COSEWIC
Assessment and Status Report

on the

Manitoba Oakworm Moth
Anisota manitobensis

in Canada

SPECIAL CONCERN
2019

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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Production note:
COSEWIC would like to acknowledge Robert Foster for writing the status report on Manitoba Oakworm Moth (*Anisota manitobensis*) in Canada, prepared under contract with Environment and Climate Change Canada. This report was overseen and edited by Jenny Heron, Co-chair of the COSEWIC Arthropods Specialist Subcommittee.

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Cover illustration/photo:
Male adult Manitoba Oakworm Moth reared from larvae collected in August from Fullers MB. Photo credit: Don Henne.

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COSEWIC
Assessment Summary

Assessment Summary – November 2019

Common name
Manitoba Oakworm Moth

Scientific name
Anisota manitobensis

Status
Special Concern

Reason for designation
This large moth has a small global distribution, most of which is in Canada, and restricted to a small area in southern Manitoba and the adjacent United States. Localized population irruptions occurred irregularly through the 1900s, but their frequency declined and the last one was in 1997; no individuals have been detected since 2000. Threats are primarily related to declines of Bur Oak, its larval host plant. Bur Oak is susceptible to secondary diseases, especially when compounded with anthropogenic and environmental stress. Other threats include fire suppression, deer browsing and subsequent invasive plant incursion, and insecticides targeting pest moths, all of which contribute cumulatively to ongoing decline in Bur Oak health and subsequent loss or reduction of habitat. Bur Oak woodlands are fragmented throughout their range in Manitoba, and subpopulations of this moth are perhaps even more fragmented because of their limited dispersal ability, and its larval preference for younger Bur Oak. This species may actually be Threatened, but data are currently insufficient to assess whether it meets thresholds for status criteria.

Occurrence
Manitoba

Status history
Designated Special Concern in November 2019.

COSEWIC
Executive Summary

Manitoba Oakworm Moth
Anisota manitobensis

Wildlife Species Description and Significance

Manitoba Oakworm Moth (*Anisota manitobensis*) is a medium-sized moth (forewing length 19-30 mm) in the family Saturniidae (silk worm moths). There are four life stages and the species grows through complete metamorphosis. Adults are brownish-orange, and females are typically pinker than darker males. The flattened, ovate eggs are smooth and yellow, turning to brownish with age. Larvae are typically dark brown to black with paler stripes (tending to pink in later instars) with spines and thoracic horns. Pupae are brown and approximately 3 cm long.

Distribution

The known global and Canadian range of Manitoba Oakworm Moth is restricted to southern Manitoba and extreme northern North Dakota and Minnesota. The majority of the global range is in Manitoba where it has been recorded from approximately 25 sites as far north as Riding Mountain National Park. The two sites in adjacent North Dakota and Minnesota are approximately 40 km and 65 km respectively from the nearest known Canadian sites. Its Canadian range is approximately 43,000 km^2, including historical sites that may still be extant.

Habitat

Manitoba Oakworm Moth is restricted to habitats where its larval food plant, Bur Oak (*Quercus macrocarpa*), is found. Currently, oak savannas and woodlands along river valleys and the Manitoba Escarpment comprise the most abundant potential habitat for this species. Manitoba Oakworm Moth was most recently found in riverine oak woodlands in Winnipeg and but also on smaller, younger oak trees in full sunlight along roadsides and rights-of-way near Fullers.

Biology

The biology of Manitoba Oakworm Moth is poorly known. Eggs of Manitoba Oakworm Moth are laid in clusters on leaves of Bur Oak in June to mid-summer. When first hatched, young caterpillars are gregarious but are less so in later instars. This species overwinters for at least eight months as a pupa in the soil. The adults have been observed from early June to late July, and mainly fly during the day.

Population Sizes and Trends

Population sizes and trends are poorly understood for Manitoba Oakworm Moth. Like many oakworm moth species, it may have periodic outbreaks with low numbers in intervening years.

Threats and Limiting Factors

Threats to Manitoba Oakworm Moth and its habitat are poorly understood. Non-target impacts from spraying of insecticide is a potential threat to this species, but likely limited to the city of Winnipeg. Residential and other urban development resulted in the loss of historical habitat and may continue to be a localized threat, as with roads and transmission line development. Soil compaction from recreational and other activities may affect oak health and indirectly impact Manitoba Oakworm Moths in Winnipeg and other urban areas. More broadly, fire suppression may reduce the quality of oak savanna habitat for Manitoba Oakworm Moth over the long term.

Manitoba Oakworm Moth is naturally limited by the abundance and distribution of Bur Oak in southern Manitoba, which has declined from historical abundance largely due to logging for wood and forest clearing for residential and other development in the 1800s and early 1900s. Adult moths do not have functional mouthparts and do not feed, instead relying on fat stored during larval development. Female moths are weak fliers, and do not likely disperse far, mainly because they are heavy with eggs. Dense vegetation may limit pheromone dispersal.

Protection, Status and Ranks

Manitoba Oakworm Moth and its habitat have no direct legal protection in Canada or the United States. The species is globally ranked as Imperilled (G2). In Canada the species is ranked as Imperiled (N2) nationally and in Manitoba (S2). In the United States it is ranked Historical (NH) nationally and at the state level in Minnesota and North Dakota (SH).

TECHNICAL SUMMARY

Anisota manitobensis

Manitoba Oakworm Moth

Anisote du Manitoba

Range of occurrence in Canada: Manitoba

Demographic Information

Generation time	1 year
Is there an [observed, inferred, or projected] continuing decline in number of mature individuals?	Unknown
Estimated percent of continuing decline in total number of mature individuals within [5 years or 2 generations]	Unknown
[Observed, estimated, inferred, or suspected] percent [reduction or increase] in total number of mature individuals over the last [10 years or 3 generations].	Unknown
[Projected or suspected] percent [reduction or increase] in total number of mature individuals over the next [10 years or 3 generations].	Unknown
[Observed, estimated, inferred, or suspected] percent [reduction or increase] in total number of mature individuals over any [10 years, or 3 generations] period, over a time period including both the past and the future.	Unknown
Are the causes of the decline a. clearly reversible and b. understood, and c. ceased?	a. Unknown b. No c. Unknown
Are there extreme fluctuations in number of mature individuals?	Yes

Extent and Occupancy Information

Estimated extent of occurrence (EOO)	43,000 km²
Index of area of occupancy (IAO) (2km x 2km grid value)	120 km²
Is the population “severely fragmented” i.e., is >50% of its total area of occupancy in habitat patches that are (a) smaller than would be required to support a viable population, and (b) separated from other habitat patches by a distance larger than the species can be expected to disperse?	a. Possibly. b. Possibly.
Number of “locations”*	4 (only sites < 50 years) – 25 (all sites including historical localities)

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

Is there an [observed, inferred, or projected] decline in extent of occurrence?	Unknown
Is there an [observed, inferred, or projected] decline in index of area of occupancy?	Unknown
Is there an [observed, inferred, or projected] decline in number of subpopulations?	Unknown
Is there an [observed, inferred, or projected] decline in number of “locations”*?	Unknown
Is there an [observed, inferred, or projected] decline in [area, extent and/or quality] of habitat?	Yes, inferred decline in quality at some sites
Are there extreme fluctuations in number of subpopulations?	Unknown
Are there extreme fluctuations in number of “locations”?	Unknown
Are there extreme fluctuations in extent of occurrence?	No
Are there extreme fluctuations in index of area of occupancy?	No

Number of Mature Individuals (in each subpopulation)

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

Quantitative Analysis

Is the probability of extinction in the wild at least [20% within 20 years or 5 generations, or 10% within 100 years]?	Unknown

Threats (direct, from highest impact to least, as per IUCN Threats Calculator)

Was a threats calculator completed for this species? Yes, January 31, 2019. Calculated at Low Impact.
Threats (from highest to lowest) are:

7.3 Other ecosystem modifications - Low
9.5 Air-borne pollutants - Low

What additional limiting factors are relevant?

- Larvae are dependent on Bur Oak to complete their life cycle.
- Adults do not feed so larvae must consume all necessary energy to sustain individuals through pupation to an adult, mating, egg development and oviposition.
- Small subpopulation size, both spatial area (e.g., limited habitat) and low moth abundance.
- Poor dispersal ability of females and short life span may limit (re)colonization of habitats.
- Natural enemies. Predators, parasites, and parasitoids are known to attack silk moths at all life stages.
- Dense vegetation may limit pheromone plume and ability for males to detect calling (i.e., emitting pheromones) females.

Rescue Effect (immigration from outside Canada)

Status of outside population(s) most likely to provide immigrants to Canada.	Unknown, possibly extirpated
Is immigration known or possible?	Unknown
Would immigrants be adapted to survive in Canada?	Yes
Is there sufficient habitat for immigrants in Canada?	Yes
Are conditions deteriorating in Canada?[+]	Yes, based on threats to Bur Oak trees and habitat
Are conditions for the source (i.e., outside) population deteriorating?[+]	Unknown
Is the Canadian population considered to be a sink?[+]	No
Is rescue from outside populations likely?	No

Data Sensitive Species

Is this a data sensitive species?	No

Status History

COSEWIC: Designated Special Concern in November 2019.

Status and Reasons for Designation:

Status: Special Concern	**Alpha-numeric codes:** Not applicable
Reasons for designation: This large moth has a small global distribution, most of which is in Canada, and restricted to a small area in southern Manitoba and the adjacent United States. Localized population irruptions occurred irregularly through the 1900s, but their frequency declined and the last one was in 1997; no individuals have been detected since 2000. Threats are primarily related to declines of Bur Oak, its larval host plant. Bur Oak is susceptible to secondary diseases, especially when compounded with anthropogenic and environmental stress. Other threats include fire suppression, deer browsing and subsequent invasive plant incursion, and insecticides targeting pest moths, all of which contribute cumulatively to ongoing decline in Bur Oak health and subsequent loss or reduction of habitat. Bur Oak woodlands are fragmented throughout their range in Manitoba, and subpopulations of this moth are perhaps even more fragmented because of their limited dispersal ability, and its larval preference for younger Bur Oak. This species may actually be Threatened, but data are currently insufficient to assess whether it meets thresholds for status criteria.	

Applicability of Criteria

Criterion A (Decline in Total Number of Mature Individuals): Not applicable. Data are insufficient.

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

Criterion B (Small Distribution Range and Decline or Fluctuation): Not applicable. EOO (43 000 km²) is greater than the threshold. Although IAO (120 km²) is less than 500 km² and there is an historical, and possibly an observed continuing decline in area, extent and quality of habitat, no other sub-criteria apply.
Criterion C (Small and Declining Number of Mature Individuals): Not applicable. May meet Threatened, C2b, with an observed and inferred decline in number of mature individuals; historical records indicate that this species may have extreme fluctuations.
Criterion D (Very Small or Restricted Population): Not applicable. No data.
Criterion E (Quantitative Analysis): Not applicable. Not completed.

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
(2019)

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

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

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

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

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

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

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WILDLIFE SPECIES DESCRIPTION AND SIGNIFICANCE

Name and Classification

Phylum: Arthropoda - arthropods

Class: Insecta - insects

Subclass: Pterygota - winged insects

Order: Lepidoptera - butterflies and moths

Superfamily: Bombycoidea

Family: Saturniidae - wild or giant silk moths

Subfamily: Ceratocampinae

Genus: *Anisota* Hübner, 1820

Species: *manitobensis* McDunnough 1921

English Common Name: Manitoba Oakworm Moth

French Common Name: Anisote du Manitoba

Type Locality: Aweme, Manitoba

Taxonomic Background: Manitoba Oakworm Moth (*Anisota manitobensis*) was originally described by McDunnough (1921) from specimens collected in Aweme, Manitoba. It is part of the *stigma* species group (Tuskes *et al*. 1996) along with Consular Oakworm Moth (*A. consularis* Dyar), Spiny Oakworm Moth (*A. stigma* Fabricius), and *A. fuscosa* Ferguson (no English common name), the latter of which is now considered a synonym of *A. stigma* (Pohl *et al*. 2018). The close affinity of the species is based primarily on adult genitalia and larval characteristics (Ferguson 1971; Riotte and Peigler 1980; Tuskes *et al*. 1996), and more recently on the size and structure of the scolus[1] from mature larvae (Burke and Peigler 2009). Pink-striped Oakworm Moth (*A. virginiensis* Drury) is the only other species of *Anisota* found in Manitoba (Figure 3).

[1] An external spine having multiple points

Tuskes *et al*. (1996) expressed uncertainty in the taxonomic status of this species and several of its congeners (e.g. *A. finlaysoni* Riotte and *A. peigleri* Riotte). However, Manitoba Oakworm Moth can be distinguished from related species (see Morphological Description) and is geographically isolated from other species in the *stigma* species group. Furthermore, it is distinct both genetically (based on DNA barcode data; deWaard pers. comm. 2019) and ecologically from the closely related Spiny Oakworm Moth (adult males are nocturnal fliers in Spiny Oakworm Moth versus diurnal fliers in other *Anisota*). As a result, recent continental and national checklists (e.g., Pohl *et al*. 2016; 2018) continue to recognize it as a full species. Should systematists decide to synonymize Manitoba Oakworm Moth within a closely related species, these same pieces of evidence would strongly support its status as a designatable unit.

Morphological Description

Manitoba Oakworm Moth has four developmental stages (egg, larva, pupa, and adult) and undergoes complete metamorphosis.

Adults:

Adult Manitoba Oakworm Moth is a brownish-orange, medium-sized moth (Figure 1), with females slightly larger (forewing 26 - 30 mm) than males (19 - 22 mm forewing). Females have more of a pinkish hue than males and simple rather than feathery (doubly bipectinate) antennae (Tuskes *et al*. 1996). There is little variation in moth colour patterning, although some males may have a slightly darker ground colour (Tuskes *et al*. 1996).

Both sexes are distinguished from the similar looking Spiny Oakworm Moth by a more pinkish overall hue (particularly females), smaller size, and the lack of black spotting on the wings of the former (Riotte and Peigler 1980; Tuskes *et al*. 1996). Male wings tend to be more acutely angled than those of most Spiny Oakworm Moths (although not necessarily of those from Wisconsin and New England). Male genitalia can be used to differentiate Manitoba Oakworm Moths from other species: males are readily separated from sympatric Pink-striped Oakworms, since the latter have a large hyaline area around the discal cell[2] on the forewing and an elongate aedeagus (male genitalia) (Tuskes *et al*. 1996).

[2] The discal cell is a cell within the wing venation of some insects and can be used as a species-specific identification feature.

Figure 1. Male holotype Manitoba Oakworm Moth from Aweme, MB (Canadian National Collection of Insects, Arachnids & Nematodes photo and specimen) (left) and female from Fullers MB (right; larval photo below)(D. Henne photo).

Eggs:

Newly laid eggs are “ovate and flattened, 1.51 x 1.25 mm, bright sulphur, shiny, quite opaque, and perfectly smooth” (Brodie 1929). A week after oviposition eggs become “very much flattened and were brownish in colour” (Brodie 1929).

Larvae:

Manitoba Oakworm Moths have five larval stages (instars) (Brodie 1929; Ferguson 1971; Henne 2002). When first hatched, larvae are creamy white but later instars are shiny brown or black with two paler dorsal stripes and a lateral stripe on each side. Larvae have thoracic horns as well as dorsal spines. Fifth instar larvae show some pink colouration and reach approximately 50 mm in length (females are slightly larger than males) (Figure 2). Late instar male larvae have a distinctive small dark spot on the bottom of the 9th abdominal segment that is lacking in females (Henne 2002).

Figure 2. Manitoba Oakworm Moth female fifth-instar larva from Fullers, MB feeding on Bur Oak 1996-08-20 (D. Henne photo).

Pupae:

Pupae are reddish brown and 29 mm long with a maximum width of 8 mm (Brodie 1929).

Population Spatial Structure and Variability

The population spatial structure, variability and size of Manitoba Oakworm Moth, including the geographic boundaries of subpopulations,[3] is poorly understood and there are no data available. There have been no subpopulation genetic studies in Canada or elsewhere in the species' global range.

[3] Subpopulations are defined as geographically or otherwise distinct groups in the population between which there is little demographic or genetic exchange (typically one successful migrant individual or gamete per year or less) (IUCN 2001)

Designatable Units

Manitoba Oakworm Moth has one designatable unit in Canada. No subspecies are recognized. The species occurs entirely within the Prairie National Ecological Area (COSEWIC 2007) and there is no information on population genetic structure among sites. There also are no data on discreteness or evolutionary significance among subpopulations.

If future genetic work suggests Manitoba Oakworm Moth is conspecific with Spiny Oakworm Moth, Manitoba subpopulations would likely represent a separate designatable unit from subpopulations in southern Ontario.

Special Significance

The global range of Manitoba Oakworm Moth may entirely be in Canada if the few subpopulations in the United States are extirpated (see Global Range).

The ecological role of Manitoba Oakworm Moth is poorly understood, but it may have a significant negative local impact on oaks during outbreaks (see Fluctuations and Trends). Manitoba Oakworm Moth may be of interest with respect to population dynamics of outbreaks, particularly for comparative studies with other congeners.

DISTRIBUTION

Global Range

The global range of Manitoba Oakworm Moth encompasses southern Manitoba and possibly adjacent areas of northwestern Minnesota (MN) and North Dakota (ND) (Figure 3). Most of the species' global range is in Canada.

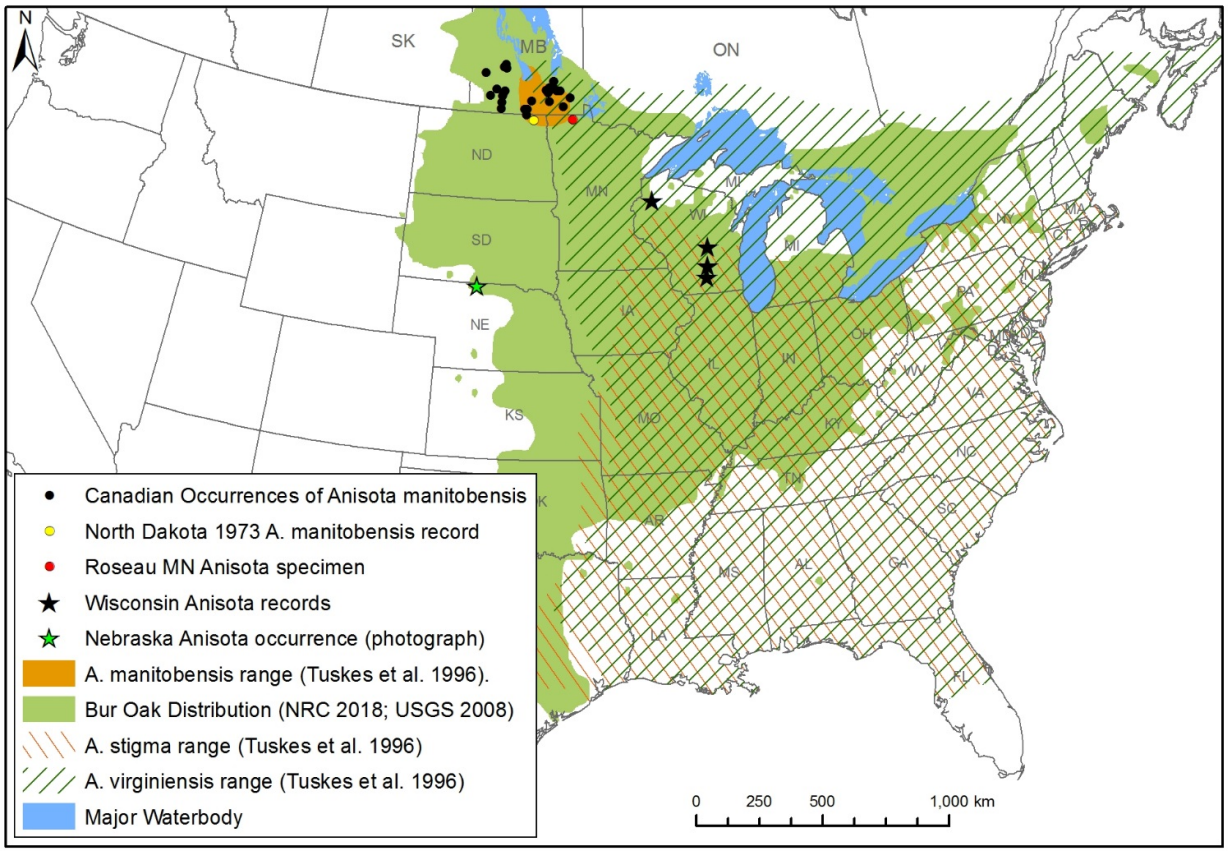

Figure 3. Known global range of Manitoba Oakworm Moth (*Anisota manitobensis*) in relation to those of Spiny Oakworm Moth (*A. stigma*) and Pink-striped Oakworm Moth (*A. virginiensis*).

There are few records from the United States portion of its global range. A single Manitoba Oakworm Moth was collected on May 17, 1973 in what is now the Tongue River Game Management Area, ND (McCabe pers. comm. 2018). Tuskes *et al*. (1996) reports a male *Anisota* collected near Roseau, MN housed at the University of Minnesota entomology collection, but no such specimen could be located (Thomson pers. comm. 2018). Potential habitat is found in the Turtle Mountains (ND) and along the Pembina River near Walhalla (ND) but the species has not been recorded in those areas (Ferguson 1971; Tuskes *et al*. 1996).

Anisota males from southeastern Wisconsin (Columbia, Dane, Wasburn, and Wauschara counties) were identified as Manitoba Oakworm Moth (Riotte and Peigler 1980) (Table 1). However, Tuskes *et al*. (1996) re-examined these specimens and concluded that all Wisconsin specimens were Spiny Oakworm Moth. Although the males looked like Manitoba Oakworm Moth, they were like atypical Spiny Oakworm Moths from New England that also have acutely angled wings (Tuskes *et al*. 1996). In addition, all the females were apparently Spiny Oakworm Moths.

A photograph of an oakworm taken at Smith Falls State Park (Keya Paha County) near Valentine, Nebraska on 15 July 2005 (BugGuide 2018) was originally identified as Spiny Oakworm Moth (and reported as such in Lotts and Naberhaus 2018). Although it has since been tentatively identified by R. Peigler as Manitoba Oakworm Moth, in the absence of a physical specimen, the identification is considered tentative. If indeed a Manitoba Oakworm Moth, it would represent a range extension of over 700 km from the nearest known record in Manitoba.

Table 1. Specimens and occurrences of Manitoba Oakworm Moth (*Anisota manitobensis*) in Canada and the United States.

Locality / Date	Life Stage[1]	#	Collector / Observer	Collection[2]	Reference[3]
Unknown					
1905-04-11	adult	1	H.J. Brodie	RSM	
1920-06-08	adult	2	?	RSM	
CANADA					
Anola					
1975-06-27[4]	adult	1	C.S. Quelche	unknown	Tuskes *et al*. (1996)
Aweme					
?	adult	1			
1904-06-23	**adul**t	1♀	N. Criddle	CNC	McDunnough (1921)
1907-06-29	adult	1	N. Criddle	CNC	McDunnough (1921)
1907-07-04	**adult**	2♂	N. Criddle	CNC	McDunnough (1921)
1912-08-??	larva	1	N. Criddle	CNC	McDunnough (1921)
1923-06-13	adult	1	N. Criddle	MMMN	R. Westwood
Birds Hill Park					
1963-07-20	adult	1		THM	Henne (2002)
1967-07-07	adult	2♂	J. Polusny	RBCM	
1967-07-14	adult	1♂	J. Polusny	RBCM	
Birds Hill Park – Pine Ridge					
?	adult	1	C.S. Quelch?	RSPC	Riotte & Peigler (1980)
1967-07-04	adult	2♂	C.S. Quelch	MNHN	
Brandon					
1899-07-05	adult	1	A. Hanham	RBCM	
1950-07-15	adult	1		JBWM	Henne (2002)
Carman					
1931-??-??	larva	lots	N. Criddle	unknown	Criddle (1932)

Locality / Date	Life Stage[1]	#	Collector / Observer	Collection[2]	Reference[3]
Darlingford					
1931-??-??	adult	1		NRC-FRS	
1952-06-06	adult	1♀, 1?		AMNH, CNC	
Fullers (3 sites)					
1996-08-20	larva	1♀,1♂	D.C. Henne	DCHC	Henne (2002)
1996-08-22	larva	1♀	D.C. Henne	DCHC	Henne (2002)
1997-06-??	larva	75♀♂	D.C. Henne	DCHC	Henne (2002)
Kelwood					
?	adult	1		CM	Riotte & Peigler (1980)
Killarney					
1947-07-10	adult	1♀	C.E. Brown	JBWM	
McCreary					
?	adult	1		RSPC	Riotte & Peigler (1980)
1961-06-16	adult	1♀		MNHN	
Middlechurch (West St. Paul)					
1954-07-01	adult	1♀	A.G. Ridley	JBWM	
Ninette					
1958-06-17	adult	1	R.L. Hurley	CNC	
Onah					
1931	larva	lots	N. Criddle	unknown	Criddle (1932)
Otterburne					
date unknown	pupa	1		ROM	
Pembina Valley[5]					
1952-1953	adult	32	MB Forest Insect Survey	CNC, ROM	
195?	larva	100+	Forest Insect Survey		McGugan 1958?
Pembina Valley Provincial Park[5]					
1953-04-14		1♀, 1?	?	CNC	
Pine Ridge (Birds Hill Park)					
1967-07-04	adult	2	C.S. Quelch	MNHN	
date unknown	adult	1	C.S. Quelch?	RSPC	Riotte & Peigler (1980)
Riding Mountain					
1936-06-19	adult	1♂	J.F. May		Ferguson (1971)
date unknown	adult	2		CM, USNM	Riotte & Peigler (1980)

Locality / Date	Life Stage[1]	#	Collector / Observer	Collection[2]	Reference[3]
Sandilands / Sandilands Provincial Forest[6]					
1971-06-10	adult	1♀,1♂	J. Polusny	RBCM	
1971-06-25	adult	1	J. Polusny?	C.S. Quelch field notes, THM	Henne (2002)
Shoal Lake					
1920-07-01	adult	1♂	G.S. Brooks	RSM	
Souris					
1954-06-08	adult	1	R.W. Hicks	JBWM	
Thornhill[5]					
1952-1953?	pupa	1	MB Forest Insect Survey	ROM	
Treesbank					
1931	larva	lots	N. Criddle	unknown	Criddle (1932)
Vivian					
1967-06-30	adult	1		C.S. Quelch field notes, THM	Henne (2002)
Winnipeg					
1898-06-24	adult	1♂	A. Hanham	RBCM	
1905-04-11	adult	2	H.J. Brodie	RSM	
1920-07-01	adult	1♂	?	JBWM	
1921-06-08	adult	1	?	RSM	
1928-06-08	adult	1	?	JBWM	
1928-06-27	adult	1	T. Short	MMMN	Brodie (1929)
1928-06-29	adult	3	H.J. Brodie	MMMN, USNM	Brodie (1929)
1928-07-19	larva	100+	H.J. Brodie	unknown	Brodie (1929)
1930-06-??	adult	19♀♂	H.J. Brodie	CNC, MMMN, RSM	
1931-??-??	adult	1♀	H.J. Brodie	AMNH	
1948-06-23	adult	1	A.V. Mitchener	RSM	
1949-07-05	adult	1♂	?	JBWM	Henne (2002)
1950-07-10	adult	1	?	THM	Henne (2002)
1954-06-26	adult	1	?	THM	Henne (2002)
1954-07-02	adult	1	?	THM	Henne (2002)
1955-07-14	adult	1	?	THM	Henne (2002)
date unknown	adult	1	?	MMMN	Westwood (pers. comm. 2018)
date unknown	adult	1	A.V. Mitchener	RSM	
date unknown	adult	1♀,1?	McConnell	RSM	
Winnipeg (Deer Lodge)					
1948-06-22	adult	1	?	CNC	

Locality / Date	Life Stage[1]	#	Collector / Observer	Collection[2]	Reference[3]
Winnipeg (Elm Park)					
1920-08-00	adult	1	?	MMMN	
Winnipeg (Manitoba Agricultural College)					
1920-07-??	adult	1♂		JBWM	
1921-06-08	adult	5♀♂	N. Pankiw	AMNH, CNC, JBWM	
1921-06-10	adult	1♂	N. Pankiw	JBWM	
1921-06-16	adult	1♂,1?	N. Pankiw	CNC, JBWM	
1930-07-03	adult	1	W.A. Cumming	JBWM	
1948-06-22	adult	1	G.L. Warren	JBWM	
1949-06-08	adult	1	P. Bergen	JBWM	
Winnipeg (St. Vital)					
1921-06-??	adult	3	?	MMMN	Westwood (pers. comm. 2018)
1921-06-20	adult	1♂	N. Pankiw	MMMN	
1921-06-8 to 20	adult	1	N. Pankiw	CNC	
1922-06-??	adult	4	?	MMMN	Westwood (pers. comm. 2018)
2000-07-05	adult	1♂	A.R. Westwood	RAWC	Westwood (pers. comm. 2018)
2000-07-10	adult	1♂	A.R. Westwood	RAWC	Westwood (pers. comm. 2018)
Winnipeg (Transcona)					
1950-07-03	adult	1♂	C.S. Quelch	MNHN	
1954-06-26	adult	2♂,1?	C.S. Quelch	MNHN, PMNH, RBCM	
1954-07-02	adult	1♀	C.S. Quelch	PMNH	
1963-07-20	adult	1♀	C.S. Quelch	MNHN	
UNITED STATES					
Roseau, Roseau County, MN (no specimen, unconfirmed)					
unknown	adult	1♂	?	UMSP[7]	Tuskes *et al*. (1996)
Smith Falls State Park, Keya Peha County, NE (based on tentative identification)					
2005-07-17	adult	1♂	L. & B. Padelford	unknown	BugGuide (2018)
Tongue River Game Management Area, ND					
1973-05-17	adult	?	T. McCabe	TMCC[2]	McCabe pers. comm. 2018
Arlington, Columbia County, WI (misidentified Spiny Oakworm Moth according to Tuskes *et al*. 1996)					
1957-07-21	adult	1♂	J. Apple	ROM	Riotte & Peigler (1980)
Madison, Dane County, WI (misidentified Spiny Oakworm Moth according to Tuskes *et al*. 1996)					
unknown	adult	1	W.E. Sieker?	WESC	Riotte & Peigler (1980)

Locality / Date	Life Stage[1]	#	Collector / Observer	Collection[2]	Reference[3]
Washburn County, WI (misidentified Spiny Oakworm Moth according to Tuskes *et al*. 1996)					
1952-06-24	adult	2♂	R.H. Jones	NESM	
Wauschara County, WI (misidentified Spiny Oakworm Moth according to Tuskes *et al*. 1996)					
1936-03-07	adult	1			Riotte & Peigler (1980)
1936-07-10	adult	1			Riotte & Peigler (1980)

[1] bolded adult are type specimens; dates from adults outside of June-August are assumed to be captive-reared

[2] see *Collections Examined*; DCHC, RAWC, RSPC, TMCC, and WESC are the personal collections of D.C. Henne, R.A. Westwood, R.S. Peigler, and T. McCabe, and W.E. Sieker respectively; THM=Transcona Heritage Museum

[3] if no reference lists, information was provided by collection managers (see *Collections Examined* for contact details)

[4] reported as 1976-06-26 in Henne (2002)

[5] due to lack of original site details, it is unknown if Pembina Valley, Pembina Valley Provincial Park, and Thornhill are the same or separate sites

[6] it is unknown if the Sandilands and the Sandilands Provincial Forest collections are from the same site. The community of Sandilands and the Sandilands P.F. Discovery Centre are mapped.

[7] this specimen could not be located at University of Minnesota – St. Paul (Thomson pers. comm. 2018).

Canadian Range

In Canada, Manitoba Oakworm Moth occurs in southern Manitoba. The boundary of its known range is McCreary (northernmost), Sandilands Provincial Forest (PF) (easternmost), Pembina Valley (southernmost) and Shoal Lake (westernmost). The species is recorded from approximately 25 collection sites, which likely represent 20 - 25 subpopulations[4] (Table 1, Figure 4). Manitoba Oakworm Moth adults are not likely to disperse over long distances: females have limited energy reserves (i.e., adults do not feed) and encumbered flight from egg weight.

For most of these collection sites, there is no detailed locality information available that would allow the exact capture site to be determined. Coarse mapping by McGugan (1958) shows 1948-1953 larval collection records localized to the Red River Valley (Figure 5). The site depicted north of Lake Winnipeg in the map presented in the Moth Photographers Group (2018) website represents a generalized provincial centroid rather than a record from northern Manitoba.

[4] A subpopulation is defined as geographically or otherwise distinct groups in the population between which there is little demographic or genetic exchange (typically one successful migrant individual or gamete per year or less). Subpopulation size is measured as numbers of mature individuals only (IUCN 2001). The subpopulation definition corresponds reasonably well to the habitat based general element occurrence delimitation standards (NatureServe 2004) where a subpopulation is defined as a group of occurrences that are separated by less than 1 km; or if separated by 1 to 3 km, with no break in suitable habitat between them exceeding 1 km.

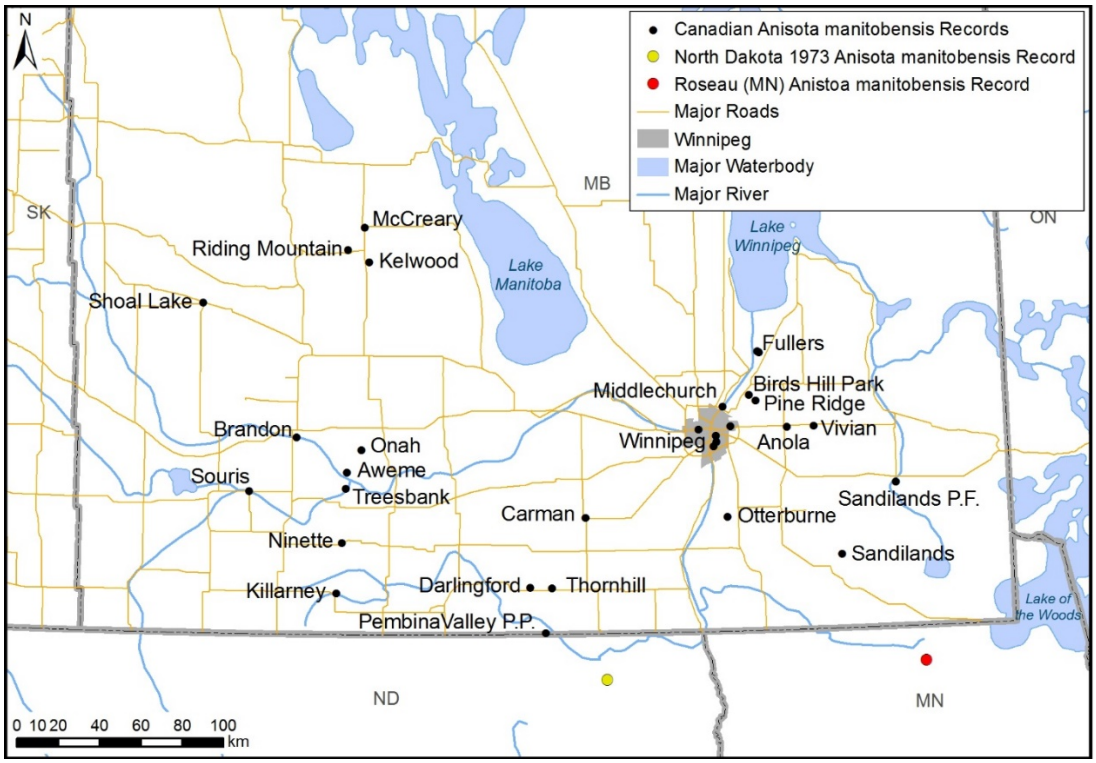

Figure 4. Canadian records of Manitoba Oakworm Moth (*Anisota manitobensis*). Winnipeg also includes those within current city limits, i.e., Deer Lodge, Elm Park, Manitoba Agricultural College (M.A.C.), St. Vital, and Transcona. It is unknown if the Sandilands and the Sandilands Provincial Forest collections are from the same site; both the community of Sandilands and the Sandilands P.F. Discovery Centre are shown on the map.

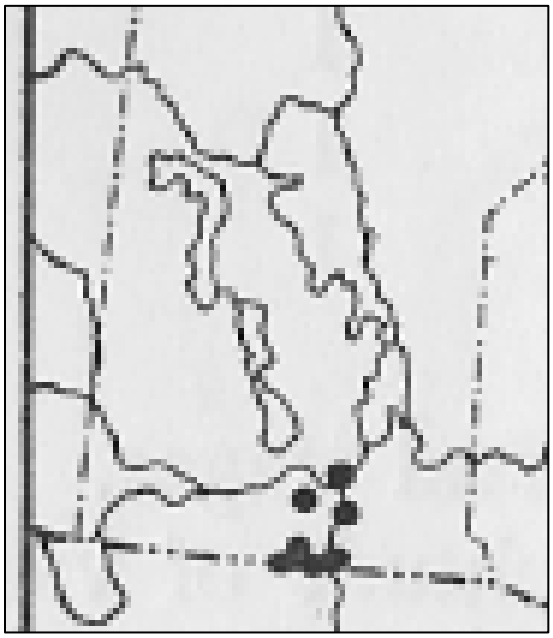

Figure 5. Collection points for Manitoba Oakworm Moth in Manitoba, 1948-1953 (modified from McGugan 1958.

Extent of Occurrence and Area of Occupancy

The maximum extent of occurrence (EOO) in Canada is 43,000 km^2 based on a minimum convex polygon of known records. Manitoba Oakworm Moth does not occupy all habitats included in this spatial calculation (e.g., where its host plant does not occur). The index of area of occupancy (IAO) (2 km x 2 km grid) is 120 km^2 (30 grid squares) based on all known records. If records from only the past 50 years (threshold to assume localities are likely extirpated[5]) are considered (Fullers [1996 and 1997]; Winnipeg [2000], Sandilands provincial forest [1971] and Anola [1975]) the IAO is 16 km^2.

Search Effort

Manitoba Oakworm Moth was first recorded in Canada in 1898 and the most recent records are from 2000 (Table 1). There are more than 450 museum specimen and sight records of the moth collected from numerous geographic areas in Manitoba (Table 1). Most specimen records are of one or two individuals.

Based on museum specimens and reports in published and grey literature (Table 1), search effort for Manitoba Oakworm Moth appears to have been sporadic since its original record in Canada in 1898. There are published sight records of larvae from six sites and approximately 140 museum specimens (including immature stages). These records represent field observations from approximately 60 separate dates, the majority (85%) of them prior to 1970 (Figure 6). Despite being an attractive and mainly diurnal moth, as of August 2019 there are no Canadian records from naturalists or other amateur entomologists on iNaturalist, BugGuide, Moth Photographers Group or similar websites. Manitoba Oakworm Moth is a difficult species to locate in the field except during an outbreak (Henne 2002). Manitoba Oakworm Moths do not feed as adults; they are not attracted to nectar sources so cannot be netted on flowers during the day, nor are they caught with baits at night.

Light-traps are often used to survey moths but most black-lighting for Manitoba Oakworm Moth has been unsuccessful (Table 2). In general, male silk moths are much more frequently taken at lights than females,[6] but male Manitoba Oakworm Moths are typically diurnal, making light-trapping ineffective. Spiny Oakworm Moths have been caught in ultraviolet light traps with a male bias (Garris and Snyder 2010); however, males of this species are predominantly nocturnal (Tuskes *et al*. 1996). Pink-striped Oakworm Moths have occasionally been light-trapped (Thomas 1996). The two most recent (July 2000) observations of Manitoba Oakworm Moth were two males caught in light traps in St. Vital Park, Winnipeg (Westwood pers. comm. 2018). Captive Manitoba Oakworm Moth females emitted pheromones in early morning but, if unsuccessful, also “called” after dark (see Biology). Male responses to female behaviours may allow them to be susceptible to light-trapping on occasion.

[5] COSEWIC Guidelines for use of Extinct or Extirpated: A wildlife species may be assessed as extinct or extirpated from Canada if: 1) there exists no remaining habitat for the wildlife species and there have been no records of the wildlife species despite recent surveys; or 50 years have passed since the last credible record of the wildlife species, despite surveys in the interim; or there is sufficient information to document that no individuals of the wildlife species remain alive.

[6] likely because egg-laden females are less vagile

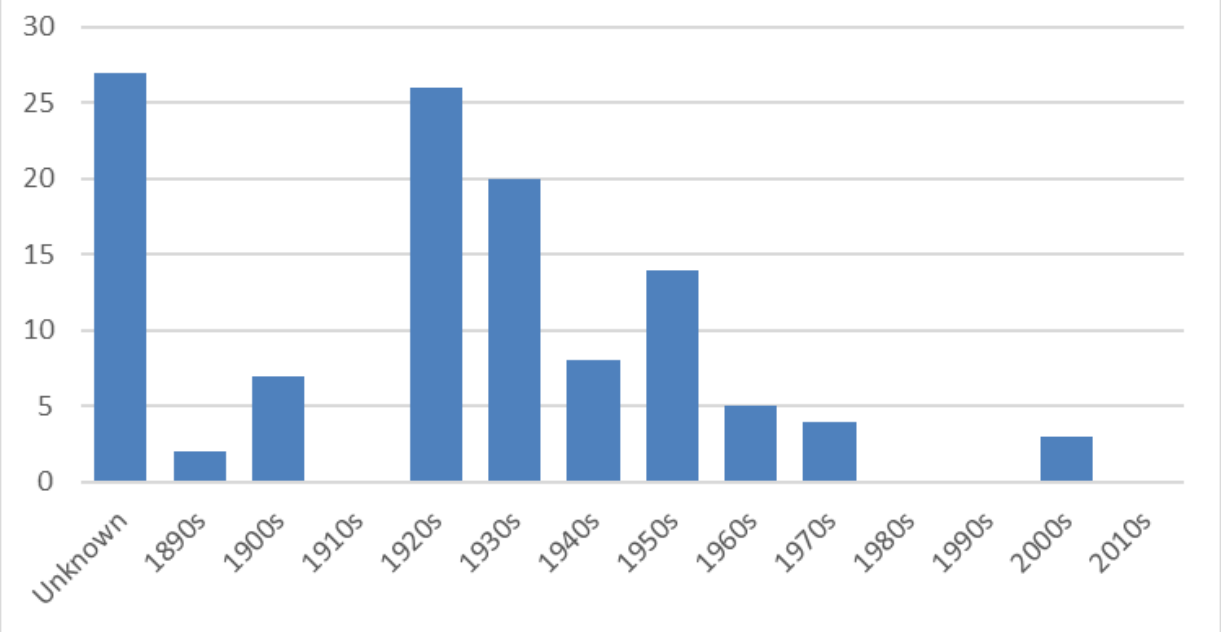

Figure 6. Canadian adult Manitoba Oakworm Moth specimens by decade.

Table 2. Summary of post-1950 search effort for Manitoba Oakworm Moth in Canada.[1]

Observer	Date	Methods	Location	Source
Canadian Forest Service	late 1940s to mid-1960s	larval searches and beating as part of broader forest pest surveys (not always targeted)	Manitoba	Brown (1952); Elliot (1964); Hildahl *et al*. (1966); McGugan (1958)
C.S. Quelch	1950s-1970s	unknown	Winnipeg area	specimens
J. Polusny	1967-1971	unknown	Winnipeg area & Sandilands	specimens
P.M. Tuskes	1970s	larval searches, UV lights, caged virgin ♀ *A. stigma*	east of Winnipeg, including some known historical sites	Tuskes *et al*. (1996)
A.R. Westwood	1980s-present	larval searches, UV lights (non-targeted)	southern Manitoba	Westwood (pers. comm. 2018)
J. Tuttle	late 1980s	black-lights	southern Manitoba	Henne (pers. comm. 2018)
D.C. Henne	1989-1995 (annually)	larval searches, black-lights	many of the historical sites, as well as new ones, often repeat visits	Henne 2002
D.C. Henne	1996-1997	larval searches	Fullers area	Henne 2002
D.C. Henne	1996	caged virgin ♀ *A. stigma*	Winnipeg area	Henne (2002, pers. comm. 2018)
D.C. Henne	2014	larval searches	Fullers area	Henne (pers. comm. 2018)
K. Johnson	2017 (Aug 14)	UV and MV lights (not targeted)	Shilo Dunes	Johnson (2017)

Observer	Date	Methods	Location	Source
D.C. Henne	2018 (Aug 7-12)	larval searches	16 historical and new sites in southern Manitoba and NW Ontario	Henne (pers. comm. 2018)
R.F. Foster	2018 (Jul 29 - Aug 5)	larval searches	23 historical and new sites in southern Manitoba	
D.C. Henne	2019 (July-August	larval searches (40+ hours)	near Belair, Neepawa, Fullers, and other areas in southern Manitoba	Henne (pers. comm. 2019)

[1] Targeted search for Manitoba Oakworm Moth unless otherwise indicated (non-targeted surveys may not have been at appropriate time of year or habitat); successful searches are shaded grey

Trials with calling (i.e., emitting pheromones) females are the most effective way to obtain hard-to-get saturniid species (Tuskes *et al*. 1996). The males of some silk moth genera will respond to the female of any species if she is available at the proper time of day and right time of year (Tuskes *et al*. 1996). Past attempts to use caged virgin females of the closely related Spiny Oakworm Moth[7] to attract male Manitoba Oakworm Moth have proven unsuccessful (Henne 2002; Tuskes *et al*. 1996). It is not known if the lack of success was because the Spiny Oakworm Moth females were not attractive to Manitoba Oakworm Moth males, or if there were no males in the area during the trial.

Larval feeding damage is perhaps the easiest way to locate this species in the field. Late oakworm (*Anisota* spp.) instars may consume the entire leaf except for the midvein and if present are readily observed on their defoliated hosts (Henne 2004 pers. comm. 2018; Tuskes *et al*. 1996). Some notodontids (*Datana* spp.) also have this distinctive feeding behaviour (Riotte and Peigler 1981) and feeding damage from Manitoba Oakworm Moth can be confused with that of the gregarious Yellow-necked Caterpillar Moth (*D. ministra*) that also occurs on oak in Manitoba (Henne 2002). Feeding damage observed by Foster and Henne in 2018 (see below) was ascribed to the latter due to more recent observations of that species in the area.

Field surveys were undertaken in 2018 during the preparation of this status report and targeted 23 historical and potential sites (Figure 7). A total of 14 hours (not including travel time) of larval surveys were conducted from July 29 to August 5, 2018, but no larvae or extensive defoliation of oaks were observed (Foster pers. comm. 2019). Fourteen hours of surveys from August 7-12, 2018 were also completed at 16 additional sites in southeastern Manitoba and northwestern Ontario (Figure 7) (Henne pers. comm. 2018) although no Manitoba Oakworm larvae were recorded.

In August 2019, over 40 hours of targeted surveys for Manitoba Oakworm Moth were completed in July-August 2019 near Neepawa, Belair, Fullers, and other areas in southern Manitoba, examining over 50,000 oak trees for feeding damage and larvae (Henne pers. comm. 2019). No specimens or feeding damage were recorded.

[7] Manitoba Oakworm Moth females being unavailable

No targeted surveys have been undertaken in North Dakota or Minnesota. It has not been observed in North Dakota by G. Fauske (Fauske pers. comm. 2018) nor in Minnesota by K. Johnson (Johnson pers. comm. 2018), both active lepidopterists within these regions.

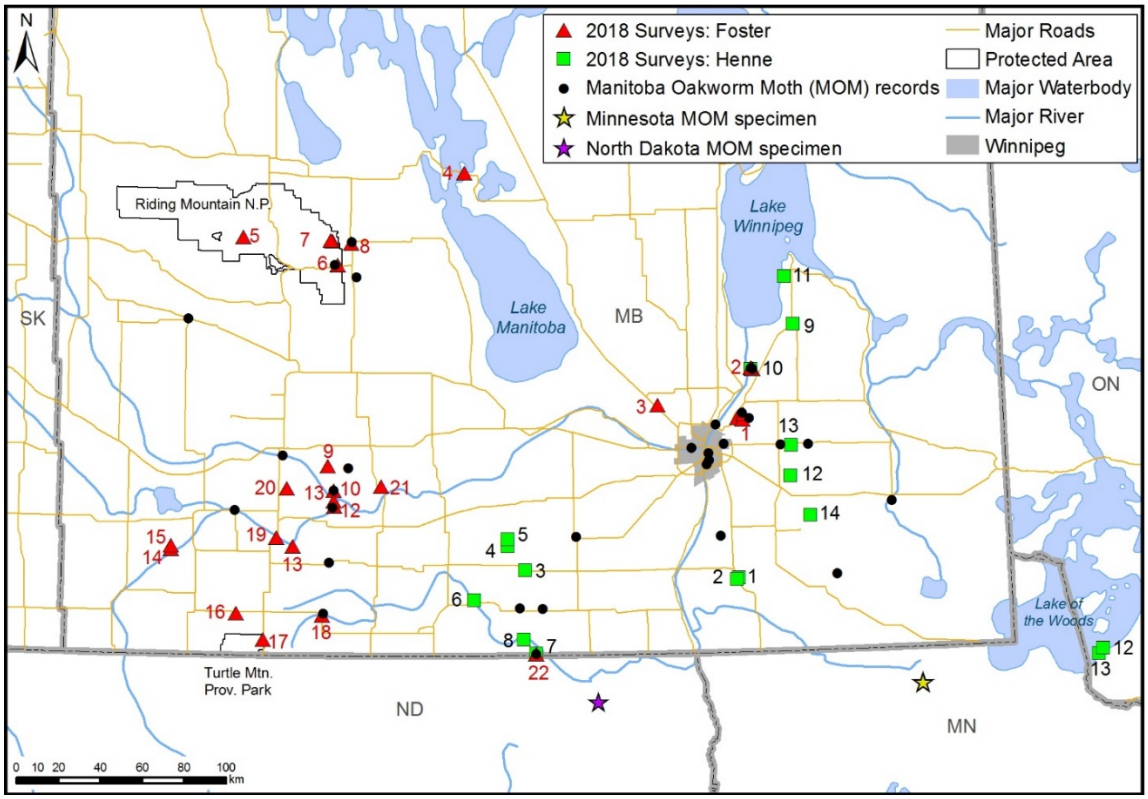

Figure 7. Survey effort for Manitoba Oakworm Moth by R. Foster and D. Henne in 2018.

HABITAT

Habitat Requirements

Manitoba Oakworm Moth requires habitat with its larval host plant, Bur Oak (*Quercus macrocarpa*).[8] Manitoba Oakworm Moth is absent (or at least unknown) from much of the Bur Oak's range, including Saskatchewan, northern Manitoba, and northwestern Ontario (Figure 3), suggesting other factors limit the species' distribution.

[8] Bur Oak is the only native oak species in Manitoba

In Manitoba, Bur Oak is found in a range of vegetation communities from riverbottom forest to drier oak savannah and alvar. On riverbottom terraces, Bur Oak is typically associated with Green Ash (*Fraxinus pennsylvanica*) and Manitoba Maple (*Acer negundo*) (Marr *et al*. 1995) and is classified as *V3: Miscellaneous Hardwoods* of Manitoba's Forest Ecosystem Classification (Zoladeski *et al*. 1995). The understory often has a tall shrub layer of Green Ash, Manitoba Maple, Basswood (*Tilia americana*), or American Elm (*Ulmus americana*); Poison Ivy (*Rhus radicans*), Western Snowberry (*Symphoricarpus occidentalis*), Chokecherry (*Prunus virginiana*), Saskatoon (*Amelanchier*), and various forbs are also common (Foster pers. obs.; Marr *et al*. 1995).

In forests of the Aspen Parkland of southwestern Manitoba, Bur Oak is typically subdominant to Trembling Aspen (*Populus tremuloides*) and often occurs as pockets along river valleys and in areas of higher elevation such as the Brandon Hills, Turtle Mountains, and Pembina Hills (Pyle *et al*. 2018). Extensive oak stands are found along the eastern edge of Riding Mountain National Park on excessively drained gravelly outwash plains at the base of the Manitoba Escarpment (Caners and Kenkel 2003); Manitoba Oakworm Moth have been collected in this area. Beaked Hazel (*Corylus cornuta*) was often a dominant understory shrub in these communities, with Poison Ivy, Saskatoon, Bush Honeysuckle (*Diervilla lonicera*), Downy Arrowwood (*Viburnum rafinesquianum*), and Spreading Dogbane (*Apocynum androsaemifolium*) also common (Foster pers. obs.). In southeastern Manitoba, Basswood is a typical associate of Bur Oak (Anderson *et al*. 2009). In the Interlake Region between Lake Winnipeg and Lake Manitoba, the Alvar Savannah – Oak Savannah Subtype has widely scattered, mature Bur Oak (Manitoba Alvar Initiative 2012) that could potentially provide suitable habitat for Manitoba Oakworm Moth.

Details regarding the age or sizes of oaks at most historical Manitoba Oakworm Moth sites are unknown. In 1996, fifth instar larvae were observed on two young (75 and 150-180 cm tall) Bur Oak trees in semi-open areas near Fullers, MB (Henne pers. comm. 2002) (Figure 8). Both oaks were at least 150 cm from other trees, had low surrounding vegetation, and were in full sun. The following year, Henne found 75 2nd instar larvae on a west-facing, terminal oak leaf 30 cm above the ground in full sunlight along the forest-field interface. Brodie (1929) reported an observation by T. Short of oviposition on an oak branch 1½ feet (45 cm) from the ground, which was presumably on a small oak since mature oaks self-prune and typically lack branches at that height (Foster pers. obs.). Based on these observations, Henne (2002) speculated that Manitoba Oakworm Moth may prefer younger, smaller oaks. However, this may also partly reflect sampling bias in terms of visibility and ease of access. Recent (2000) observations of Manitoba Oakworm Moth in the St. Vital area of Winnipeg (Table 1) were apparently along the Assiniboine River in more mesic conditions with mature trees (Westwood pers. comm. 2018). Forest pest surveys in the 1950s (e.g., McGugan 1958) presumably were of mature trees.

Figure 8. Manitoba Oakworm Moth larval habitat near Fullers, MB (R. Foster photo).

Habitat Trends

Suitable habitat for Manitoba Oakworm Moth is less abundant today than it was in the past. Before European settlement, much of the natural vegetation throughout much of southern Manitoba was forested river valleys shifting to prairie further away as moisture became less available (Hanuta 2006; Catton *et al* 2007). Throughout the early and mid-1800s, much of this forest was cut by settlers for firewood and building materials and by the mid-1800s the Red River settlement (i.e., Winnipeg) was largely denuded of trees (St. George and Nielsen 2002; Catton *et al*. 2007). The largely treeless landscape near the Manitoba Agricultural College (circa 1925) is near where Manitoba Oakworm Moth was collected in 1921 (see Figure 9). Similar but less pronounced effects likely occurred elsewhere along the Red and Assiniboine river valleys, as well as other river valleys and areas suitable for settlement. Using Dominion Land Survey records and other data for 170 townships in southern Manitoba (16,500 km^2), Hanuta (2006) documented a decline in wooded area from approximately 35% in the 1870s to 9% at the date of publication (2006).

Figure 9. Manitoba Agricultural College (red arrow) circa 1925 near where Manitoba Oakworm Moth was collected in 1921. Gordon Goldsborough photo (Manitoba Historical Society 2019).

Oak forests in the Red River settlement recovered in the mid- to late 1800s as young oaks germinated, eventually giving rise to many of the mature trees now found in urban Winnipeg (Catton *et al*. 2007). However, rapid post-World War Two human population growth resulted in extensive residential and commercial expansion in Winnipeg. Photographs of the landscape near the Manitoba Agricultural College (a historical Manitoba Oakworm Moth site) in 1942 and approximately 60 years later show this development (see Figures 10 and 11). Several sites where Manitoba Oakworm Moth were historically collected (e.g., St. Vital, Elm Park; Table 1) formerly had large areas with Bur Oak that have now been largely lost to development (Westwood pers. comm. 2018).

Within the Winnipeg city limits, approximately 416 ha of Bur Oak forest remains concentrated along the Red, Assiniboine, and Seine rivers (Figure 12). A total of 17,239 Bur Oak trees are registered and tracked in the City of Winnipeg's tree inventory (Urban Forestry Branch, unpublished data), of which 22% are found in mapped oak forest. Winnipeg also has about 860 ha of mapped aspen-dominated forest that have some Bur Oak; these forests only contain about 1.4% (n=242) of the Bur Oak trees in the City of Winnipeg's tree inventory. The remaining Bur Oaks in the inventory occur as lone trees or patches too small to map as forest polygons (i.e., < 5 m^2).

Despite historical losses, there remains relatively abundant oak-dominated habitat scattered across much of southern Manitoba, including the type locality near Treesbank. Potentially suitable oak habitat was mapped using forest resource inventory (FRI) data[9] available from Manitoba Sustainable Development (2018). Oak-dominated polygons (i.e., Working Group 96) encompass about 930 km^2 and are found across southern Manitoba, with concentrations along major river valleys and the Manitoba Escarpment (Figure 13**)**. This is only a rough estimate of potentially available habitat, as it includes mature oaks in dense forest habitat that may be less suitable while missing small patches of scrubby oak habitat that may be preferred by Manitoba Oakworm Moth. Clearing of oaks for agriculture and development has fragmented Manitoba Oakworm Moth habitat at some historical collecting localities (Henne 2002). However, much of the remaining oak habitat is connected along river valleys and may not be isolated depending on the dispersal abilities of adult Manitoba Oakworm Moths (see **Dispersal and Migration**). Throughout the range of Bur Oak, there are numerous diseases and insect pests which cumulatively impact oak health, longevity and ultimately affect the habitat quality available for Manitoba Oakworm Moth (discussed in **Threat 7.3 Other ecosystem modifications**).

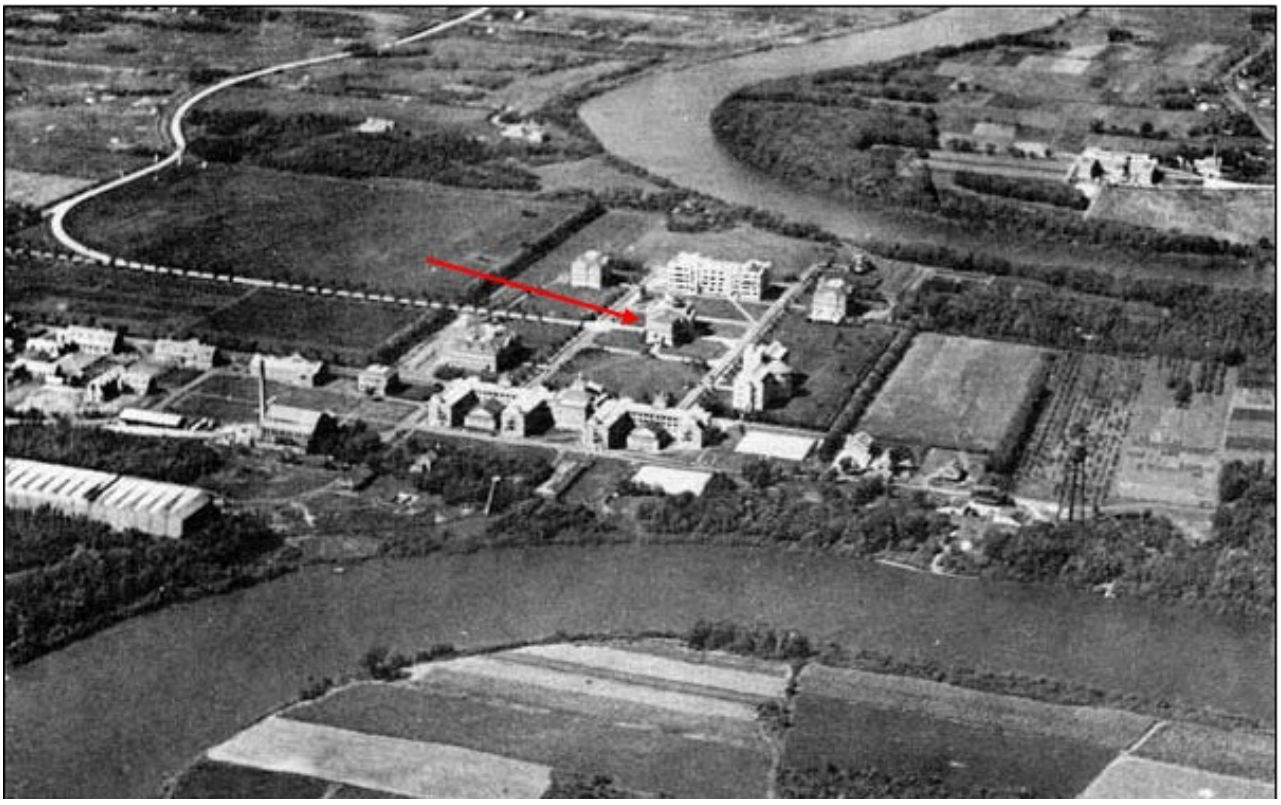

Figure 10. Aerial view of the Manitoba Agricultural College (red arrow) on the University of Manitoba grounds circa 1942. Gordon Goldsborough photo (Manitoba Historical Society 2019).

[9] The FRI polygons were originally interpreted from 1:15:840 aerial photography

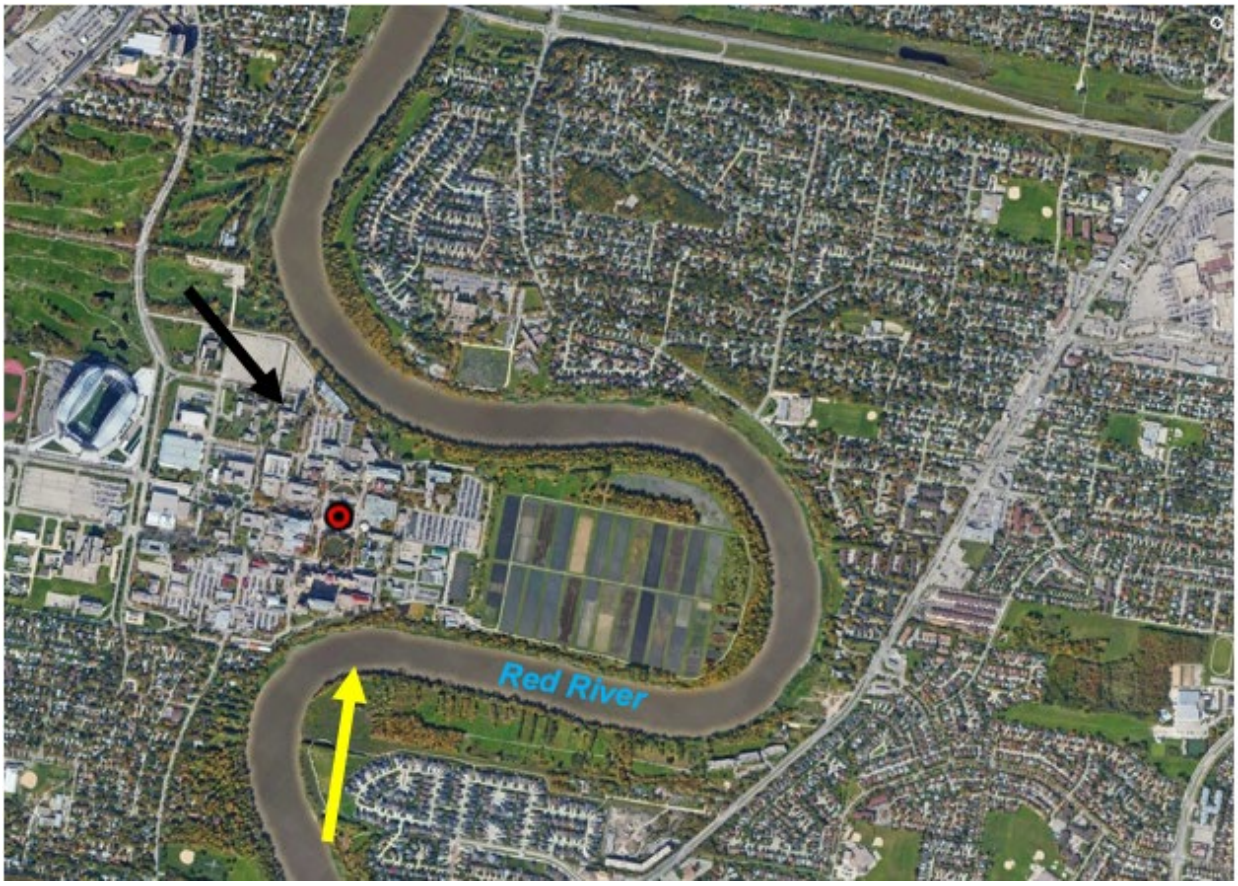

Figure 11. 2002 GoogleEarth imagery of the landscape around the Manitoba Agricultural College (red symbol) in Winnipeg. Black and yellow arrows denote the approximate directions in which the photos in Figure 9 and Figure 10 were taken respectively.

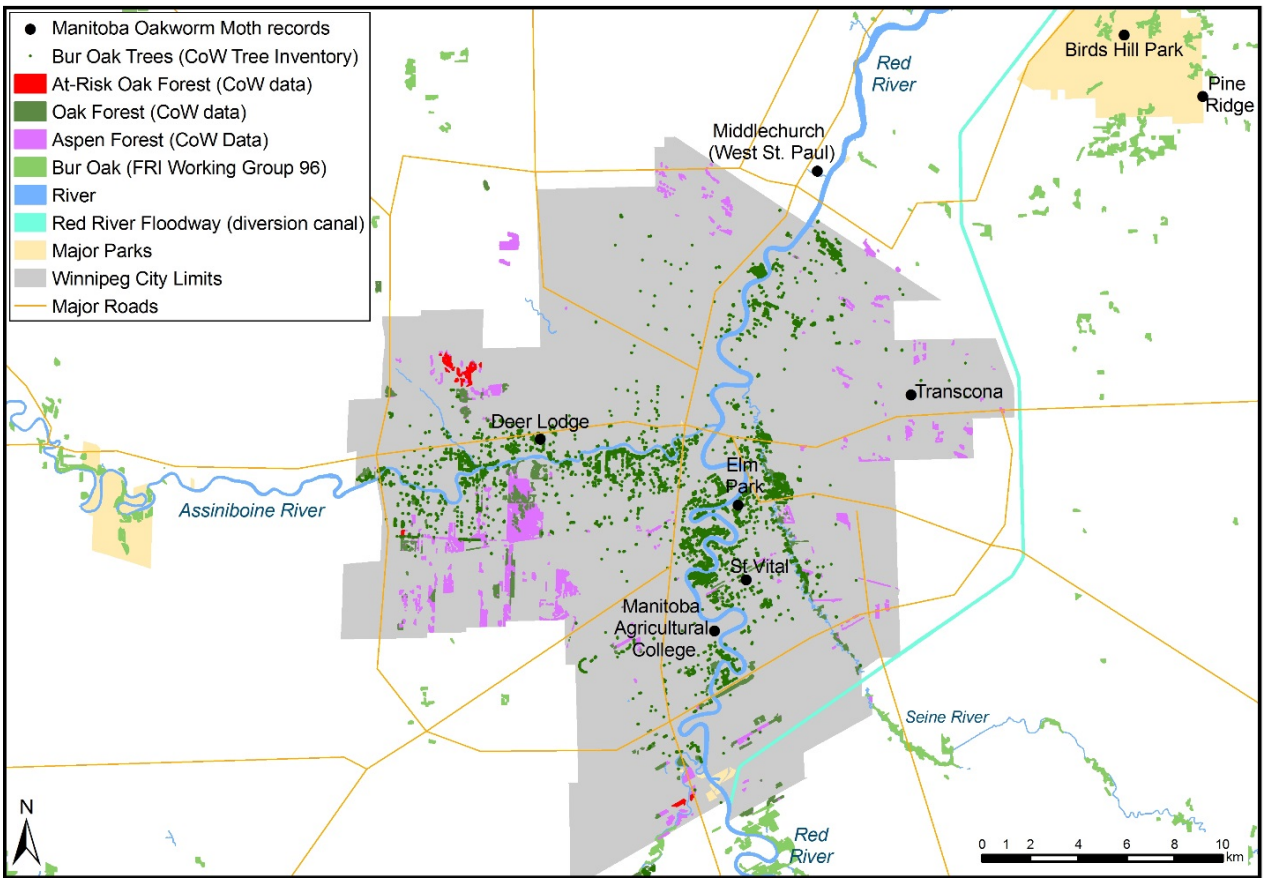

Figure 12. City of Winnipeg (CoW) Bur Oak habitat in relation to known Manitoba Oakworm Moth sites.

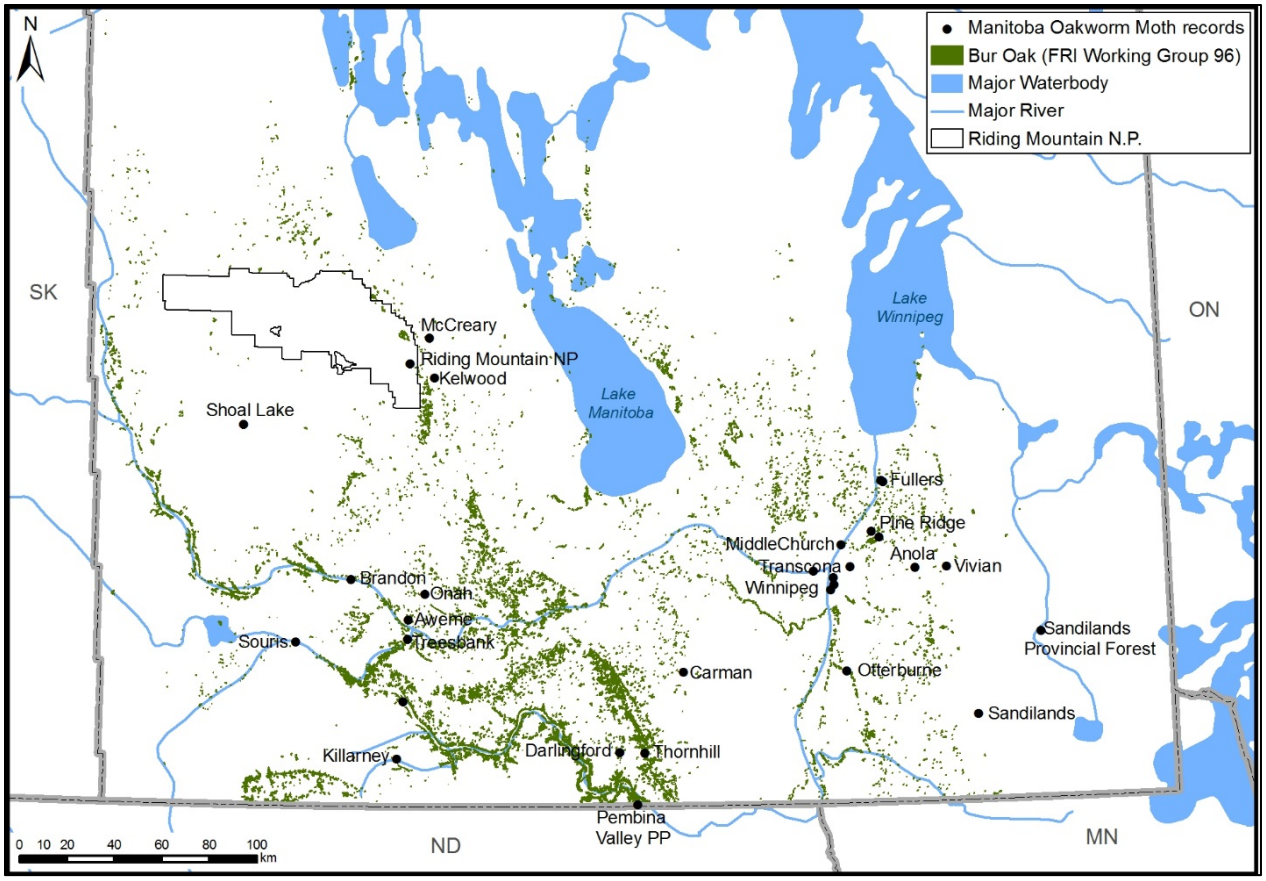

Figure 13. Oak-dominated habitat in Manitoba that is potentially suitable for Manitoba Oakworm Moth. See Figure 12 for Winnipeg detail.

BIOLOGY

The biology of Manitoba Oakworm Moths is poorly known. Information below is summarized from field observations (e.g., Brodie 1929; Henne 2002) and general information on silk moths.

Life Cycle and Reproduction

Manitoba Oakworm Moth has a one-year life cycle with four life stages (see **Morphological Description**) that develop through complete metamorphosis. There are minimal field observations of Manitoba Oakworm Moth at any life stage and much of the life cycle information has been gained through captive-bred observations (e.g., Brodie 1929; Henne 2002). Wild adults have been collected from June 2 to July 21 in Canada (Table 1). There are some specimens in museum collections from April or earlier, but these are presumably captive-reared. Adult Manitoba Oakworm Moths live only a few days, since they lack functional mouthparts and do not feed as adults. Therefore, the flight period represents the sequential presence of multiple Manitoba Oakworm Moths, rather than the persistence of individual moths.

Mating occurs in June and July shortly after emergence. Wild observations are lacking, but Henne (2002) describes the following behaviour in captive-reared adults. Adults emerged around 0600 and females immediately began calling. This occurred often within 30 minutes of emergence and as soon as their wings were fully expanded. Most females mated in the early morning (i.e., 0630 to 0900 CDT) and remained *in copula* until dusk, at which time females would begin ovipositing. Copulation ranged from one to several hours. If unmated during the morning, females would exhibit a second calling period during the night (0100 to 0300). Some adults delayed emergence until shortly after sunset (i.e., 2100 to 2200). This emergence and mating behaviour are like Spiny Oakworm Moth (see Tuskes *et al*. 1996).

Oviposition observations in the wild are limited; although based on a few observations, larvae are thought to be present from mid-July to late August. On 12 June 1928, a female was observed ovipositing on a low-lying oak branch in full sun at 16:00 (Brodie 1929). These eggs hatched out (in captivity) on July 10. A cluster of 16 Manitoba Oakworm Moth eggs was observed August 20, 1996 at the tip of an oak leaf at the end of a branch on a small Bur Oak (150-180 cm tall) (Henne 2002). The eggs were approximately 45 cm above ground level and facing south; twelve had hatched (four were dead) and two late fifth-instar larvae were observed on the same oak. A single captive female laid 185 eggs over a three-day period (Henne 2002).

Upon hatching, Manitoba Oakworm Moth larvae begin feeding upon the leaves of their host plant, Bur Oak (Henne 2002). There are also some old reports of Manitoba Oakworm Moths also feeding on hazel (*Corylus* sp.) (McGugan *et al* 1958), but that may only occur during outbreaks when nearby food plants are limited. Covell (1984) also lists Bur Oak and “hazelnut trees” as host plants. Larvae moult as they grow, passing through five instars. Second instar larvae have been seen in June and fifth instar larvae have been observed August 20 – 22 (Henne 2002). Early instar larvae are gregarious (Henne 2002) and Brodie (1929) observed “a cluster of over one hundred larvae of this species on a young oak by the river bank on July 19, 1928”. McGugan (1958) called Manitoba Oakworm Moth a “solitary defoliator” but this was likely based on observations of later instars, which abandon the gregarious feeding strategy (Tuskes *et al*. 1996). McGugan (1958) reports that larvae can be observed until late September, but more typically until late August. Manitoba Oakworm Moth overwinters as a pupa in a loosely constructed subterranean cell (Tuskes *et al*. 1996).

Physiology and Adaptability

No data on the specific physiology and adaptability of Manitoba Oakworm Moth has been reported. It appears to have only one main host plant (Bur Oak).

Dispersal and Migration

Little is known about the dispersal ability of Manitoba Oakworm Moth. Males fly well (Henne pers. comm. 2018) but females are poor fliers (Riotte and Peigler 1981). Like all silk moths, Manitoba Oakworm Moth adults live only a few days before they reproduce and die, and egg-laden females do not disperse far due to their heavy weight (Tuskes *et al*. 1996). Dispersal corridors along waterways connecting metapopulations may be critical for overall population viability of this species. Manitoba Oakworm Moths do not migrate.

Manitoba Oakworm Moth may meet the definition of severely fragmented[10]. Historically, Bur Oak habitats were more connected and widespread, but present-day ecosystems are isolated and fragmented; this combined with poor dispersal ability of moth and a low number of separate and isolated extant subpopulations, especially across unsuitable habitat between Bur Oak populations, may effectively fragment populations.

Interspecific Interactions

No known parasitoids for Manitoba Oakworm Moth are listed in Tuskes *et al*. (1996) or Peigler (1994), but closely related Spiny Oakworm Moths have chalcid, braconid, and ichneumonid parasitoids (Hymenoptera). Several species of tachinid (Diptera) parasitoids have been reported from Pink-striped Oakworm Moth larvae or pupae in Manitoba including *Houghia sternalis*, *Lepesia anisotae*, and particularly *Winthemia datanae*, as well as the ichneumonids *Habronyx magniceps* and *Hyposoter fugitivus* (Henne 2004). The non-native tachinid *C. concinnata* is known to parasitize *Anisota* spp. (Arnaud 1978) but is not known from southern Manitoba (see Table 3).

Like most Lepidoptera, Manitoba Oakworm Moth is likely subject to predation by a range of vertebrates and invertebrates.

Numerous other Lepidoptera such as the Pink-striped Oakworm (Henne 2004), Yellow-necked Caterpillar Moth (*Datana ministra*) (Henne 2002) and Polyphemus Moth (*Antheraea polyphemus*) (Foster pers. obs.) also feed on Bur Oak in Manitoba and are potential competitors. There is no evidence, however, that they have populations large enough to limit host plant availability to Manitoba Oakworm Moths; competition would likely be limited to individual trees or at most a small stand. Within the city of Winnipeg, there have been increases in Two-lined Chestnut Borer, *Agrilus bilineatus* (Coleoptera: Buprestidae), which is contributing to the decline in Bur Oak health (Barwinsky pers. comm. 2019).

[10] "A taxon can be considered to be severely fragmented if most (>50%) of its total area of occupancy is in habitat patches that are (1) smaller than would be required to support a viable population, and (2) separated from other habitat patches by a large distance. Fragmentation must be assessed at a scale that is appropriate to biological isolation in the taxon under consideration." (Source: IUCN 2010). For complete guidance it is strongly suggested that IUCN 2010 is read.

Table 3. Results for the Manitoba Oakworm Moth (*Anisota manitobensis*) threats assessment in Canada. The classification below is based on the IUCN-CMP (World Conservation Union–Conservation Measures Partnership) unified threats classification system. For a detailed description of the threat classification system, see the CMP web site (CMP 2010). Threats may be observed, inferred, or projected to occur in the near term. Threats are characterized here in terms of scope, severity, and timing. Threat "impact" is calculated from scope and severity. For information on how the values are assigned, see Master *et al.* (2009), Salafsky *et al.* (2008) and footnotes to this table.

Species:	Manitoba Oakworm Moth (*Anisota manitobensis*)
Assessors:	Rob Foster (report writer), Jennifer Heron (Arthropods SSC Co-chair and notetaker), Dave Fraser (COSEWIC member and facilitator), Marie-France Noel (COSEWIC Secretariat), Karen Timm (COSEWIC Secretariat), Sarah Semmler (Arthropods SSC), John Klymko (Arthropods SSC), Jeremy deWaard (Arthropods SSC).
References:	Draft COSEWIC status report

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

Threat		Impact[1] (calculated)	Scope[2] (next 10 Yrs)	Severity[3] (10 Yrs or 3 Gen.)	Timing[4]	Comments
1	Residential & commercial development	Negligible	Negligible (<1%)	Negligible (<1%)	High (continuing)	
1.1	Housing & urban areas	Negligible	Negligible (<1%)	Moderate (11-30%)	Low	See text in report.
1.2	Commercial & industrial areas	Negligible	Unknown	Extreme (71-100%)	Low	Same as 1.1.
1.3	Tourism & recreation areas	Negligible	Negligible (<1%)	Negligible (<1%)	High (continuing)	Same as 1.1 but with trees typically spared in recreational areas.
2	Agriculture & aquaculture	Negligible	Negligible (<1%)	Negligible (<1%)	High (continuing)	
2.3	Livestock farming & ranching	Negligible	Negligible (<1%)	Negligible (<1%)	High (continuing)	Considered negligible. Livestock grazing could potentially crush pupae in soil; however, grazing may also keep a more open habitat that may be preferred by Manitoba Oakworm Moth, by allowing greater sun exposure.
4	Transportation & service corridors	Negligible	Negligible (<1%)	Negligible (<1%)	High (continuing)	

Threat		Impact[1] (calculated)	Scope[2] (next 10 Yrs)	Severity[3] (10 Yrs or 3 Gen.)	Timing[4]	Comments
4.1	Roads & railroads	Negligible	Negligible (<1%)	Negligible (<1%)	High (continuing)	See text in report.
4.2	Utility & service lines	Negligible	Negligible (<1%)	Negligible (<1%)	High (continuing)	See text in report.
5	Biological resource use					
5.1	Hunting & collecting terrestrial animals					Not considered a threat. There are few records of adult Manitoba Oakworm Moth and the species is difficult to find even by qualified entomologists.
5.2	Gathering terrestrial plants					Not considered a threat. Oaks (host plant) aren't gathered for cultural or other purposes.
6	Human intrusions & disturbance	Negligible	Negligible (<1%)	Negligible (<1%)	High (Continuing)	
6.1	Recreational activities	Negligible	Negligible (<1%)	Negligible (<1%)	High (Continuing)	See text in report.
6.3	Work & other activities		Negligible (<1%)	Negligible (<1%)	High (Continuing)	See text in report.
7	Natural system modifications	Low	Small (1-10%)	Extreme (71-100%)	High (Continuing)	
7.1	Fire & fire suppression	Negligible (<1%)	Negligible (<1%)	Negligible (<1%)	High (Continuing)	See text in report.
7.2	Dams & water management /use					Not applicable. Dams may have been a historical threat as past riverine oak habitat may have been flooded. Not considered a current or future threat. The Red River Diversion has reduced flooding in Winnipeg, which could potentially benefit Manitoba Oakworm Moth subterranean pupae by reducing the risk of drowning.
7.3	Other ecosystem modifications	Low	Small (1-10%)	Extreme (71-100%)	High (Continuing)	See text in report.
8	Invasive & other problematic species & genes	Negligible (<1%)	Unknown	Unknown	Unknown	

Threat		Impact[1] (calculated)	Scope[2] (next 10 Yrs)	Severity[3] (10 Yrs or 3 Gen.)	Timing[4]	Comments
8.1	Invasive non-native/alien species	Unknown	Unknown	Unknown	Unknown	Unknown. The fly *Compsilura concinnata* (Tachinidae) was introduced to North America in 1906 to control the Gypsy Moth (*Lymantria dispar*), a non-native pest that attacks oak trees. This generalist parasitoid lays its eggs on a wide variety of moth species and has been demonstrated to have severe impacts on native silk moths (Saturniidae) in northeastern North America (Boettner *et al*. 2000; Elkinton and Boettner 2012). *C. concinnata* is known to parasitize *Anisota* spp. (Arnaud 1978) but does not appear to be the cause of observed declines in several oakworm species in the northeastern United States (Schweitzer 2004). *C. concinnata* was identified as a potential threat to Manitoba Oakworm Moths by NatureServe (2018). The fly was reported by Arnaud (1978) as being present in Manitoba, but this appears to be based on a single CNC specimen from near Churchill. Williams *et al*. (1996) did not collect *C. concinnata* from forest tent caterpillars in the Prairie Provinces, nor was it found during a 1989-1999 parasitoid survey of Pink-striped Oakworm Moths near Belair MB (Henne 2004).

Threat		Impact[1] (calculated)	Scope[2] (next 10 Yrs)	Severity[3] (10 Yrs or 3 Gen.)	Timing[4]	Comments
8.2	Problematic native species					Discussed under 7.3 Other ecosystem modifications. Two-lined Chestnut Borer is a native pest of oaks, that typically attacks Bur Oaks stressed from other factors (City of Winnipeg 2018a; USDA 2018). Indirect impacts on degradation or loss of potential Manitoba Oakworm Moth habitat is difficult to quantify. Moth eggs and larvae may be subject to direct mortality or damage by White-tailed Deer (*Odocoileus virginianus*) and other ungulates known to browse on Bur Oak (Ritchie *et al*. 1998). Some parts of the range of Manitoba Oakworm Moth may have overabundant deer populations. When this is the case, deer become a direct threat to the moth (Rooney 2001; Schweitzer *et al*. 2011).
9	Pollution	Low	Small (1-10%)	Serious-Slight (1-70%)	High (Continuing)	
9.3	Agricultural & forestry effluents	Low	Small (1-10%)	Serious - Slight (1-70%)	High (Continuing)	See text in report.
9.5	Air-borne pollutants	Low	Small (1-10%)	Serious – Slight (1-70%)	High (Continuing)	See text in report.
9.6	Excess energy					Not applicable. Unlike many moths, this species is not attracted to lights.
11	Climate change & severe weather	Unknown	Unknown	Unknown	Unknown	
11.1	Habitat shifting & alteration					Not scored, oaks are long-lived and over time this may apply but not in the next ten years.
11.2	Droughts	Unknown	Unknown	Unknown	Unknown	Droughts weaken and stress oaks causing them to be more vulnerable to insect and disease problems, particularly the Two-lined Chestnut Borer (City of Winnipeg 2018). See 8.2

Threat		Impact[1] (calculated)	Scope[2] (next 10 Yrs)	Severity[3] (10 Yrs or 3 Gen.)	Timing[4]	Comments
11.3	Temperature extremes	Unknown	Unknown	Unknown	High (continuing)	In the short-term, small, isolated subpopulations of Manitoba Oakworm Moth may be vulnerable to stochastic events and could be threatened by hailstorms or severe early or late frosts, particularly if the frequency and intensity of severe weather events increases due to climate change.
11.4	Storms & flooding	Negligible	Negligible (<1%)	Negligible (<1%)	High (continuing)	Floods could drown pupae in riverine habitats but no evidence of impacts on Manitoba Oakworm Moth; Fauske (pers. comm. 2018) speculated that the multiple years of severe flooding throughout the Red River Valley in North Dakota could have negatively impacted Manitoba Oakworm Moth if it did indeed exist in the state.

Classification of Threats adopted from IUCN-CMP, Salafsky *et al.* (2008).

[1]**Impact** – The degree to which a species is observed, inferred, or suspected to be directly or indirectly threatened in the area of interest. The impact of each stress is based on Severity and Scope rating and considers only present and future threats. Threat impact reflects a reduction of a species population or decline/degradation of the area of an ecosystem. The median rate of population reduction or area decline for each combination of scope and severity corresponds to the following classes of threat impact: very high (75% declines), high (40%), medium (15%), and low (3%). Unknown: used when impact cannot be determined (e.g., if values for either scope or severity is unknown).

[2]**Scope** – Proportion of the species that can reasonably be expected to be affected by the threat within 10 years. Usually measured as a proportion of the species' population in the area of interest. (Pervasive = 71–100%; Large = 31–70%; Restricted = 11–30%; Small = 1–10%)

[3]**Severity** – Within the scope, the level of damage to the species from the threat that can reasonably be expected to be affected by the threat within a 10-year or three-generation timeframe. Usually measured as the degree of reduction of the species' population (Extreme = 71–100%; Serious = 31–70%; Moderate = 11–30%; Slight = 1–10%).

[4]**Timing** – High = continuing; Moderate = only in the future (could happen in the short term [< 10 years or 3 generations]) or now suspended (could come back in the short term); Low = only in the future (could happen in the long term) or now suspended (could come back in the long term); Insignificant/Negligible = only in the past and unlikely to return, or no direct effect but limiting.

POPULATION SIZES AND TRENDS

Sampling Effort and Methods

No sampling has been conducted to estimate population sizes or trends of Manitoba Oakworm Moth in Canada or elsewhere within the species' global range.

Abundance

The abundance of Manitoba Oakworm Moths is difficult to quantify since they likely have periodic outbreaks as has been reported in other species of *Anisota* (Coffelt and Schultz 1990; Serrano and Foltz 2003; Henne 2004) (see Fluctuations and Trends). Targeted surveys to assess population abundance have not been completed since the more general forest pest surveys of the 1950s and 1960s. It can be argued that if there had been widespread outbreaks recently (i.e., last several decades), they would not have gone unnoticed and undocumented, suggesting that there has been a decline in abundance compared to historical levels.

Fluctuations and Trends

Little is known about trends in Manitoba Oakworm Moth subpopulations due to paucity of field observations (see **Abundance**). Canadian subpopulations apparently undergo extreme fluctuations[11] and the genus *Anisota* is known to experience boom and bust cycles (Henne 2002). Criddle (1932) reported that 3 acres (approx. 1.2 ha) of Bur Oak south of Carman were severely defoliated in 1931 by Manitoba Oakworm Moth. McGugan (1958) described Manitoba Oakworm Moth as “generally found in small numbers but isolated severe infestations do occur”. McGugan (1958) reported one collection[12] in 1948 (unknown number of larvae), 23 collections in 1952 (246 larvae total), and two collections in 1953 (300 larvae total) (Figure 5). According to Brown (1952), Manitoba Oakworm Moth “caused severe defoliation of oak” in 1952 in the Pembina Valley south of Thornhill. The most recent reported outbreak was in 1997 near Fullers (Henne 2002) (see Table 1).

It is unknown if outbreaks occur with a regular periodicity or in response to extrinsic factors. The length of outbreaks is unknown but typically last several 2-3 years in the related Pink-striped Oakworm (Ives and Wong 1988; Henne 2004) or even longer in other *Anisota* species (e.g., Serrano and Foltz 2003). Predation, parasitism, competition, disease epizootics and other factors probably contribute to suppress population outbreaks in oakworms (Henne 2004).

Rescue Effect

The only two known sites outside Canada are in North Dakota and Minnesota, approximately 40 km and 65 km respectively from the nearest known Canadian sites. There has not been recent search effort within these areas, there does not appear to be much suitable intervening habitat and it is unknown whether these sites are extant. Considering that females are flightless, rescue from the United States is considered unlikely.

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[11] changes in the total number of mature individuals that occur rapidly and frequently, and are typically of more than one order of magnitude (IUCN 2010)

[12] it is unknown if “collections” refer to separate sites or repeat collection at the same site.

THREATS AND LIMITING FACTORS

The threats classification for Manitoba Oakworm Moth was calculated using the International Union for Conservation of Nature - Conservation Measures Partnership (IUCN-CMP) unified threats classification system (Master *et al*. 2012; Salafsky *et al.* 2008). There is little information available on specific threats to Manitoba Oakworm Moth and most threats are based on habitat trend information.

The overall Threat Impact for the species is calculated as Low. Threats to Bur Oak health and longevity (scored under 7.3 Other ecosystems modifications) and pollution (9.3 Agricultural and forestry effluents and 9.5 Air-borne pollution) are threats to Manitoba Oakworm Moth. Urban development, the development of transportation/utility corridors, and human intrusion are either direct threats to Manitoba Oakworm Moth or its oak habitat in Winnipeg and possibly other urban areas. However, these threats are considered negligible, due mainly to their scope being limited to the city of Winnipeg. Although about ¼ of known Manitoba Oakworm Moth sites are from Winnipeg, the oak habitat there represents less than 1% of the oak-dominated habitats in Manitoba.

Details are discussed below and in Table 3 using the IUCN-CMP unified threats classification system headings and numbering scheme, ranked in decreasing order of importance.

Threat 9: Pollution (Low Impact)

9.3 Agricultural & Forestry Effluents (Low impact)

The City of Winnipeg's Insect Control Branch routinely sprays for Forest Tent Caterpillar (*Malacosoma disstria*) and Fall Cankerworm (*Alsophila pometaria*) on city-owned trees and properties using several Lepidoptera-targeting biological insecticides including those with Btk (*Bacillus thuringiensis* var*. kurstaki*) spores (City of Winnipeg 2018b). Such pesticides are lethal to non-target species, including Manitoba Oakworm Moth (Schweitzer 2004; Henne pers. comm. 2018). Depending on the timing of the application, control of Fall Cankerworm could benefit Manitoba Oakworm Moth subpopulations by preventing a reduction in their oak food supply and potentially reducing the number of parasitoids. The City of Winnipeg (2018b) typically sprays for Fall Cankerworm in the spring and early summer (in 2018 spraying was concluded by June 18) when Manitoba Oakworm Moth would still be in the egg or more vulnerable first instar life stage. The City of Winnipeg also sprays DeltaGard© (a pyrethroid insecticide) to control mosquitoes (City of Winnipeg 2019). Although applied using ultra-low volume (ULV) ground sprayers, there is the potential for non-target impacts on Manitoba Oakworm Moth (e.g., impacts on subterranean pupae from pesticide-tainted surface water runoff).

Potential impacts on Manitoba Oakworm Moth from rural or agricultural spraying of pesticides are unknown.

De-icing spray and salt damage from roads may contribute to oak decline in Winnipeg and other urban areas (Barwinsky pers. comm. 2019).

9.5 Air-borne pollutants. (Low impact)

There is the potential for pesticide drift from agricultural areas into adjacent remnant natural habitats where Bur Oak and moth subpopulations occur. This threat is difficult to score because this information is not accurately always tracked and some crops require different pesticides, some landowners may not use pesticides (e.g., organic crops) nor apply pesticides during the active Manitoba Oakworm Moth larval period. Pesticide drift could be fatal to larvae though and this is possible within the ten-year assessment timeframe.

Threat 7: Natural System Modifications (Low Impact)

7.1 Fire and Fire Suppression (Negligible impact)

Many of the upland (i.e., non-riverine) Bur Oak stands have a Trembling Aspen component, which is probably a result of fire suppression. Fire suppression over the last century may have led to the encroachment of less fire-tolerant species such as Trembling Aspen, likely reducing the habitat availability for Manitoba Oakworm Moth.

Fire suppression is not seen as a short-term threat (i.e., next 10 years) to riverine oak woodland, which historically may have had a longer fire interval due to moister conditions. However, fire suppression may be a threat over the long-term if it results in a change in oak habitat due to aspen encroachment or reduced oak abundance.

7.3 Other ecosystem modifications (Low impact)

Bur Oak (host plant to Manitoba Oakworm Moth) is extremely sensitive to environmental stress and even small changes to the growing environment can lead to tree death (City of Winnipeg 2018a). Damage to the tree, including changes in the air-to-moisture ratio in soil, soil compaction to the root zone or damage to the tree during construction activities, grade changes to the surrounding environment, and other factors that weaken or stress the tree can all lead to wilt and/or death of the tree (City of Winnipeg 2018a). These cumulative factors cause the tree to become more vulnerable to fungal and insect diseases.

Numerous diseases affect Bur Oak trees and have a cumulative effect on the habitat quality and quantity of oak trees available to Manitoba Oakworm Moth. Diseases include:

- Oak Decline. Since 1986, Bur Oaks in southern Manitoba have experienced environmentally related stress and dieback referred to as “oak decline” (Allen and Kuta 1994; City of Winnipeg 2018a). This decline is not the result of a single

pathogen but is a disease that has been attributed to several cumulative factors that weaken the tree (e.g., flooding, soil compaction) making it more vulnerable to forest pests. In response to this problem, over 1700 affected Bur Oaks were removed from the city between 1986 and 2000 (Allen pers. comm. in Catton *et al*. 2007). Many of the remaining oaks in the St. Vital area have suffered from oak decline, with removal of decadent trees reducing the amount of potentially suitable habitat for Manitoba Oakworm Moth (Westwood pers. comm. 2018). Although this decline in oak habitat within Winnipeg potentially has affected as many as six historical collection sites (i.e., Winnipeg, Deer Lodge, Elm Park, Manitoba Agricultural College, St. Vital, and Transcona), it represents a small proportion (<1%) of the oak-dominated habitat in Manitoba (see below). In addition, oak forest within the city of Winnipeg is quite fragmented, with a mean patch size of only 1.6 ha (Naturalist Services Branch, City of Winnipeg, unpublished data).

- Armillaria Root Rot (*Armillaria* spp.) is a fungal disease first documented in Canada in 1918 and now known from within forested areas across Canada. The species is a significant disease of young conifers in the prairie provinces (Hiratsuka 1987), leading to rot and eventual death of the tree (Catton *et al*. 2007).
- Two-lined Chestnut Borer (*Agrilus bilineatus* (Weber)) is a beetle whose larvae bore into Bur Oak and after 3 – 4 years of branch dieback, tree mortality occurs (Catton *et al*. 2007; Natural Resources Canada 2015; City of Winnipeg 2018a).
- Cynipid Gall Wasps (Hymenoptera: Family Cynipidae). Nineteen different cynipid species are known to form galls on Bur Oak (Digweed 2005). Gall wasps do not kill the tree; however, they make the tree more susceptible to other diseases.
- Oak Twig Girdler/Pruner (*Anelaphus parallelus* (Newman)) is a longhorn beetle. Adults emerge in late summer and feed on the twig tips, and eventually mate and lay eggs in these dead tips. This is because developing larvae need dead material. This causes injury and offshoot development, forks, stem deformities and crooks. This then limits growth of the tree and weakens the overall health of the tree.
- Anthracnose is a complex of numerous fungi, which causes irregular brown or tan patches on leaf surfaces, distorted appearance and eventual premature drop. Other symptoms include twig or branch dieback, and eventual damage from secondary infection.
- Tubakia Leaf Spot (*Tubakia dryina*) and Bur Oak Blight (unnamed *Tubakia* spp.) are both fungal diseases that causes spots on the leaves of numerous tree and plant species, including oaks. The damage is cosmetic; however, the fungus does weaken the tree and make it more susceptible to other secondary diseases and eventual death.
- Bacterial Leaf Scorch (*Xylella fastidiosa*) is a bacterium which grows within and plugs the xylem of the tree, preventing nutrients from getting to the shoots and crown. Eventually, leaf scorch leads to the death of the tree.
- Oak Wilt (*Bretziella fagacearum*) is a fungus spread by insects or by root grafting. Infection leads to leaf wilt, discolouration, defoliation and eventual death of oak trees.

Threat 1: Residential and Commercial Development (Negligible Impact)

1.1 Housing & Urban Areas

Riverine and other oak forest has potential for development in urban areas since it often represents some of the few remaining undeveloped pockets. For example, approximately 2 ha of oak forest near the Harte Trail in Winnipeg will be lost to residential development in the next 10 years (Semmler pers. comm. 2019). However, urban development of Manitoba Oakworm Moth habitats has occurred primarily in Winnipeg, which represents a very small proportion (< 1%) of potentially suitable oak habitat in southern Manitoba.

Threat 4: Transmission & Service Corridors (Negligible Impact)

4.1 Roads and Railroads and 4.2 Utility and Service Lines

Construction of roads and railroads has the potential to destroy or fragment Manitoba Oakworm Moth habitat. Approximately 32 ha of oak forest are slated to be cleared in northwest Winnipeg over the next ten years for the CentrePort highway expansion (Naturalist Services Branch City of Winnipeg unpublished data) (Figure 12). Although large areas of oak habitat will be permanently lost, it may create sunny edges that Manitoba Oakworm Moth may prefer. One subpopulation is found along a provincial highway and transmission line right-of-way at Fullers (Henne 2002).

Clearing of oak forest for utility and service lines may destroy most of the habitat but may still leave some suitable habitat with small oaks persisting despite maintenance activities. Approximately 9 ha of oak forest will be cleared in the next 10 years near the City Tree Nursery in southern Winnipeg for the placement of transmission towers (Semmler pers. comm. 2019).

Threat 6: Human Intrusion and Disturbance (Negligible Impact)

6.1 Recreational Activities and 6.3 Work & Other Activities

Compaction of soil around oaks from trampling in urban parks in Winnipeg (USDA 2018; Westwood pers. comm. 2018; City of Winnipeg 2018a) can stress Bur Oaks, contributing to their decline and eventual death, thus reducing potential habitat for Manitoba Oakworm Moths at least in Winnipeg and other urban areas. Work such as street and other maintenance can also lead to compaction around Bur Oaks, mechanical damage, grade changes, and other impacts that can weaken oaks making them more susceptible to insect pests and “oak decline” (see *Habitat Trends* and Table 3).

Limiting Factors

Limiting factors are generally not human-induced and include characteristics that

make the species less likely to respond to conservation efforts. The main limiting factors for Manitoba Oakworm Moth are speculative but are likely a combination of the following.

- *Small subpopulation size, both spatial area and moth abundance*. Limited to habitats with Bur Oak, which has a patchy distribution across its range. Ecological theory predicts that the risk of a subpopulation going extinct in a single patch such as an area of oak habitat is reduced with increasing numbers of surrounding subpopulations. Between outbreaks, Manitoba Oakworm Moth may occur as small or localized subpopulations, thus preventing genetic mixing between subpopulations, leading to inbreeding depression and increasing the chance of local extirpation.
- *Poor dispersal ability*. Female moths are not highly mobile and are unlikely to disperse far due to their heavy egg-laden bodies. Historically, oak habitats were more connected and widespread; however, present-day ecosystems are isolated and fragmented. Manitoba Oakworm Moth appears not to be able to disperse long distances through unsuitable habitat.
- *Natural enemies*. Predators, parasites, and parasitoids are known to attack silk moths, including other oakworms, at all life stages and likely limit Manitoba Oakworm Moth.
- *Larval host plant specificity*. Manitoba Oakworm Moth larvae are dependent on Bur Oak to complete their life cycle (see **Biology**). Bur Oak is the only oak species in Manitoba.
- *Limited adult lifespan*. Adult moths do not have functional mouthparts and do not feed; individuals rely on stored body fat and energy to mate and lay eggs. The adult life span is less than one week.
- *Limited and unsuitable habitat*. Females emit pheromones to attract males, if the vegetation is too dense, the sphere of the pheromone plume is smaller and/or the pheromone not disperse far, and the number of potential mates declines.

Number of Locations

It is not possible to accurately estimate the number of locations[13] for Manitoba Oakworm Moth. If records from only the past 50 years (threshold to assume localities are likely extirpated) are considered, there are four sites (Fullers [1996 and 1997]; Winnipeg [2000], Sandilands provincial forest [1971] and Anola [1975]). If each of these sites were considered to have different land management regimes, the argument for four different locations is plausible. There may be 20-25 locations depending on the specific locality and, because the status of historical sites is unknown, some are likely extirpated. In

[13] The term ‘location' defines a geographically or ecologically distinct area in which a single threatening event can rapidly affect all individuals of the taxon present. The size of the location depends on the area covered by the threatening event and may include part of one or many subpopulations. Where a taxon is affected by more than one threatening event, location should be defined by considering the most serious plausible threat. Where the most serious plausible threat does not affect all the taxon's distribution, other threats can be used to define and count locations in those areas not affected by the most serious plausible threat. (Source: IUCN 2010, 2011). In the absence of any plausible threat for the taxon, the term "location" cannot be used and the subcriteria that refer to the number of locations will not be met. (Source: IUCN 2010, 2011)

addition, there may be additional undocumented extant occurrences.

PROTECTION, STATUS AND RANKS

Legal Protection and Status

There are currently no federal or provincial laws that specifically protect Manitoba Oakworm Moth or its habitat. As with other animals, any Manitoba Oakworm Moths within Riding Mountain National Park are protected under the *Canada National Parks Act* and relevant regulations. As with other species, Manitoba Oakworm Moths would be similarly protected under Manitoba's *Provincial Park Act* and relevant regulations if they occur within Pembina Valley, Birds Hill, and Turtle Mountain provincial parks.

Non-Legal Status and Ranks

The conservation status ranks for Manitoba Oakworm Moth (NatureServe 2018):

- Global Status: G2Q[14] (Imperilled) (August 2017).
- National Status: Canada - N2 (Imperilled); United States – NH (Historical) (December 2000)
- Provincial Status: Manitoba - S2 (Imperilled)
- State Status: Minnesota and North Dakota - SH (Historical); Wisconsin and Nebraska – not yet ranked.

Habitat Protection and Ownership

The ownership and degree of protection for Manitoba Oakworm Moth habitat is difficult to estimate given the uncertainty regarding its current distribution and abundance throughout its Canadian range. Within Manitoba, some of its habitat may be protected within Pembina Valley, Birds Hill, and Turtle Mountain provincial parks, Riding Mountain National Park (federal), and other smaller protected areas such as municipal parks or provincial Wildlife Management Areas. The Manitoba *Endangered Species and Ecosystems Act* could conceivably protect potential oak habitat in alvars and tall grass prairies although there are no documented occurrences of Manitoba Oakworm Moth in these areas.

[14] "Questionable taxonomy that may reduce conservation priority - Distinctiveness of this entity as a taxon or ecosystem type at the current level is questionable; resolution of this uncertainty may result in change from a species to a subspecies or hybrid, or inclusion of this taxon or type in another taxon or type, with the resulting taxon having a lower-priority (numerically higher) conservation status rank. The "Q" modifier is only used at a global level and not at a national or subnational level" (NatureServe 2019). See **Taxonomic Background** for the explanation of taxonomic uncertainty.

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Cover photo (D. Henne) of male adult Manitoba Oakworm Moth reared from larvae collected in August from Fullers MB. Specimen in D. Henne personal collection. Sarah Semmler, Rodney Penner, Kerienne L. France, Kevin Land, and Martha Barwinsky from the City of Winnipeg are thanked for information on oaks and threats in Winnipeg.

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INFORMATION SOURCES

Allen, M., and G. Kuta. 1994. Oak Decline. Natural Resources of Canada, Canadian Forest Service, Northwest Region, Forestry Leaflet 28, Edmonton, Alberta.

Anderson, R.C., J.S. Fralish, and J.M. Baskin. 2009.Savannas, Barrens, and Rock Outcrop Plant Communities of North America. Cambridge University Press. 484 pp.

Arnaud, P.H., Jr. 1978. A host-parasite catalog of North American Tachinidae (Diptera). United States Department of Agriculture. Miscellaneous Publication 1319: 1-860.

Barwinsky, M. pers. comm. 2019. *Email correspondence to S. Semmler.* February 2019. City Forester, Naturalist Services Branch, City of Winnipeg. Winnipeg Manitoba.

Boettner, G.H., J.S. Elkinton, and C. Boettner. 2000. Effects of a biological control introduction on three nontarget native species of saturniid moths. Conservation Biology 14(6):1796-1806.

Brodie, H.J. 1929. Notes on the early stages of *Anisota manitobensis* (Lepid.). Canadian Entomologist 61:98-100.

Brown, C.E. 1952. Canada Forest Service Bi-monthly Research Notes 8:(1-6):3.

BugGuide. 2018. Oakworm Moth – *Anisota manitobensis* Website: https://bugguide.net/node/view/1170047 [Accessed September 2018].

Burke and R.S. Peigler. 2009. Phylogenetic analysis of Anisota (Insecta: Lepidoptera: Saturniidae) based on scolus size and structure of mature larvae. Southeastern Naturalist 8(4):739-745.

Caners, R.T. and N.C. Kenkel. 2003. Forest stand structure and dynamics at Riding Mountain National Park, Manitoba, Canada. Community Ecology 4(2):185-204.

Catton, H.A., S. St. George, and W.R. Remphrey. 2007 An Evaluation of Bur Oak (*Quercus macrocarpa*) Decline in the Urban Forest of Winnipeg, Manitoba, Canada. Arboriculture & Urban Forestry 33(1):22-30.

City of Winnipeg. 2019. DeltaGard. Public Works Department, Insect Control. Website: https://winnipeg.ca/publicworks/insectcontrol/mosquitoes/deltagard.stm [accessed March 2019].

City of Winnipeg. 2018a. Oak Decline. Public Works Department, Urban Forestry Branch. Website: https://www.winnipeg.ca/PublicWorks/parksOpenSpace/UrbanForestry/PDF/OAK_DECLINE_PAMPHLET.pdf [Accessed September 2018].

City of Winnipeg. 2018b. Tree Pest Caterpillar Spraying Schedule 2018. Public Works Department, Urban Forestry Branch. Website: https://www.winnipeg.ca/publicworks/insectcontrol/cankerworms/spraying.stm [accessed September 2018].

CMP (Conservation Measures Partnership). 2010. Threats taxonomy. www.conservationmeasures.org [Accessed September 5, 2019].

Coffelt, M.A. and P.B. Schultz. 1992. Parasitism of orange-striped oakworm (Lepidoptera: Saturniidae) eggs in the urban landscape. Biological Control 2: 306-311.

Committee on the Status of Endangered Wildlife in Canada (COSEWIC). 2007. COSEWIC National Ecological Areas. Website: https://www.canada.ca/content/dam/eccc/migration/cosewic-cosepac/dd31eaee-efba-448b-86ab-4ba8a68d7ea4/fig1-terrestrialecologicalareas_eng.jpg [accessed February 2019].

Covel, C.V. Jr. 1984. Eastern Moths, Peterson Field Guides. Houghton Mifflin Company, Boston, Massachusetts. 496 p.

Digweed, S. 2005. Diversity of gall wasps (Hymenoptera: Cynipidae) on bur oak (*Quercus macrocarpa* Michx.) in Riding Mountain National Park, Manitoba, Canada. Conference: Volume: 53, Entomological Society of Alberta Annual Meeting November 2005, Canmore, Alberta, Canada

Elkinton, J.S. and G.H. Boettner. 2012. Benefits and harm caused by the introduced generalist tachinid, *Compsilura concinnata*, in North America. BioControl 57:277-288.

Elliot, K.R. 1964. The forest insect and disease survey in Manitoba and Saskatchewan. Proc. Entomol. Soc. Manitoba 20:45-53.

Ferguson, D. C. 1971. Bombycoidea: Saturniidae, Citheroniinae and Hemileucinae. Part I. Moths of America North of Mexico, Fascicle 20.2B. E.W. Classey Ltd. and R.B.D. Publications, London, England.

Fauske, G. pers. comm. 2018. *Email correspondence to R. Foster.* April 2018. Research Specialist / Collection Manager, NDS Insect Research Collection, North Dakota State University, Fargo, North Dakota.

Garris, H.W. and J. Snyder 2010. Sex-specific attraction of a moth species to ultraviolet light traps. Southeastern Naturalist 9(3): 427-434.

Hanuta, I. 2006. Land Cover and Climate for Part of Southern Manitoba: A Reconstruction from Dominion Land Survey Maps and Historical Records of the 1870s. D.Ph. Dissertation, University of Manitoba, Winnipeg, Manitoba. 487 p.

Henne, D.C. pers. comm. 2018-2019. *Email correspondence to R. Foster.* Assistant Professor, Faculty of Resource Management, Lakehead University, Thunder Bay, Ontario.

Henne, D.C. 2002. Distribution and biology of *Anisota manitobensis* in southern Manitoba. Journal of the Lepidopterists Society 56(1):5-8.

Henne, D.C. 2004. Parasitoid survey of *Anisota virginiensis* (Lepidoptera: Saturniidae) at Belair, Manitoba from 1989-1999. Proceedings of the Entomological Society of Manitoba 60: 5-10.

Hildahl, V., A.E. Campbell, K.L. Mortensen, G.N. Still, L.L. McDowall, R.W. Hancox, R.C. Tidsbury, B.B. McLeod, R. Van den Abeele, and C.L. Rentz. 1966. Annual District Reports Forest Insect and Disease Survey, Manitoba-Saskatchewan Region 1965. Canada Department of Forestry, Winnipeg, Manitoba. 207 p.

Hiratsuka, Y. 1987. Forest tree diseases of the prairie provinces. Can. For. Serv., North. For. Cent., Edmonton, Alberta. Inv. Rep. NOR-X-286.

IUCN (International Union for the Conservation of Nature) Standards and Petitions Subcommittee. 2010. Guidelines for Using the IUCN Red List Categories and Criteria. Version 8.0. Prepared by the Standards and Petitions Subcommittee in March 2010.

Ives, W.G.H and H.R. Wong. 1988. Canadian Forestry Service, Northern Forestry Centre, Edmonton, AB. Information Report NOR-X-292. 327 p.

Johnson, K. 2017. Lepidoptera surveys in Manitoba and Saskatchewan with emphasis on *Papaipema aweme* 2016-2017. Unpublished report for Canadian Wildlife Service, Ontario. 34 p.

Lotts, K. and T. Naberhaus (coordinators). 2018. Butterflies and Moths of North America. Spiny Oakworm Moth *Anisota stigma*. Website: https://www.butterfliesandmoths.org/species/Anisota-stigma [Accessed September 30, 2018].

Manitoba Alvar Initiative. 2012. Alvars in Manitoba: A Description of their Extent, Characteristics & Land Use. Nature Conservancy of Canada, Manitoba Region, Winnipeg, Manitoba and Manitoba Conservation and Water Stewardship, Winnipeg. 42 pp.

Manitoba Historical Society. 2019. Historic Sites of Manitoba: Manitoba Agricultural College / University of Manitoba, Fort Garry Campus (Winnipeg). Website: http://www.mhs.mb.ca/docs/sites/universityofmanitoba.shtml [accessed March 2019].

Manitoba Sustainable Development. 2018. Manitoba Land Initiative, Core Maps – Data Warehouse: Forest Inventory Maps. Website: http://mli2.gov.mb.ca/forestry/index.html [accessed September 2018].

Marr Consulting & Communications Ltd. and Synthen Resource Services. 1995. Riverbottom Forest Assessment: Forest Ecosystem Classification and Management Recommendations. Final report for Canadian Forest Service Contract #4Y080-3-1429. 63 pp.

Master, L.L., D. Faber-Langendoen, R. Bittman, G.A. Hammerson, B. Heidel, L. Ramsay, K. Snow, A. Teucher, and A. Tomaino. 2012. NatureServe conservation status assessments: factors for evaluating species and ecosystems at risk. NatureServe, Arlington, Virginia. Website: http://www.natureserve.org/sites/default/files/publications/files/natureserveconservationstatusfactors_apr12_1.pdf [accessed October 2018].

McCabe, T. pers. comm. 2018. *Email correspondence to R. Foster*. State Entomologist, Curator of Entomology, New York State Museum, Albany, NY.

McDunnough, J. 1921. A new *Anisota* species from Manitoba (Lepid). Canadian Entomologist 53:75.

McGugan, R.M. 1958. Forest Lepidoptera of Canada recorded by the Forest Insect Survey. 1. Papilionidae to Arctiidae. Forest Biology Division, Canada Department of Agriculture, Publication 1034, Ottawa, Ontario.

Moth Photographers Group. 2018. *Anisota manitobensis*. Website: http://mothphotographersgroup.msstate.edu/species.php?hodges=7717 [accessed September 2018].

Natural Resources Canada (NRC). 2018. Bur Oak. Website: https://tidcf.nrcan.gc.ca/en/trees/factsheet/65 [accessed September 2018].

NatureServe. 2018. NatureServe Explorer. Website: http://www.natureserve.org/explorer/ [accessed September 30, 2018].

NatureServe. 2019. Definitions of NatureServe Conservation Status Ranks. http://help.natureserve.org/biotics/Content/Record_Management/Element_Files/Element_Tracking/ETRACK_Definitions_of_Heritage_Conservation_Status_Ranks.htm [Accessed September 5, 2019].

Natural Resources Canada. 2015. Two-lined chestnut borer (*Agrilus bilineatus* (Weber)) fact sheet website https://tidcf.nrcan.gc.ca/en/insects/factsheet/284 [Accessed September 15, 2019]

Peigler, R.S. 1994. Catalog of parasitoids of Saturniidae of the world. J. Res. Lepid. 33: 1-121.

Pohl, G.R., Patterson, B., and Pelham, J.P. 2016. Annotated taxonomic checklist of the Lepidoptera of North America, North of Mexico. Working paper published online by the authors at ResearchGate.net. 766 pp.

Pohl, G.R., Landry, J.-F., Schmidt, B.C., Lafontaine, J.D., Troubridge, J.T., Macaulay, A.D., van Nieukerken, E.J., deWaard, J.R., Dombroskie, J.J., Klymko, J., Nazari, V., and Stead, K. 2018. Annotated checklist of the Moths and Butterflies of Canada and Alaska. Pensoft Publishers, Sofia, Bulgaria, 580 pp.

Pyle, L.A., Elsinger, M.E., and LaForge, K. 2018. Manitoba's Rangeland Plant Communities of the Aspen Parkland and Assiniboine Delta Rangeland Ecoregions. A First Approximation. Manitoba Forage and Grassland Association.138 pp.

Riley, CG.; Denyer, W.B.; Whitney, RD. 1952. Prairie provinces. Pages 140-146 in Annual report of the forest insect and disease survey, 1951. Agric. Can., Div. For. BioI. Sci. Serv., Ottawa, Ontario.

Riotte J.C.E. and R.S, Peigler 1980. A revision of the American genus *Anisota* (Saturniidae). J. Res. Lepid. 19:101-180.

Ritchie, M.E., D. Tilman and J.M.H. Knops. 1998. Herbivore effects on plant and nitrogen dynamics in oak savanna. Ecology 79:165-177.

Rooney, T.P. 2001. Deer impacts on forest ecosystems: a North American perspective. Forestry 74: 201 – 208.

Salafsky, N., D. Salzer, A.J. Stattersfield, C. Hilton-Taylor, R. Neugarten, S.H.M. Butchart, B. Collen, N. Cox, L.L. Master, S. O'Connor, and D. Wilkie. 2008. A standard lexicon for biodiversity conservation: unified classifications of threats and actions. Conservation Biology 22:897–911.

Schweitzer, D.F. 2004. Gypsy Moth (*Lymantria dispar*): Impacts and Options for Biodiversity-Oriented Land Managers. NatureServe: Arlington, Virginia 59 p.

Schweitzer, D.F., M.C. Minno, and D.L. Wagner. 2011. Rare, declining and poorly known butterflies and moths (Lepidoptera) of forests and woodlands in the Eastern United Sates. U.S. Forest Service, Forest Health Technology Enterprise Tam, 2011-01. (pg. 33).

Semmler, S. 2018. Personal communication to R. Foster. December 2018. City of Winnipeg, Winnipeg, Manitoba.

Serrano, D. and J.L. Foltz. 2003. Natural history of *Anisota peigleri* (Lepidoptera: Saturniidae) in Gainesville, Florida. Fla. Ent. 86(2): 217-218.

St. George, S., and E. Nielsen. 2002. Hydroclimatic change in southern Manitoba since A.D. 1409 Inferred from tree rings. Quaternary Research 58:103–111.

Thomson, R. pers. comm. 2018. *Email correspondence to R. Foster.* April 2018. Curator, Insect Collection, University of Minnesota, St. Paul, Minnesota.

Tuskes, P.M., J.P. Tuttle and M.M. Collins. 1996. The wild silk moths of North America: a natural history of the Saturniidae of the United States and Canada. Ithaca, NY and London: Cornell University Press. iv + 250 pp.

United States Department of Agriculture (USDA). 2018. Twolined Chestnut Borer. Website: https://www.fs.usda.gov/Internet/FSE_DOCUMENTS/stelprdb5350723.pdf [accessed September 2018].

United States Geological Survey (USGS). 2008. Digital representations of tree species range maps from Atlas of United States trees by Elbert L. Little, Jr. [Online]. Website: esp.cr.usgs.gov/data/ atlas/little [accessed September 2018].

Westwood, R. pers. comm. 2018. Email correspondence to R. Foster. April 2018. Dept. of Environmental Science and Studies and Dept. of Biology, University of Winnipeg, Winnipeg, Manitoba.

Williams, D.J.M., D. Parry and D.W. Langor. 1996. Sampling and identification of forest tent caterpillar parasitoids in the prairie provinces. Natural Resources Canada information report NOR-X-345.

Zoladeski, C.A., G.M. Wickware, R.J. Delorme, R.A. Sims, R.A., and I.G.W. Corns. 1995. Forest ecosystem classification for Manitoba: field guide. Natural Resources Canada, Canadian Forest Service, Northern Forestry Centre, Edmonton, Alberta. Special Report 2. 205 pp.

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COLLECTIONS EXAMINED

The following collections were queried for Canadian specimens of Manitoba Oakworm Moth:

- American Museum of Natural History (AMNH), New York, New York (Courtney Richenbacher)
- Canadian National Collection (CNC) of Insects, Acari and Nematodes, Ottawa, Ontario (Owen Lonsdale)
- Carnegie Museum of Natural History, Pittsburgh, Pennsylvania (Bob Davison)
- Chicago Field Museum of Natural History, Chicago, Illinois. (Crystal Maier)
- E.H. Strickland Entomological Museum, University of Alberta, Edmonton, Alberta (online search)
- J.B. Wallis / R.E. Roughley Museum of Entomology, Winnipeg, Manitoba (Jason Gibbs)

- Olds College, Alberta (Ken Fry)
- Manitoba Museum of Man and Nature (MMMN), Winnipeg, Manitoba (Randall Mooi)
- Milwaukee Public Museum, Milwaukee, Wisconsin (Jen Zaspel)
- Musée National d'Histoire Naturelle (MNHN), Paris, France (Rodolphe Rougerie)
- Natural History Museum (NHM), London, England (online search)
- North Dakota State Insect Reference Collection, North Dakota State University, Fargo, North Dakota. (David Rider)
- Northern Forestry Centre (NRC-FRS), Natural Resources Canada, Edmonton, Alberta. (Greg Pohl)
- Royal Alberta Museum, Edmonton, Alberta. (Matthias Buck)
- Royal British Columbia Museum (RBCM), Victoria, British Columbia. (Claudia Copley)
- Royal Ontario Museum (ROM), Toronto, Ontario. (Brad Hubley)
- Royal Saskatchewan Museum, Saskatoon, Saskatchewan (Cory Sheffield)
- Smithsonian National Museum of Natural History (USNM), Washington, D.C. (online search)
- Severin-McDaniel Insect Research Collection, South Dakota State University, Brookings, South Dakota. (Paul Johnson)
- Spencer Entomological Collection, Beaty Biodiversity Museum, University of British Columbia, Vancouver, British Columbia (online search)
- Texas A & M University, College Station, Texas (Karen Wright)
- University of Guelph, Guelph, Ontario. (Steve Paiero)
- University of Calgary, Calgary, Alberta. (John Swann)
- University of Minnesota (UMSP), St. Paul, Minnestoa. (Robin Thomson)
- University of Nebraska State Museum, Lincoln, Nebraska (Brett Ratcliff)
- University of Saskatchewan, Saskatoon, Saskatchewan (Bob Randall)
- Wisconsin Insect Research Collection, University of Wisconsin, Madison, Wisconsin (Craig Babant)
- Yale Peabody Museum of Natural History (PMNH), New Haven, Connecticut (online search)