broyles 1998) also found that inbreeding is not currently an evolutionarily significant process in isolated northern populations of *A. exaltata.* Four-leaved Milkweed likely has a similar level of genetic interchange, making the species similarly resistant to inbreeding effects with sufficient population sizes. Nonetheless, the limited number of mature Four-leaved Milkweed plants (between 16 and 42) at the Macauley Mountain site could conceivably have caused or could lead to inbreeding effects (see review in Hansson and Westerberg 2002). The restricted area of occurrence at the Macauley Mountain site also increases the risk level relative to any local anthropogenic or natural disturbance event.

Off-road vehicle traffic and trampling

As noted, the present low level of off-road vehicle traffic at McMahon Bluff seems to be benefiting Four-leaved Milkweed by providing slightly brighter conditions along the trail than in the surrounding woodland. If, however, the trail became substantially more heavily used, milkweed plants could certainly be damaged or lost. The Macauley Mountain population is adjacent to a hiking trail with trampling a potential threat to a small portion of plants.

SPECIAL SIGNIFICANCE OF THE SPECIES

Four-leaved Milkweed is biogeographically interesting as one of the best examples of a species of southern affinity having colonized Canada from both eastern and western ends of Lake Ontario. It is one of relatively few nationally imperiled vascular plants in southeastern Ontario, especially in the Prince Edward County region in which it occurs. It occurs within very rare and threatened plant communities, which at McMahon Bluff support two other nationally rare species (Midland Sedge - *Carex mesochorea*, S1 and Bicknell's Sedge - *Carex bicknellii*, S2), with a third species (Few-fruited Sedge – *Carex oligocarpa*, S2) present in immediately adjacent communities. Four-leaved Milkweed's Prince Edward County occurrences are well-isolated and at the northern edge of the species' range which could make them significantly genetically divergent from central populations (Lesica and Allendorf 1995).

All the human uses of *Asclepias* spp. (well summarized in Plants for a Future 2008) appear unlikely to be relevant to Four-leaved Milkweed because of its small size, moderate latex production and limited seed pod production, with the possible exception of several listed medicinal uses. Aboriginal Traditional Knowledge related to medicinal uses have been documented in (Moerman 2010) for First Nations in the United States but no data are available from Canadian sources.

EXISTING PROTECTION OR OTHER STATUS DESIGNATIONS

Four-leaved Milkweed is considered globally secure (G5 rank) but critically imperiled in Canada and Ontario (N1 and S1 ranks) (NatureServe Explorer 2008). Table 1 indicates S-ranks and provincial or state status designations. Four-leaved Milkweed is potentially extirpated (SH) in Delaware, critically imperiled (S1 rank) in Rhode Island and Kansas, imperiled (S2) in New Hampshire and sensitive (S3) in Iowa and Vermont. It has a state-level Threatened status in New Hampshire and Rhode Island. Four-leaved Milkweed is not ranked (SNR, which usually means a species is considered secure) in 13 states and secure (S4 or S5) in seven other states.

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BIOGRAPHICAL SUMMARY OF REPORT WRITER

Sean Blaney is the Botanist and Assistant Director of the Atlantic Canada Conservation Data Centre (AC CDC), where he is responsible for maintaining status ranks and a rare plant occurrence database for plants in each of the three Maritime provinces. Since beginning with the AC CDC in 1999, he has conducted an extensive fieldwork program across the Maritimes region, discovering dozens of new provincial records for vascular plants and documenting several thousand rare plant locations. Sean is also a member of the COSEWIC Vascular Plant Species Specialist Committee, the Nova Scotia Atlantic Coastal Plain Flora Recovery Team, and has co-authored several COSEWIC and provincial status reports. Prior to employment with AC CDC, Sean received a B.Sc. in Biology (Botany Minor) from the University of Guelph and an M.Sc. in Plant Ecology from the University of Toronto, and worked on a number of biological inventory projects in Ontario as well as spending eight summers as a naturalist in Algonquin Park, where he co-authored the second edition of the park's plant checklist.

COLLECTIONS EXAMINED

Ontario collections were fully catalogued for the *Atlas of the Rare Vascular Plants of Ontario* project (Argus *et al*. 1982-1987). A scanned specimen from the McGill Herbarium (MTMG 1127) duplicating the 1868 Macoun collection at DAO (D 680714A) was examined during the preparation of this COSEWIC report. One of two plants on the sheet was erroneously annotated as *Vincetoxicum nigrum* by B. Boivin in 1964 and “probably *V. rossicum*” by S. Darbyshire in 2003. The plant is clearly a mature, seed-bearing Four-leaved Milkweed collected later in the season than the stated collection date of July 1, 1868, which probably referred to the other flowering plant on the sheet.