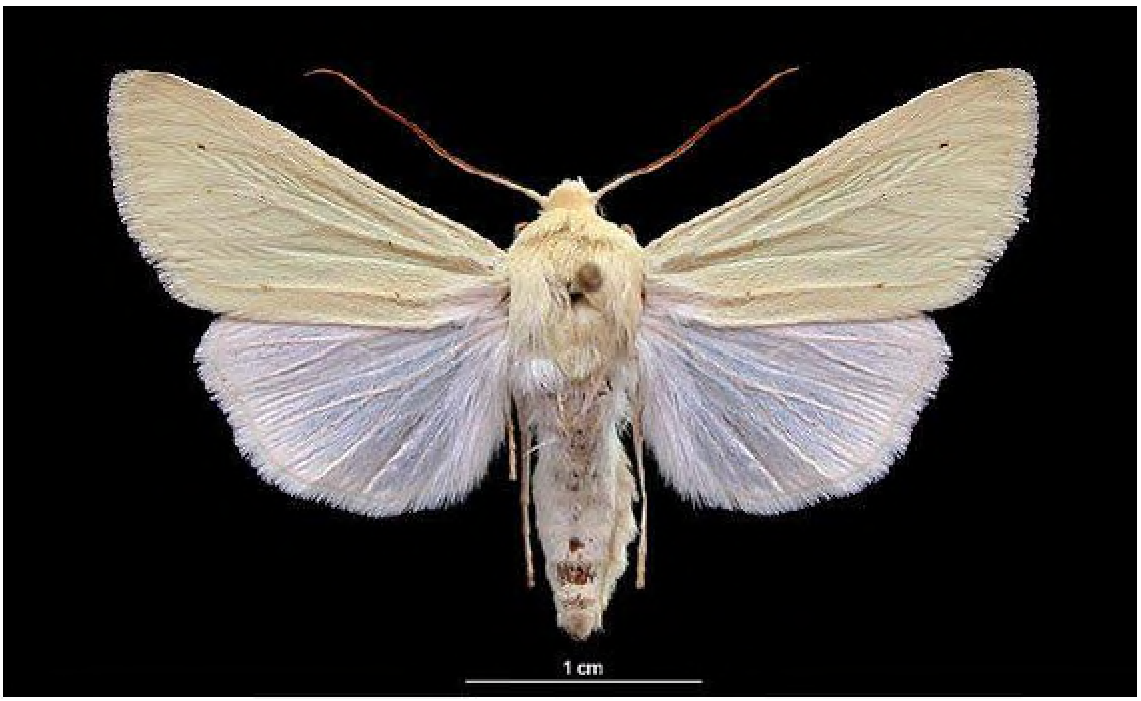
COSEWIC
Assessment and Status Report

on the

Pale Yellow Dune Moth
Copablepharon grandis

in Canada



SPECIAL CONCERN
2018

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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Previous report(s):

COSEWIC. 2007. COSEWIC assessment and status report on the Pale Yellow Dune Moth *Copablepharon grandis* in Canada. Committee on the Status of Endangered Wildlife in Canada. Ottawa. vii + 28 pp. (www.sararegistry.gc.ca/status/status_e.cfm).

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Cover photo of Pale Yellow Dune Moth from the Strickland Museum collection (University of Alberta, Edmonton, Alberta) collected at Chauvin, Alberta by B. Christian Schmidt; photo by G.G. Anweiler.

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COSEWIC
Assessment Summary

Assessment Summary – November 2018

Common name
Pale Yellow Dune Moth

Scientific name
Copablepharon grandis

Status
Special Concern

Reason for designation
This moth is known from 13 subpopulations restricted to widely-separated active sand hills and dunes on the prairies of Alberta, Saskatchewan, and Manitoba. Natural disturbance processes once maintained these open habitats for the moth. However, wildfire suppression and extirpation of Plains Bison, combined with climate warming, has led to increased vegetation succession. A population decline is inferred at known sites based on vegetation succession that would result in loss of open, active sand hill and dune habitats. Low detectability and some unchecked habitat leave the possibility of a handful of additional subpopulations.

Occurrence
Alberta, Saskatchewan, Manitoba

Status history
Designated Special Concern in November 2007. Status re-examined and confirmed in November 2018.

COSEWIC
Executive Summary

Pale Yellow Dune Moth
Copablepharon grandis

Wildlife Species Description and Significance

Pale Yellow Dune Moth is a medium-sized (16-20 mm wingspan) noctuid (cutworm or owlet) moth with pale yellow forewings and white hindwings. It is a member of a highly specialized dune-dwelling community of plants and animals that are restricted to the isolated and widely separated active sand dunes left across the prairie landscape with the retreat of the continental glaciers thousands of years ago.

Distribution

Pale Yellow Dune Moth is widely distributed in western North America. The species occurs from southern California in the southwest to central Texas in the southeast and as far north as Lloydminster, Alberta. It has been found at approximately 100 localities in North America including 13 extant subpopulations in Canada: six in Alberta, five in Saskatchewan, and two in Manitoba.

Habitat

Pale Yellow Dune Moth occurs in sparsely vegetated, sandy habitats that are typically associated with dune fields. The species appears to prefer the transition habitat between active open dunes with frequent sand movement, and fully vegetated stabilized dunes with little or no open sand. Over the last 100 years, active dune habitats and the associated sparsely vegetated periphery on which the moth depends, have significantly declined in quantity and quality throughout the Canadian prairies.

Biology

Little is known about the biology of Pale Yellow Dune Moth. The species is nocturnal with one short summer flight season from early July to late August; two factors that make it difficult to observe in the field. Eggs are fully formed in newly emerged adults, but mating and oviposition (egg laying) have not been observed. Eggs are likely deposited in shallow sand, and larvae likely hatch approximately three weeks later, feed nocturnally on the above-ground parts of plants and bury themselves in the sand during the day. They may also feed below ground. Larvae probably burrow into the soil for the winter and wake the following spring and feed prior to pupation. Pupation occurs in an earthen cell in the soil.

Pale Yellow Dune Moth does not appear to be limited to a single hostplant for larval feeding, adult nectaring or reproduction.

Dispersal abilities of Pale Yellow Dune Moth adults have not been measured. Given that dune habitats are often patchily distributed, it is likely that short-distance dispersal occurs between habitat patches. However, dispersal between regionally isolated dunes systems (>10 km) is considered unlikely.

Population Sizes and Trends

The number of sites occupied by Pale Yellow Dune Moth in Canada appears to be relatively stable but has likely declined from historical levels due to habitat loss from vegetation ingrowth and dune stabilization. Too few data are available on which to base extant site subpopulation estimates or a Canada-wide population estimate.

Threats and Limiting Factors

The major threat to the long-term survival Pale Yellow Dune Moth in Canada appears to be the loss of habitat, and the sparsely vegetated periphery that the moth prefers, resulting from the stabilization of active sand dunes by both native and introduced vegetation. This natural process is largely driven by regional climate trends, but has accelerated over the last 150 years, in part due to decreasing aridity, reduced wildfire, extirpation of Plains Bison (*Bison bison bison*), and other factors. The primary limiting factor is availability of sparsely vegetated dune habitat.

Protection, Status and Ranks

Most of the extant subpopulations are associated with secure tenure on leased provincial Crown land, within provincial or regional parks, or the federal Department of National Defence lands. A few subpopulations are on private land or where the land tenure is unknown (particularly for historical occurrences).

Pale Yellow Dune Moth is listed as Special Concern under federal *Species at Risk Act* and Endangered under the Manitoba *Endangered Species and Ecosystems Act*. It is globally ranked by NatureServe as Apparently to Demonstrably Secure (G4G5), nationally in Canada as Imperilled (N2), and provincially in Manitoba as Critically Imperilled (S1), Alberta as Critically Imperilled (S1S2), and Saskatchewan as Imperilled (S2).

TECHNICAL SUMMARY

Copablepharon grandis

Pale Yellow Dune Moth

Noctuelle jaune pâle des dunes

Range of occurrence in Canada: Alberta, Saskatchewan, Manitoba

Demographic Information

Generation time	1 year; larval diapause over 1 year is possible
Is there an [observed, inferred, or projected] continuing decline in number of mature individuals?	Yes. Suspected decline based on decline in spatial area due to sand dune/hill stabilization.
Estimated percent of continuing decline in total number of mature individuals within [5 years or 2 generations]	Unknown
[Observed, estimated, inferred, or suspected] percent [reduction or increase] in total number of mature individuals over the last [10 years, or 3 generations].	Yes. Suspected reduction of 10 – 40% sand dune/hill habitat decline per decade; the average dune/hill decline will be less (e.g., some dunes won't decline, others will decline more) (Wolfe 2010).
[Projected or suspected] percent [reduction or increase] in total number of mature individuals over the next [10 years, or 3 generations].	Yes. Projected reduction of 10 – 40% sand dune habitat declines (30% estimate based on SW SK and E AB becoming stabilized) (Wolfe 2010).
[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.	Yes. Suspected and projected reduction of 10 – 40% sand dune habitat declines (30% estimate based on SW SK and E AB becoming stabilized) (Wolfe 2010).
Are the causes of the decline a) clearly reversible and b) understood and c) ceased?	a. Possibly b. Yes c. No
Are there extreme fluctuations in number of mature individuals?	No

Extent and Occupancy Information

Estimated extent of occurrence	144,280 km²
Index of area of occupancy (IAO)	76 km² (extant sites)

Is the population “severely fragmented” i.e., is >50% of its total area of occupancy is 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, but unknown. b. Yes
Number of “locations”*	13-17; each sand dune/hill represents one location; land management practices at each dune/hill influence the rate of dune succession. Range of locations reflects uncertainty at historical sites
Is there an [observed, inferred, or projected] decline in extent of occurrence?	Yes. Projected based on habitat decline, however, beyond 10 years.
Is there an [observed, inferred, or projected] decline in index of area of occupancy?	Yes. Projected based on habitat decline, however, beyond 10 years.
Is there an [observed, inferred, or projected] decline in number of subpopulations?	Yes. Inferred based on habitat decline (Wolfe 2010).
Is there an [observed, inferred, or projected] decline in number of “locations”?	Yes. Projected based on habitat decline, however, beyond 10 years.
Is there an [observed, inferred, or projected] decline in [area, extent and/or quality] of habitat?	Yes, inferred decline of habitat area/ quality based of sand dune/hill stabilization.
Are there extreme fluctuations in number of subpopulations?	No
Are there extreme fluctuations in number of “locations”*?	No
Are there extreme fluctuations in extent of occurrence?	No
Are there extreme fluctuations in index of area of occupancy?	No

Number of Mature Individuals (in each subpopulation)

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

Quantitative Analysis

Probability of extinction in the wild is at least [20% within 20 years or 5 generations, or 10% within 100 years].	Insufficient data to complete analysis.

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

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

Was a threats calculator completed for this species? Yes. Medium – Low threat impact. 2.1 Annual and perennial non-timber crops (Medium – Low) 7.3 Other ecosystem modifications (Medium – Low) 6.1 Recreational activities (Low) 6.2 War, civil unrest and military exercises (Low) 6.3 Work and other activities (Low)

Rescue Effect (immigration from outside Canada)

Status of outside population(s) most likely to provide immigrants to Canada.	Unknown
Is immigration known or possible?	Unlikely; nearest known population is in North Dakota, approximately 100 km from known Canadian site
Would immigrants be adapted to survive in Canada?	Yes, likely.
Is there sufficient habitat for immigrants in Canada?	Possibly. Suitable habitat is declining but it might not be limiting for immigrants
Are conditions deteriorating in Canada?[†+]	Yes. Habitat quality and quantity declining from dune stabilization
Are conditions for the source population deteriorating?[+]	Yes. Habitat quality and quantity declining from dune stabilization at sites in the United States.
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 Status History: Designated Special Concern in November 2007. Status re-examined and confirmed in November 2018.

Status and Reasons for Designation:

Status: Special Concern	**Alpha-numeric codes:** Not applicable
Reasons for designation: This moth is known from 13 subpopulations restricted to widely-separated active sand hills and dunes on the prairies of Alberta, Saskatchewan, and Manitoba. Natural disturbance processes once maintained these open habitats for the moth. However, wildfire suppression and extirpation of Plains Bison, combined with climate warming, has led to increased vegetation succession. A population decline is inferred at known sites based on vegetation succession that would result in loss of open, active sand hill and dune habitats. Low detectability and some unchecked habitat leave the possibility of a handful of additional subpopulations.	

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

Applicability of Criteria

Criterion A (Decline in Total Number of Mature Individuals): Not applicable.
Criterion B (Small Distribution Range and Decline or Fluctuation): Not applicable. Qualifies for Endangered, B2, because IAO=76 km^2, but does not meet other criteria.
Criterion C (Small and Declining Number of Mature Individuals): Not applicable.
Criterion D (Very Small or Restricted Population): Not applicable.
Criterion E (Quantitative Analysis): Not applicable.

PREFACE

Pale Yellow Dune Moth was assessed by COSEWIC as Special Concern in 2007. Since the initial status report, four additional subpopulations have been recorded in Canada, bringing the total to 13 extant subpopulations within sparsely vegetated sand dune/hill habitat throughout the Prairies ecozone. These additional subpopulations are not considered a range expansion; they are due to a better understanding of the moth's habitat requirements and additional surveys. No documented Pale Yellow Dune Moth subpopulations have been extirpated over the last ten years; however, the species has likely declined from historical levels and is predicted to decline into the future due to ongoing habitat loss from natural vegetation succession and sand dune/hill stabilization.

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
(2018)

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

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

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

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

Environment and Climate Change Canada
Canadian Wildlife Service

Environnement et Changement climatique Canada
Service canadien de la faune

Canada

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

COSEWIC Status Report

on the

Pale Yellow Dune Moth
Copablepharon grandis

in Canada

2018

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WILDLIFE SPECIES DESCRIPTION AND SIGNIFICANCE

Name and Classification

Order: Lepidoptera

Superfamily: Noctuoidea Latreille, 1809

Family: Noctuidae Latreille, 1809 – owlet or cutworm moths

Subfamily: Noctuinae Boisduval, 1828 – flower or dagger moths

Tribe: Agrotini

Genus: *Copablepharon* Harvey, 1878

Species: *C. grandis* (Strecker, 1878)

Subspecies: There are no named subspecies.

Synonyms: *Aedophron grandis* Strecker, 1878
Ablepharon grandis Strecker (1878)
Copablepharon grande Franclemont and Todd, 1983
Copablepharon subflavidens Grote, 1882

Type locality: Arizona, United States of America (US).

Type specimens: lectotype held at Field Museum of Natural History, Chicago, Illinois.

English Common Names: Pale Yellow Dune Moth; Grand Copablepharon was suggested by Hooper (1994)

French Common Name: *Noctuelle jaune pâle des dunes*

Pale Yellow Dune Moth (*Copablepharon grandis*) is a long-standing valid taxonomic entity. Of the 23 species of *Copablepharon* described from North America, Pale Yellow Dune Moth is one of only two species in the *grandis* group (Lafontaine 2004). The other member of the group is *Copablepharon sanctaemonicae*, which is found in sand dunes of the southern Californian coast and does not range in Canada. The *grandis* group is characterized by a narrow, s-shaped clasper of the male genitalia, and elongate, pointed anal papillae in females.

Morphological Description

Pale Yellow Dune Moth has four distinct morphological forms (adult, pupa, larva and egg) and develops through complete metamorphosis.

Adults:

Pale Yellow Dune Moth is a medium-sized moth with pale, uniformly yellow forewings and white hindwings in both sexes (Figure 1). Forewing length varies from 16–20 mm, but there is some geographical variation, with specimens from the Great Basin tending to be smaller than those from the Great Plains, including Canada (Lafontaine 2004). The forewing is typically uniform in colour but may have one or more small dark dots on the subterminal band; hindwings may have dark shading on the margins. The forewing postmedial line is marked by black dots on the veins in some specimens. The costa and fringe are identical to the ground colour. The hindwing median line is also evident as black dots in some individuals, but there is no grey shading (Lafontaine *et al*. 2004; PNM 2017). The head and thorax are yellow like the forewings while the abdomen is light yellow-grey. The male antenna is beaded.

Figure 1. Adult Pale Yellow Dune Moth (*Copablepharon grandis*) in White Evening Primrose (*Oenothera nuttalli*) on July 13, 2016 in the Wainwright Dunes Ecological Reserve, Alberta. Photo by Doug Macaulay.

Eggs:

Pale Yellow Dune Moth eggs are sub-globular and greenish-white, with a shallowly wrinkled upper surface and a smooth underside (Strickland 1920).

Larva:

The larva of Pale Yellow Dune Moth is light brown with white median and lateral lines, and 38 mm long when mature. It was described by Strickland (1920) as like that of Red-backed Cutworm (*Euxoa ochrogaster*) larvae, but more lightly pigmented. Another noteworthy feature is that the D-1 and D-2 setae are similar in size, unlike those in *Euxoa* species (Fauske 1992).

Pupa:

The pupa of Pale Yellow Dune Moth is about 19 mm long with an external sheath (haustellum) enclosing the proboscis (tongue) which extends 2 mm beyond the apex of the abdomen (Figure 2). The cremaster (hook-like tip of the pupae, which is used as an anchor) is short and smooth, and the terminal setae are straight (Lafontaine 2004). Pupation occurs in an earthen cell that is like that of *Euxoa* species (Strickland 1920).

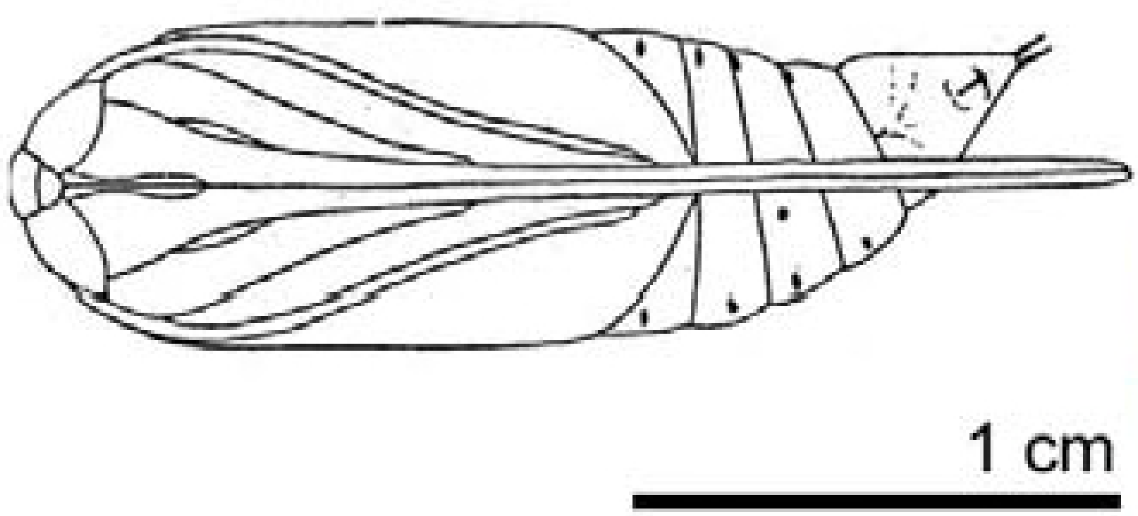

Figure 2. Drawing of Pale Yellow Dune Moth (*Copablepharon grandis*) pupa from Strickland (1920); note the length of the external proboscis sheath (image reproduced with permission).

Similar species:

Adult Pale Yellow Dune moths can be confused with several other *Copablepharon* species within the same habitats and range, particularly old or worn individuals (Crabo pers. comm. 2017; PNM 2017). In Canada, the species is most likely confused with pale forms of *C. viridisparsa*, *C. absidum*, *C. canarianum*, and *C*. *spiritum lutescens*. Antennae, genitalia, and genetic barcodes may need to be examined to identify some *Copablepharon* individuals (Lafontaine pers. comm. 2017). Yellow forms of the cutworm moth, *Euxoa aurulenta*, are often mistaken for Pale Yellow Dune Moth (Lafontaine pers. comm. 2017).

Population Spatial Structure and Variability

The population structure of Pale Yellow Dune Moth, including the boundaries of subpopulations, has not been studied. Sampling records show the moth is found in sparsely vegetated, sandy habitats that are patchily distributed within a matrix of more densely vegetated grasslands, shrublands, and forests. This distribution suggests that subpopulations are connected through dispersal at a local scale (0.5–2 km) but are isolated at a regional scale (COSEWIC 2007b). Although no genetic information is available for Canadian populations, five specimens from Colorado and New Mexico have had their mitochondrial CO1 gene bar-coded (Boldsystems 2017).

Designatable Units

Pale Yellow Dune Moths has one designatable unit in Canada. All Canadian subpopulations fall within the Prairie National Ecological Area (COSEWIC 2017). There are no subspecies. Although there is likely some genetic differentiation among widely separated subpopulations, there is no evidence to suggest they are discrete and evolutionarily significant.

Special Significance

Pale Yellow Dune Moth is a member of a highly specialized sand dune-dwelling community of plants and animals that are restricted to the isolated and widely separated islands of active sand dunes left thousands of years ago by the retreat of the continental glaciers. Pale Yellow Dune Moth and other *Copablepharon* species are of interest to entomologists and other scientists because of their association with isolated dune habitats, a rare and disappearing habitat in Canada.

DISTRIBUTION

Global Range

Pale Yellow Dune Moth is widely distributed in western North America (Figures 3 and 4). In the United States (US) it ranges from southern California east to central Texas, and north to the Canadian Prairies (Alberta [AB], Saskatchewan [SK] and Manitoba [MB]). The species has been recorded from approximately 100 localities in 16 states and three Canadian provinces (Lafontaine 2004; Figure 3). Sampling records suggest it is most prevalent in the arid steppe of the Great Basin and the southern Rocky Mountains (NatureServe 2017). There appears to be a range disjunction, with one group of localities in the southwestern US, and a second group west of the Great Lakes and extending in to the Canadian prairies (see Figure 4); although there is some search effort in this intervening habitat, more sampling is required in the portion of the Great Plains to ascertain its distribution (COSEWIC 2007b; Natureserve 2017). Numerous dune systems in the western US have not been surveyed for *Copablepharon* moths (Lafontaine pers. comm. 2017).

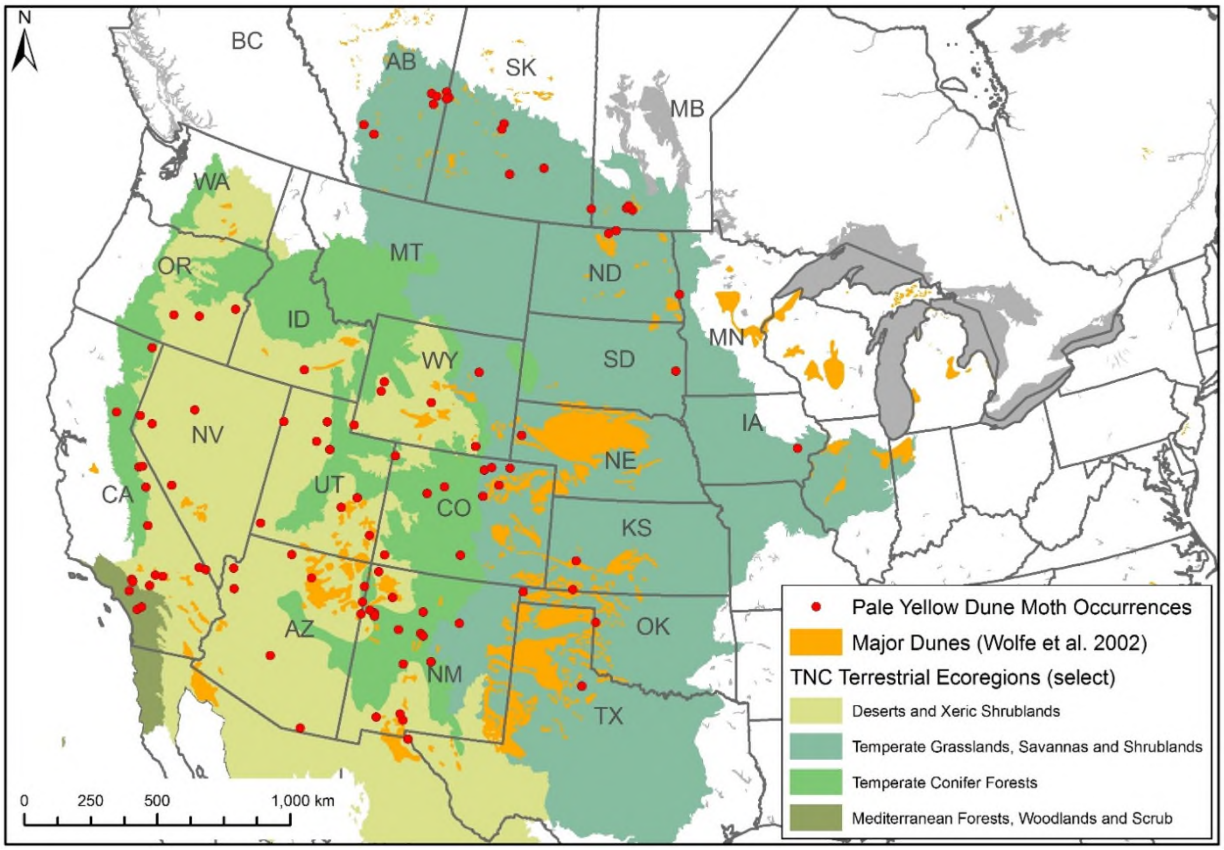

Figure 3. Global records of Pale Yellow Dune Moth (*Copablepharon grandis*) in relation to major dunes and terrestrial ecoregions (The Nature Conservancy; Fisher (pers. comm. 2017); Lafontaine (2004); Opler *et al*. (2017); PNM (2017)).

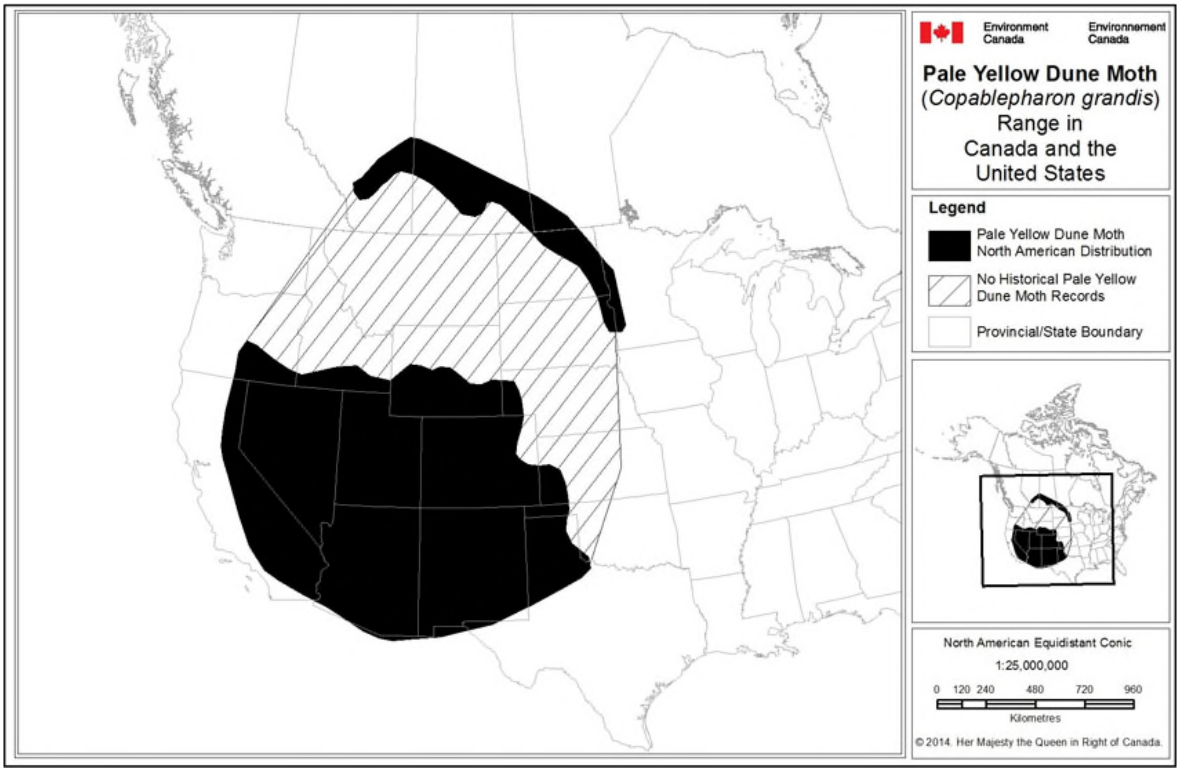

Figure 4. Range of the Pale Yellow Dune Moth (*Copablepharon grandis*) in North America, indicating areas within the range where no historical observations exist (adapted from Lafontaine 2004) (from Environment Canada 2016).

Some Pale Yellow Dune Moth records near the periphery of its range may be erroneous. For example, records in the Pacific Northwest may represent pale or worn specimens of *C. canarianum* (Crabo pers. comm. 2017). The isolated Iowa record, which is over 500 km from the nearest known locality in South Dakota, is supported by a specimen, but no other records are known from the state (Durbin pers. comm. 2017; Summerville pers. comm. 2017). Some of the Arizona records may also be misidentifications (Lafontaine pers. comm. 2017; Wagner pers. comm. 2017).

Canadian Range

The Canadian range of Pale Yellow Dune Moth extends from Spruce Woods Provincial Park in southwestern Manitoba, through southern Saskatchewan to central Alberta (Figure 4). The distribution is not continuous and is contained within small, highly fragmented, discrete areas of suitable habitat.

In Canada, Pale Yellow Dune Moth is known from 17 localities: 13 extant subpopulations and four historical (Table 1, Figure 5). Since the first COSEWIC (2007) status report, four additional subpopulations have been recorded: Wainwright Dunes Ecological Reserve (SK), Dillberry Lake Provincial Park (AB), Carseland (AB), and Canadian Forces Base (CFB) Shilo (MB). The additional localities are a result of additional survey effort, rather than range expansion; the historical range remains unchanged. The exact collection sites of the four historical localities at Calgary (AB, in 1904), Maryfield (SK, in 1980), Fort Qu'appelle (SK, in 1985) and Saskatoon (SK, 1939) are unknown, as precise locality information was not documented and is not displayed on the specimen labels. The exact localities of the historical Aweme collections (1904-1927) are also unknown. Within the Aweme area, potentially suitable habitat is widely distributed in the adjacent Brandon Sand Hills[2] (SH) and the 2017 CFB Shilo subpopulation may overlap with these historical records. The collection site of the 1976 Carseland record has been clarified since the 2016 management plan (Environment Canada 2016) as being along the Bow River near the Gleichen SH (Hilchie pers. comm. 2017). The 1913 record from Monarch (AB) is of a single Pale Yellow Dune Moth larva collected from a "stubble field" that was apparently reared to an adult (Strickland 1920). No specimen is available, and the exact collection locality is unknown, but it is in an area of arid, sandy habitats along the Oldman River (COSEWIC 2007b).

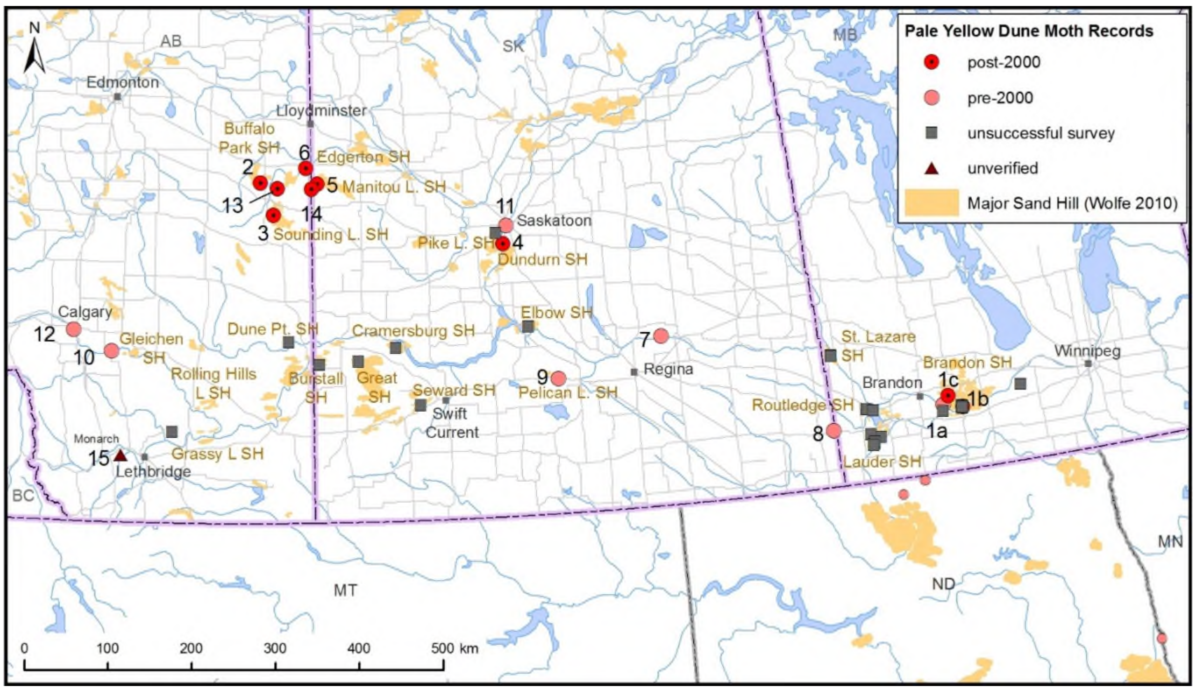

Figure 5. Known Canadian records for Pale Yellow Dune Moth (*Copablepharon grandis*). See Table 1 for site details.

[2] A sand hill is a "mound or hill of sand of either constructional or erosional origin resulting from either physical or anthropogenic processes. A sand hills area is a specific, well-defined occurrence of sand dunes and other sand hills" (David 1977).

A 2010 report of Pale Yellow Dune Moth from Pakowski Lake (AB) is erroneous (Anweiler pers. comm. 2014), as is a 2004 record from southern British Columbia (BC) (Schmidt pers. comm. 2017). A Pale Yellow Dune Moth record from north-central Manitoba (MPG 2017) is likely erroneous (Lafontaine pers. comm. 2017). Three 1917 specimens labelled as *C. grande* from Malahat on Vancouver Island, BC (RBCM 2017) were misidentified (Copley pers. comm. 2017).

Table 1. Canadian specimens of Pale Yellow Dune Moth (*Copablepharon grandis*)[1].

Map Label	Locality[2]	Prov.	Dune Field	Date	Collector(s)	# individuals	Museum	New information since the first status report[3]
1a	Aweme (Historical, nearby habitat)	MB	Brandon Sand Hills	1904-07-03	J. Fletcher	1	CNC	
				1910-07-04	N. Criddle	1	CNC	
				1910-07-10	N. Criddle	1	CNC	
				1911-07-08	N. Criddle	2	CNC	
				1911-07-08	N. Criddle	2	JBWM	Y
				1911-07-12	N. Criddle	1	RSM	
				1911-07-14	N. Criddle	1	RSM	
				1911-07-14	N. Criddle	1	JBWM	Y
				1912-07-28	N. Criddle	1	CNC	
				1915-08-04	N. Criddle	1	CNC	
				1920-07-10	J.B. Wallis	1	RSM	
				1920-07-18	N. Criddle	1	LACM	
				1920-07-23	N. Criddle	1	CNC	
				1920-08-28	N. Criddle	1	CNC	
				1921-07-12	N. Criddle	1	CNC	
				1921-07-15	N. Criddle	2	CNC	
				1921-07-21	J.B. Wallis	1	RSM	
				1923-07-14	J.B. Wallis	2	RSM	
				1925-07-11	J.B. Wallis	2	MMMN	
				1925-07-12	J.B. Wallis	2	RSM	
				1925-07-26	N. Criddle	1	CNC	
				1927-07-15	J.B. Wallis	1	RSM	
				????-??-??	N. Criddle	1	USNM	
				????-07-11	unknown	1	CNC	
				????-07-20	J.B. Wallis	1	RSM	
1b	Spruce Woods Provincial Park – Spirit Sands (Extant)	MB	Brandon Sand Hills	2003-07-21	J. Troubridge, D. Lafontaine	8	CNC	
				2004-07-29	G.G. Anweiler	1	UASM	
				2012-07-17	C. Murray	4		Y
				2012-07-17	C. Murray	1		Y
				2012-07-18	C. Murray	1		Y

Map Label	Locality[2]	Prov.	Dune Field	Date	Collector(s)	# individuals	Museum	New information since the first status report[3]
				2012-07-19	C. Murray	2		Y
				2012-08-08	C. Murray	1		Y
				2012-08-08	C. Murray	3		Y
				2012-08-09	C. Murray	1		Y
				2013-07-30	C. Murray	2		Y
				2013-07-31	C. Murray	2		Y
				2013-07-31	C. Murray	2		Y
				2013-07-31	C. Murray, C. Friesen	3		Y
				2013-08-01	C. Murray	1		Y
				2013-08-01	C. Murray	3		Y
1c	CFB Shilo (Extant)	MB	Brandon Sand Hills	2017-08-14	K.E. Johnson	2	none taken	Y
				2017-08-14	S. Branksky	3	none taken	Y
2	CFB Wainwright (Extant)	AB	Buffalo Park Sand Hills	2005-07-27	N. Page, D. Mou	1	CNC	
				2016-08-2 to 2016-08-05[4]	Stantec Consulting Ltd.	60	NA	Y
3	Provost – Sounding Lake (Extant)	AB	Sounding Lake Sand Hills	2005-07-26	N. Page, D. Mou	2	CNC	
4	CFAD Dundurn (Extant)	SK	Dundurn Sand Hills	2004-08-03	N. Page, D. Mou	14	CNC	
5	Suffern Lake Regional Park – Artland (Extant)	SK	Manitou Lake Sand Hills	2004-07-31	N. Page, D. Mou	1	CNC	
6	Chauvin (13 km N of), Siegner Lake (Extant)	AB	Edgerton Sand Hills [5]	2004-07-25	B.C. Schmidt	15	UASM	
				2004-07-29	G.G. Anweiler	1	UASM	Y
7	Fort Qu'Appelle (unknown, some habitat)	SK		1985-07-22	R. Hooper	1	RSM	
8	Maryfield, Pipestone Valley (Historical, some habitat)	SK		1980-08-15	R. Hooper	1	RSM	
9	Caron (2 mi SW) (unknown)	SK	Pelican Lake Sand Hills	1968-08-21	D.F. Hardwick	1	CNC	
10	Carseland (unknown, some habitat)	AB	Gleichen Sand Hills	1976-07-0	G. Hilchie	?	pers. coll.	Y
11	Saskatoon (unknown site) (Historical)	SK		1939-07-19	K.M. King	1	CNC	
				1939-07-24	K.M. King	1	CNC	
12	Calgary (unknown site) (Historical)	AB		1902-08-09	I.N. Willing	1	CNC	
13	Wainwright Dunes Ecological Reserve (Extant)	AB	Buffalo Park Sand Hills	2016-07-13	D. Macaulay	1	personal collection[6]	Y

Map Label	Locality[2]	Prov.	Dune Field	Date	Collector(s)	# individuals	Museum	New information since the first status report[3]
14	Dillberry Lake Provincial Park (Extant)	AB	Manitou Lake Sand Hills	2016-07-31	D. Macaulay	3	personal collection[6]	Y
				2017-??-??	D. Macaulay	?	personal collection[6]	Y
15	Monarch (Historical, some habitat)	AB		1913-??-??		1	unknown	

[1] Sources: AB CDC (2017); COSEWIC (2007b); E. H. Strickland Museum (2017); Hilchie (pers. comm. 2017); Johnson (pers. comm. 2017), Macaulay (2016, pers. comm. 2017); MB CDC (2017); Northern Forestry Centre (2017); Stantec Consulting Ltd. (2016); J. B. Wallis / R. E. Roughley Museum of Entomology (2017);

[2] Localities labelled to be consistent with Environment Canada (2015) where possible.

[3] New or additional record since COSEWIC 2007b.

[4] No voucher specimens were taken, and Figure 6 of Stantec Consulting Ltd. (2016) suggests that some individuals may have been misidentified.

[5] Although called "Seigner Lake Sandhills" in COSEWIC (2007b), the Chauvin site is actually in the Edgerton Sand Hills as per Wolfe (2010)

[6] To be donated to a provincial collection once survey work is complete (Macaulay pers. comm. 2018)

Extent of Occurrence and Area of Occupancy

The extent of occurrence (EOO) in Canada is approximately 144,280 km^2 using a minimum convex polygon encompassing all 13 extant subpopulations. This value is smaller than the EOO of 184,590 km^2 from the 2007 COSEWIC assessment, due to the exclusion of historical sites at Calgary, Monarch, Saskatoon, and Aweme.

The current index of area of occupancy (IAO) is 76 km^2 (19 - 2 x 2 km grid squares). The previous IAO estimate was less than 50 km^2 (COSEWIC 2007b); the increase is due to the four new subpopulations.

Search Effort

Records for Pale Yellow Dune Moth in Canada are from 1902 – 2017. The species has been captured on 50 dates at 17 localities. Thirteen localities are considered extant subpopulations. There is a minimum of 176 specimens collected and stored in various museums (Table 1).

Trapping for nocturnal moths involves an ultraviolet (UV) or mercury vapour (MV) light set on (or suspended over) a collecting bucket and powered by a closed cell 12 volt battery. Vanes may or may not be used to direct moths through a funnel into the holding bucket, which usually holds some carton or other shelter, possibly with a killing agent. Mercury vapour lights have also been less frequently used in conjunction with a white sheet suspended from a frame (e.g., at CFB Shilo in 2017 [Government of Canada 2017b]). Traps are used from dusk to dawn, often with a photovoltaic timer to preserve battery life. Multiple traps have often been used at a site to sample both open sand and semi-stabilized habitats. Most sites have had limited trapping, often only one night, that focused on confirming presence (null results do not confirm absence). These methods are considered effective for surveying Pale Yellow Dune Moth (Anweiler pers. comm. 2018; Schmidt pers. comm. 2017).

Surveys in preparation for the first COSEWIC (2007b) status report totalled 28 trap-nights at ten sites with potentially suitable habitat between July 31–August 6, 2004 and July 23–27, 2005 in southern Saskatchewan and Alberta (Table 2). Pale Yellow Dune Moths were captured in six traps from four sites: Canadian Forces Ammunition Depot (CFAD) Dundurn, CFB Wainwright, Sounding Lake, and Suffern Lake Regional Park (Table 1), with the latter three being new Canadian records (Figure 5). Additional sampling was undertaken in 2004 and a new locality was found near Chauvin (SK) (Tables 1 and 2; Figure 5). Although the larger Edgerton SH approximately 14 km southwest of the Chauvin site have been extensively trapped over several years, Pale Yellow Dune Moth has not been recorded, perhaps due to the coarser sand, fewer blowouts[3], and vegetation that is more parkland than prairie (Schmidt pers. comm. 2017).

Table 2. Search effort for moths in the Canadian prairies (Alberta [AB], Saskatchewan [SK] and Manitoba [MB]).

Date	Province	Survey details	Reference
2000 – 2011 (not yearly)	AB	Most sand dunes in the province were surveyed during this time including: • Edgerton • Canadian Forces Base (CFB) Wainwright • Sandy Point/Empress (more riparian type sand type) • Pakowski Dunes • Jasper Lake dunes • Dune Point (east of Empress Dunes) • Opal dunes north of Edmonton (Boreal ecozone but have some southern species present) • Redwater dunes north of Edmonton (Boreal ecozone but have some southern species present) • Kootenay Plains west or Nordegg (sandy ecosystem but not dunes). • There are other smaller dunes that would have had more sporadic sampling.	Anweiler pers. comm. 2018; Schmidt pers. comm. 2018
2004	SK	• Chauvin (Pale Yellow Dune Moth confirmed at this site) • Edgerton Sand Hills, approximately 14 km southwest of Chauvin, have been extensively trapped over several years although Pale Yellow Dune Moths have been found, perhaps due to the coarser sand, fewer blowouts, and vegetation that is more parkland than prairie.	Schmidt pers. comm. 2018
2004	SK	• North Burstall Sand Dunes • Suffern Lake Regional Park • CFB. Dundurn, Saskatoon • Douglas Provincial Park • southeast Elbow • Seward Sand Dunes and • Northeast Webb.	COSEWIC 2005

[3] A blowout "refers to a small, typically less than one hectare in size, area of wind-blown sand, which is commonly bowl shaped and somewhat elongated in the direction of transporting winds. Thus, road tracks, all-terrain vehicle trails, cattle trails, oil/gas well pads, dugouts, cattle-disturbed areas around water wells sites and ranches, and sand pits" are not considered to be natural wind-blown blowouts (Wolfe 2010).

Date	Province	Survey details	Reference
2003 - 2007	MB	Spirit Sand Dunes and other sand habitats during preparation of the White Flower Moth (*Schinia bimatris*) COSEWIC (2005) status report and subsequent surveys as part of recovery actions for the species.	COSEWIC 2005, Westwood and Friesen 2009; MB CDC unpublished data
2004 – 2005;	AB, SK	July 31–August 6, 2004 and July 23–27, 2005. 28 trap-nights at ten sites with potentially suitable habitat. Pale Yellow Dune Moths were captured in six traps from four sites: • Canadian Forces Ammunition Depot (CFAD) Dundurn, • CFB Wainwright, • Sounding Lake, and • Suffern Lake Regional Park (Table 1), with the latter three being new Canadian records for the species. See Figure 5 for survey sites and COSEWIC (2007b) for details.	COSEWIC 2007b
2008-2011	AB, SK, MB	A total of 16 sites in 13 sand hills were surveyed using light traps; no Pale Yellow Dune Moths were caught but several other sand dune specialist species (e.g., *C. viridisparsa* and *Cucullia luna*) were collected.	Curteanu *et al*. 2011
2009	AB	A total of 11 trap-nights (one trap for 1 night = 1 trap-night) at 11 dune complexes in southern AB	Anweiler 2009
2009 - 2011	AB, SK, MB	While conducting surveys for two other moth species at risk (*Schinia avemensis* and *Copablepharon longipenne*)	Belair *et al*. 2011, Curteanu pers. comm. 2013
2009 - 2013	MB	Sand dune complexes – larger open sand areas • Bald Head Hills (Spruce Woods-CFB Shilo-Carberry sand dune complex) • Lauder • Portage-St. Claude • Routledge-Oaklake • Brandon (n=22 trap-nights) • Lauder (n=9), Portage (n=1) • St. Lazare (n=5) • Routledge (n=3) and Treesbank Sand Hill (n=1) sand hills. • A total of 28 individuals were caught in the Spirit Sands of Spruce Woods Provincial Park within the Brandon SH's, but at no other site	Friesen and Murray 2010, 2011; Murray and Friesen 2012; Murray 2013, 2014; Murray and Church 2015
2015	SK	Dune Point Sand Hills and Burstall Sand Dunes. Pale Yellow Dune Moth was not recorded.	Curteanu pers. comm. 2017; Snable pers. comm. 2015
2015-2016	AB	Surveys confirmed Pale Yellow Dune Moth at Wainwright Dunes Ecological Reserve and nearby Dillberry Lake Provincial Park	Macaulay 2016; Macaulay pers. comm. 2017
2016	AB	20 trap-nights were conducted during targeted surveys at CFB Wainwright. A total of 60 Pale Yellow Dune Moths were caught at 9 of 12 sites, within about 4 km of each other in the Buffalo Sand Hills at the southern periphery of the base	Stantec Consulting Ltd. 2016

No fieldwork associated with the preparation of this 2018 COSEWIC update report was undertaken; other surveys for both Pale Yellow Dune Moth and other rare prairie dune/hill moths are described below and summarized in Table 2 and Figure 5.

Alberta:

Between 2000 and 2011 (although not yearly) most of the sand dune habitat in Alberta was surveyed for sand dune obligate moths including the Pakowski Dunes and the dunes at Jasper Lake in 2006 – 2011 (Schmidt pers. comm. 2018). Other sand ecosystems include Edgerton, Wainwright, Sandy Point/Empress (more riparian type sand type), Dune Point (east of Empress Dunes), Opal and Redwater dunes north of Edmonton (these sandy sites are more in the Boreal ecozone but have some southern species present), sandy area at Kootenay Plains west or Nordegg (sandy ecosystem but not dunes). There are other smaller dunes that would have had more sporadic sampling (Anweiler pers. comm. 2018; Schmidt pers. comm. 2018).

In 2016, 20 trap-nights from August 20-23, 2016 at CFB Wainwright (Stantec Consulting Ltd. 2016) recorded 60 putative Pale Yellow Dune Moths at 9 of the 12 sites, within about 4 km of each other in the Buffalo SH at the southern periphery of the base[4]. Recent (2015 - 2016) trapping with light-traps at Wainwright Dunes Ecological Reserve and nearby Dillberry Lake Provincial Park confirmed new occurrences of Pale Yellow Dune Moth at both habitats (Macaulay 2016; pers. comm. 2017).

Targeted surveys for Pale Yellow Dune Moths and other dune taxa were conducted in AB, SK and MB in 2008-2011 (Curteanu *et al.* 2011). A total of 16 sites in 13 sand hills were surveyed using light traps; no Pale Yellow Dune Moths were caught but several other sand dune specialist species (e.g., *C. viridisparsa and Cucullia luna*) were collected. Additional unsuccessful surveys were also conducted in 2015 at Dune Point SH and Burstall Sand Dune (Curtenau pers. comm. 2017; Snable pers. comm. 2015). The lack of success in finding Pale Yellow Dune Moths in these sand hills where other *Copablepharon* species occur could suggest that some other factor (e.g., climate, dispersal) may limit habitat use by this species in this area west of Saskatoon (i.e., the Palliser Triangle).

Saskatchewan:

There are at minimum five suitable sand dune sites surveyed where Pale Yellow Dune Moth would have been noted: North Burstall Sand Dunes, Suffern Lake Regional Park, CFB Dundurn, Saskatoon, Douglas Provincial Park, southeast Elbow, Seward Sand Dunes, and northeast Webb. Light traps were deployed only at North Burstall Sand Dunes for one night totalling six traps (COSEWIC 2005).

[4] The very high number of individuals caught relative to other surveys and lack of confirmed specimens raises some concern about potential misidentifications.

Manitoba:

In 2003 and 2007, extensive black light trapping occurred in the Spirit Sand Dunes (COSEWIC 2005, Westwood and Friesen 2009) and between 2009 and 2014, extensive day surveys (54 sites) and night surveys using black-light trapping (50 trap nights) were conducted in sand dune complexes (Table 2). Survey sites targeted larger open sand areas in the Bald Head Hills (Spruce Woods-CFB Shilo-Carberry sand dune complex) and adjacent smaller sand complexes at Brandon (n=22 trap-nights), Lauder (n=9), Portage (n=1), St. Lazare (n=5), Routledge (n=3), and Treesbank SH (n=1) sand hills (Friesen and Murray 2010; Friesen and Murray 2011; Murray and Friesen 2012; Murray 2013; Murray 2014; Murray and Church 2015). A total of 28 individuals were caught in the Spirit Sands of Spruce Woods Provincial Park within the Brandon SH, but at no other locality.

Between 2009 and 2011 in AB, SK and MB, Pale Yellow Dune Moth may have been recorded while conducting surveys for *Schinia avemensis* and *Copablepharon longipenne* (Belair *et al*. 2011, Curteanu pers. comm. 2013). There has been extensive trapping in the appropriate habitat and time of year in at least the Middle SHs / CFB Suffield and the dunes near Burstall (SK), and Great SHs (AB), and there is reasonable confidence that Pale Yellow Dune Moth is not in these habitats (Schmidt pers. comm. 2018).

A recent physiographic inventory of dunes and blowouts[5] in the sand hills of the Canadian Prairie provinces (Wolfe 2010) suggests there remains some potential Pale Yellow Dune Moth habitat in need of additional survey. The 23 sand hills within the Canadian range of Pale Yellow Dune Moth encompass 78 mapped dunes and 607 blowouts that together represent over 700 ha of bare sand area. Some of these areas have been surveyed (see Figure 5). There may be as many as 200 1-km^2 grid squares that contain at least some potentially suitable habitat based on interpretation of satellite imagery (COSEWIC 2007b; Wolfe 2010), most of which has not been completely surveyed. Much of this potential habitat is within the current Canadian extent of occurrence (see Extent of Occurrence and Area of Occupancy), and most would be if the extent of occurrence includes the historical records.

[5] A *sand dune* is a "mound, hill or ridge of windblown sand, either bare or variously covered by vegetation, capable of movement from place to place through the development of a slip face, but always retaining its own characteristic shape for an extended period" (David 1977).

A *blowout* "refers to a small, typically less than 1 hectare in size, area of windblown sand, which is commonly bowl shaped and somewhat elongated in the direction of transporting winds. Thus, road tracks, all-terrain vehicle trails, cattle trails, oil/gas well pads, dugouts, cattle-disturbed areas around water wells sites and ranches, and sand pits" are not considered to be natural windblown blowouts (Wolfe 2010).

The term *sand hills* refer to a well-defined geographic region where several sand dune occurrences exist (David 1977).

Although Pale Yellow Dune Moths appear to use semi-stabilized dunes adjacent to open sand areas rather than bare sand itself (see *Habitat Requirements*), this suggests potentially suitable habitat remains to be surveyed. Additional subpopulations in the Canadian prairies likely occur in some of these unsurveyed sandy grassland edges with appropriate habitat (e.g., Bushy Lake SH, Maskwa Lake SH) (Page pers. comm. 2017), and further investigation is required (Environment Canada 2016). Regardless, the habitat that remains is widely separated and amounts to a small overall area of habitat (i.e., less than 700ha), Pale Yellow Dune Moth appears to occur in low abundance making detection difficult, and this habitat is declining in the longer-term due to vegetation stabilization (see **Habitat Trends** and **Threats**).

HABITAT

Habitat Requirements

Pale Yellow Dune Moths occur in sparsely vegetated grasslands with patches of open sand, but do not appear to require habitats with large areas of active sand movement (COSEWIC 2007b). Suitable habitat seems to occur in the transition between open active dunes with frequent sand movement, and stable dunes that are fully vegetated with little or no open sand (Environment Canada 2016). They do not appear to use habitats with dense vegetation or grass thatch, and may require open sand for egg-laying and larval development, including winter diapause (COSEWIC 2007b; Environment Canada 2016). The sand substrate may offer a humid and stable microclimate during the vulnerable pupal stage, and may facilitate the burrowing activity during the larval feeding on plant roots.

In Canada, Pale Yellow Dune Moths have been captured in or near sandy blowouts, dune ridges, road cuts, and unvegetated fire guards (COSEWIC 2007b) (Figure 6). Road cuts and other disturbed areas can be a source of open sand in otherwise stabilized sand dunes (COSEWIC 2007b; Johnson pers. comm. 2017). Most Pale Yellow Dune Moth subpopulations are in sand hills comprised of glaciofluvial or glaciodeltaic sand deposits that have been reworked into dunes by wind at varying times throughout the Holocene (Wolfe 1997, 2002, 2010) (Figure 6). Three Canadian Pale Yellow Dune Moth subpopulations (Maryfield, Fort Qu’appelle, and Carseland) occur in sandy, eroded areas that are not characterized as sand hills. In Oregon and Idaho, Pale Yellow Dune Moth is restricted to sandy riparian habitats, where it is relatively rare (Hammond pers. comm. 2017).

Figure 6. Habitat characteristics of sites where Pale Yellow Dune Moth has been collected a) open blow-out near Artland, SK ; b) semi-stable blowout near Dundurn, SK; c) human-made fireguard near Dundurn, SK); d) large south-facing semi-stable dune at CFB Wainwright, AB; e) sand exposure along disturbed roadside in Sounding Lake, AB area; and f) at the Wainwright Dunes Ecological Reserve, AB. Photos a-e) by N.A. Page (with permission); photo f) D. Macaulay (with permission).

Pale Yellow Dune Moth does not appear dependent on a specific host-plant for feeding, laying eggs, or nectaring (see **Biology**). However, it is often associated with certain ecological communities such as midgrass and bunchgrass prairies (Fauske 1992). In AB, Pale Yellow Dune Moth subpopulations are recorded in: 1) Sand Grass–Sand Dropseed–Hay Sedge (*Calamovilfa longifolia - Sporobolus cryptandrus - Carex siccata*) herbaceous vegetation or 2) Creeping Juniper–Sand Grass–Sun-loving Sedge dwarf shrubland (*Juniperus horizontalis / Calamovilfa longifolia – Carex pensylvanica* ssp. *heliophile*) (Coenen 2003). These two communities develop on sloped, well-drained sandy soils with some sand movement; the former has approximately 60% open sand while the latter has 30%). Although ecological communities in semi-stable, sparsely vegetated sand dunes in AB, SK and MB vary regionally, they are often similar in structure (COSEWIC 2007b).

The habitat in which Pale Yellow Dune Moths were recently found in Wainwright Dunes Ecological Reserve and Dillberry Lake Provincial Park was described as sandy grassland with patches of bare sand as well as patches of forbs and shrubs (e.g., Thin-leaved Snowberry (*Symphoricarpos albus*) and Chokecherry (*Prunus virginiana*)) (Macaulay pers. comm. 2017) (Figure 6). Semi-stabilized dunes are 5 – 10 m high at Wainwright (Figure 6) and lower at Dillberry Lake.

At CFB Shilo near Aweme (MB), Pale Yellow Dune Moths habitat is gently hilly, dry, mixedgrass prairie dunes with a few areas of exposed sand and scattered groves of poplar (*Populus spp.*), White Spruce (*Picea glauca*), and cherry (*Prunus spp.*); both collection sites were near extensive exposed sand at the roads and fire lanes, as well as a few blowouts (Johnson pers. comm. 2017). At Spirit Sands in Spruce Woods Provincial Park, Pale Yellow Dune Moths were caught in traps set from 10-50 m from the dune face in stabilized open White Spruce forest (Murray 2013). It is unknown if the moths were blown into this habitat, attracted by the trap's night light, or actively use the habitat.

Habitat Trends

Sandy soils are widespread in the southern Canadian prairies and are composed of glaciofluvial, glaciolacustrine, and deltaic sediments from the last glaciation that have been reworked by wind action (David 1977). However, dune stabilization has affected most dune systems in the Canadian prairies in the last 200 years. Most sandy habitats are now stable, vegetated, and lack open sand patches except in isolated blowouts, drier dune ridges, road cuts, and other disturbed sites. Pale Yellow Dune Moth appears to be associated with transitional habitat that occurs between active dunes and stable, sandy grasslands. Vegetation succession on dunes often leads to the development of heavily vegetated sandy grassland that may exclude Pale Yellow Dune Moths. For example, exposed sand in the blowout shown in Figure 6b will likely be lost as vegetation, such as Creeping Juniper and bryophytes, colonizes these open sites.

Trends in Pale Yellow Dune Moth habitat in Canada are therefore largely driven by the patterns of dune activity and stabilization in the southern Prairies. These dune systems are derived from sandy deposits left behind by the receding Laurentide Ice Sheet and reworked by aeolian and other processes (Hugenholtz *et al.* 2010). Dune activity depends on climatic and biological or anthropogenic factors that control sediment availability and/or transport capacity (Muhs and Wolfe 1999; Hugenholtz and Wolfe 2005b). Stratigraphic and chronological studies (e.g., Dean *et al.* 1996; Wolfe *et al.* 2002, 2004, 2006) document a history of alternating periods of dune activity and stability across the Prairies during the last 10,000 years. Following an active period of approximately 80 years during the 1800s, archival aerial photographs and satellite imagery document widespread dune stabilization across the southern Canadian prairies since the early 1900s, despite periodic drought intervals (Hugenholtz and Wolfe 2005a; Wolfe *et al.* 2001, 2007).

Many active dunes have been stabilized by vegetation at a rate of 10-40% per decade, and less than 1% of the sand hill area in the Canadian prairies is currently active with bare sand (Wolfe 2010). Between 1928 and 2006, the open sand area within the 1350 km^2 Brandon SH decreased by 95% (Hugenholtz *et al.* 2010; Wolfe et al. 2000), and only about 80 ha of open sand dune remains (Wolfe 2010). Much of this open area is within Spirit Sands (Spruce Woods Provincial Park), where Pale Yellow Dune Moths were first recorded in 2012 (Table 1). The species also persists in the Brandon SH at CFB Shilo (Table 1), where military activities maintain some open sand areas (e.g., roads) in a matrix of more stabilized dune habitat (Johnson pers. comm. 2017). Many smaller sand hills with minor levels of dune activity in the mid-1900s now sustain only small pockets of active sand (Hugenholtz *et al.* 2010). The semi-stabilized periphery around these open sand areas represents potentially suitable Pale Yellow Dune Moth habitat, although with increasing stabilization these areas may become unsuitable for this species.

Although regional climate is the primary driver over the long term, widespread irrigation, the extirpation of Plains Bison (*Bison bison bison*) herds, and the suppression of fires have also been cited as factors contributing to dune stabilization in the 1900s (Wolfe and Nickling 1997; Forman *et al.* 2001; Hugenholtz *et al.* 2010). Although climate explains a significant portion of the historical trend towards dune stabilization at a regional scale, disturbance accounts for the persistence of some active dunes and blowouts in areas that are otherwise stabilized by vegetation (Hugenholtz *et al.* 2010). Threats from fire, cultivation, logging, off-road vehicle traffic and livestock grazing can increase or restore dune activity and lead to the development of new generations of dunes (Hugenholtz *et al.* 2010). Blowouts develop when a localized disturbance produces a breach in the vegetation cover, thus enabling deflation by wind (Wolfe and Nickling 1997). Vegetation growth is inhibited where high wind stress and low moisture availability prevail, such as windward and south-facing slopes (Hugenholtz and Wolfe 2005b). The process of dune stabilization tends not to be a linear function of time, with stabilization slowing and following a negative exponential function in later stages (Hugenholtz and Wolfe 2005b). This might account for the persistence of some base level of dune activity (Wolfe *et al.* 2007).

In addition to habitat loss, dune stabilization results in a more fragmented habitat as active dune areas shrink and disappear, likely with adverse impacts on Pale Yellow Dune Moth metapopulation dynamics. Under these dynamics, even a small loss of habitat, such as a centrally placed, partially stabilized dune, can significantly reduce subpopulation persistence (e.g., see Bascompte and Soulé 1996), especially if dispersal among sand dunes is disrupted by the loss of a ‘stepping-stone’ habitat patch (Hugenholtz *et al.* 2010; see *Dispersal and Migration*).

Although dune activity is expected to continue to decline in the coming decades under the present climate and disturbance regimes (Wolfe 2010), dunes are extremely sensitive to climatic variability and the potential for reactivation is high (Muhs and Holliday 1995). Although regional reactivation of sand dunes may require several decades (Wolfe 1997; Wolfe *et al.* 2001), this may eventually result in an increasing amount of suitable habitat for Pale Yellow Dune Moths if subpopulations remain nearby to recolonize it.

BIOLOGY

The biology of Pale Yellow Dune Moth is poorly known. This nocturnal moth with a short summer flight season is only rarely observed.

Life Cycle and Reproduction

Like all Lepidoptera, Pale Yellow Dune Moth undergoes complete metamorphosis with egg, larval, pupal and adult life stages. Larval and pupal life stages have not been described; however, Strickland (1920) collected a fourth instar larva on May 9, 1913 in a “stubble field” at Monarch, AB. This larva was “found below ground, among other cutworms, and it fed freely on alfalfa and to some extent on barley”. When mature, the larva measured 1½ inches (38 mm), and by July 5 it had pupated in an earthen cell. The captive adult laid eggs in the soil (Strickland 1920). No specimen is available to confirm the identification.

Eggs are fully formed in newly emerged adult females, but mating and egg-laying have not been observed (COSEWIC 2007b). Eggs are believed to be deposited in loose, sandy soil, and based on observations in the related Dusky Dune Moth (*C. longipenne*), eggs may hatch approximately three weeks later (COSEWIC 2007a). Based on Strickland’s (1920) observations and some other *Copablepharon* behaviour, larvae are believed to feed nocturnally on a variety of plant species and spend the day buried in the sand (Macaulay pers. comm. 2017). They may also feed on below-ground roots and shoots (COSEWIC 2007b). Larval growth likely occurs between hatching in August and the onset of cool weather in October. Larvae may undergo a below-ground diapause between the fall and early spring, although the microsite and depth of burial are unknown (COSEWIC 2007b). Spring or early summer feeding may also occur prior to pupation as observed in Dusky Dune Moth (COSEWIC 2007a). The pupal stage likely begins in late June or early July in Canada (July 5 for Strickland’s captured specimen) and pupation occurs in an “earthen cell” below ground (Strickland 1920).

The flight period of Pale Yellow Dune Moth in Canada (based on Canadian specimen observations) is from July 3 to August 14, with a peak around late July (Table 1). Reproduction coincides with the flight season, and adults likely die shortly after reproducing. Sex ratios (based on collection information) are generally evenly split. Adults are nocturnal, but appear to be most active shortly after nightfall, possibly due to rapidly dropping air temperatures in open dune habitats. Larvae are active at and shortly after dusk (Macaulay pers. comm. 2018) and have been observed resting inside White Evening Primrose (*Oenothera nuttalli*) (Macaulay 2016; Schmidt pers. comm. 2017). *Copablepharon* spp. have an unusually long proboscis for a noctuid (similar in length to a small sphingid moth) and they might nectar preferentially at flowers with deep nectaries (Schmidt pers. comm. 2017), such as White Evening Primrose.

Physiology and Adaptability

Little is known about the physiology and adaptability of Pale Yellow Dune Moth. The influence of climate on Pale Yellow Dune Moth distribution is not known, but low temperatures may limit its northern distribution. The lack of captures from the dune systems in the Palliser Triangle may also be related to climatic factors. However, the species is found across a broad latitudinal gradient in North America with a correspondingly wide variation in precipitation and temperatures.

Observations to date indicate Pale Yellow Dune Moth is not dependent on a unique host-plant for feeding or laying eggs. A Pale Yellow Dune Moth larva fed on both a common legume species (Alfalfa, *Medicago sativa*) and a grass species (barley, *Hordeum* sp.), while reared in captivity (Strickland 1920), suggesting the moth is a generallist feeder. In addition, the species does not appear to have specific or obligate host plants. The moth has not been observed using leaves or flowers for ovipositing, and sand may be the preferred medium for egg deposition (COSEWIC 2007b).

Dispersal and Migration

The dispersal abilities of Pale Yellow Dune Moth have not been documented (COSEWIC 2007b; Environment Canada 2016). Sand dunes and sandy grasslands in the southern Canadian prairies are widespread, rare, discontinuous, and often separated by large patches of habitat not suitable for dune moths; therefore, local subpopulations may be isolated (Environment Canada 2016). *Copablepharon* species that have been observed in the field: i.e., Sand-verbena Moth (*C. fuscum*) and Dusky Dune Moth (*C. longipenne*), are strong fliers (COSEWIC 2003, 2007a). Given that dune habitats are often patchily distributed across the landscape (100 m to 2 km apart), it is likely that dispersal occurs infrequently at this scale. However, dispersal between regionally isolated dune systems (>10 km) is unlikely or infrequent (COSEWIC 2007b). The potential for long-distance dispersal has likely declined as agricultural activity has developed the landscape between sandy habitats. There is no information that suggests that Pale Yellow Dune Moth migrates.

Interspecific Interactions

Interspecific interactions such as predation, parasitism, and disease have not been documented for Pale Yellow Dune Moth. Like most Lepidoptera, Pale Yellow Dune Moths are undoubtedly subject to competition, predation and parasitism by a variety of insects, birds, and other animals during all life stages. Songbirds were observed feeding on adult Dusky Dune Moths in the Great SH and Burstall Sand Dunes in July 2004 and may also consume Pale Yellow Dune Moths (COSEWIC 2007b). Pale Yellow Dune Moths are often captured with *C. viridisparsa*, but it is unknown whether there is any competition between the species (COSEWIC 2007b).

POPULATION SIZES AND TRENDS

Sampling Effort and Methods

There have been no studies to assess the Canadian population or individual subpopulations of Pale Yellow Dune Moth. Moths have been recorded in high abundance at the Spirit Sands area of Spruce Woods Provincial Park, which has had the most intensive sampling effort, with a combined total of 25+ trap-nights of effort in 2003-2004 and 2012-2013 (MB CDC unpublished data; Table 1). See Search Effort for survey methodology. During 2004-2005 fieldwork, 18 Pale Yellow Dune Moth specimens were captured in 28 trap-nights, with up to 12 Pale Yellow Dune Moths per trap (COSEWIC 2007b).

Abundance

There are no quantitative data available on population sizes for Pale Yellow Dune Moth in Canada. The total number of occupied habitat patches in Canada and the number of moths at these sites is unknown. The focus of most surveys has not been total counts, and no mark-recapture studies have been conducted to estimate population or subpopulation size for this species. Sequential visits at individual sites during the same flight season have generally been lacking, so the number of individuals caught on any single visit likely represents only a fraction of the subpopulation at that site. Subpopulation sizes of many moth species vary greatly from year to year due to weather and other factors (Pohl *et al.* 2004). During moth surveys at Chauvin (SK) in 2004, 15 Pale Yellow Dune Moth were captured in five UV light-traps while sampling for *Schinia* species in sandy grassland. These captures represent less than 1% of the total number of moths captured in these sites, an indication of the low local abundance of the species (Schmidt pers. comm. 2018).

Pale Yellow Dune Moth was first recorded in Canada in 1902 and in total at least 176 specimens have been caught or observed in Canada (Table 1). The greatest number of Pale Yellow Dune Moths (n=60) has been captured at CFB Wainwright in the Buffalo Park SHs, although this may be a function of greater sampling effort (some specimens may have been misidentified, as no voucher specimens were taken). At least 44 have been caught in the Spirit Sands (Spruce Woods Provincial Park). These may be part of the largest population of Pale Yellow Dune Moth given the extensive potential habitat in the Brandon SH, the 2nd largest sand hill area in Canada after the Great SH in SK.

Fluctuations and Trends

There is no quantitative information on the Canadian population or individual subpopulation fluctuations and trends for the Pale Yellow Dune Moth. The progressive stabilization and loss of active dune complexes in Canada during the past 100 years (Wolfe *et al.* 2000) has likely resulted in a corresponding reduction in the size and number of Pale Yellow Dune Moth subpopulations during that period. Pale Yellow Dune Moth has persisted in the Brandon SHs for more than 100 years (Table 1), but its abundance has likely declined with a loss of semi-stabilized dune habitat on the periphery of open sand areas (see *Habitat Trends*). Captures of Pale Yellow Dune Moths at CFAD Dundurn in 2004 confirm its continuing presence in the Saskatoon area (the precise locality of the 1939 Saskatoon record unknown) (Table 1).

Rescue Effect

The nearest known US records of Pale Yellow Dune Moth are from Turtle Mountain, North Dakota, approximately 100 km south of the closest Canadian locality at Spruce Woods Provincial Park (MB). It is unknown if the Turtle Mountain population is extant, the intervening landscape has been heavily developed by agriculture (based on GoogleEarth imagery), and recolonization over this distance is unlikely (COSEWIC 2007b).

THREATS AND LIMITING FACTORS

The progressive stabilization of semi-stabilized sand dune habitat at extant subpopulation habitats is the most significant threat to Pale Yellow Dune Moth (COSEWIC 2007b; Environment Canada 2016). This natural process is largely driven by regional climate trends, but has accelerated over the last 150 years, in part due to decreasing aridity, reduced wildfire, extirpation of Plains Bison, and other factors. Threats are described below using categories outlined in the International Union of Conservation Networks (2013) threats assessment calculator. The assigned threat impact for Pale Yellow Dune Moth is Medium-Low. Threats that are scored or unknown are discussed below and negligible/non-threats addressed in Table 3.

Table 3. Results for the Pale Yellow Dune Moth (*Copablepharon grandis*) 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 website (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) and table footnotes for details.

Species:	Pale Yellow Dune Moth (*Copablepharon grandis*)
Assessors:	December 2017 teleconference call: Jennifer Heron (Arthropods SSC Co-chair), Paul Grant (Arthropods SSC co-chair), Diana Ghikas (CWS, Regina), Syd Cannings (CWS COSEWIC Member, Whitehorse), Brian Starzomski (Arthropods SSC Member), Angèle Cyr (COSEWIC Secretariat), Rob Foster (status report author), John Klymko (Arthropods SSC Member). January 2016 teleconference call: Jennifer Heron (Arthropods SSC Co-chair), Diana Ghikas (CWS, Regina), Victoria Schnable (CWS, Edmonton), Syd Cannings (CWS COSEWIC Member, Whitehorse), Brian Starzomski (Arthropods SSC Member), Angèle Cyr (COSEWIC Secretariat).
References:	Pale Yellow Dune Moth Management Plan (Environment Canada 2016); COSEWIC Report on Pale Yellow Dune Moth (COSEWIC 2007); White Flower Moth updated COSEWIC Report (COSEWIC 2014) and other sand ecosystem species with a similar range and habitat.

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	2	0
D	Low	1	3
	Calculated Overall Threat Impact:	Medium	Low
	Assigned Overall Threat Impact:	Medium - Low	

Threat		**Impact[1] (calculated)**	**Scope[2] (next 10 Yrs)**	**Severity[3] (10 Yrs or 3 Gen.)**	**Timing[4]**	**Comments**
1	Residential and commercial development	Negligible	Negligible (<1%)	Negligible (<1%)	Moderate (Possibly in the short term, < 10 yrs/3 gen)	
1.1	Housing and urban areas	Negligible	Negligible (<1%)	Negligible (<1%)	Moderate (Possibly in the short term, < 10 yrs/3 gen)	Not considered threats; semi-stabilized dune areas are generally unsuitable for these types of development.
1.2	Commercial and industrial areas	Negligible	Negligible (<1%)	Negligible (<1%)	Moderate (Possibly in the short term, < 10 yrs/3 gen)	Not considered threats; semi-stabilized dune areas are generally unsuitable for these types of development.
1.3	Tourism and recreation areas	Negligible	Negligible (<1%)	Negligible (<1%)	Moderate (Possibly in the short term, < 10 yrs/3 gen)	Hiking trail expansion at Spruce Woods Provincial Park or federal lands (e.g., military lands) is unlikely.
2	Agriculture and aquaculture	Medium - Low	Restricted - Small (1-30%)	Serious - Slight (1-70%)	High (Continuing)	
2.1	Annual and perennial non-timber crops	Medium - Low	Restricted - Small (1-30%)	Serious - Slight (1-70%)	High (Continuing)	Due to the very dry and sandy soils of Pale Yellow Dune Moth (PYDM) habitat and surrounding areas, conversion to agricultural crop or forage production is not likely. However, some irrigated potato farming and haying occurs in marginal adjacent areas in southern AB and MB.

Threat		Impact[1] (calculated)	Scope[2] (next 10 Yrs)	Severity[3] (10 Yrs or 3 Gen.)	Timing[4]	Comments
2.2	Wood and pulp plantations	Not Calculated (outside assessment timeframe)			Insignificant/ Negligible (Past or no direct effect)	Historically trees were planted to provide windbreaks for areas prone to severe wind erosion. However, they were not planted directly within occupied moth habitat and may promote encroachment and stabilization and thereby indirectly affect open sand dune habitat further downwind.
2.3	Livestock farming and ranching	Not a Threat	Large - Restricted (11-70%)	Neutral or Potential Benefit	High (Continuing)	Although heavy cattle grazing was cited as a likely threat in the first status report (COSEWIC 2007b), effects of livestock are complex and their potential impact on PYDM is poorly understood. Ranching with cattle and other livestock may replace, in part, the ecological role that was historically played by Plains Bison. Grazing and trampling may enable sparsely vegetated habitats required by PYDM to remain open, but overgrazing could have negative impacts on PYDM, potentially through soil compaction. Livestock farming or ranching occurs within some of the extant sites, but not others (e.g., parks and military bases). The sand hills used by PYDM are generally too dry and sandy for agriculture but are widely used as pasture for livestock. Cattle are grazed at several known PYDM sites, including those on private land, community pastures, or government grazing leases (COSEWIC 2007b). Numerous PYDMs have been found at Dillberry Lake Provincial Park where there is apparently no cattle grazing. Only one PYDM has been caught in multiple years of surveys at Wainwright Dunes E.R. which has light grazing (likely once a year); none have been found at adjacent lands outside the ecological reserve that are heavily grazed (Macaulay pers. comm. 2017). It is possible that cattle may graze on vegetation used by larval PYDMs for feeding, or may result in soil compaction, or trampling of eggs, larvae, or pupae (COSEWIC 2007b). Cattle could have a beneficial impact on PYDM habitat in Canada by slowing the rate of dune stabilization due to disturbance by trampling and grazing, especially at small blowouts that would otherwise become overgrown. In this way, cattle may help compensate for the loss of disturbance historically caused by Plains Bison (Fox *et al*. 2012). Compared to Plains Bison, cattle are considered a poor ecological substitute for creating open-sand habitats for sensitive sand dune species (Environment Canada 2016). Unlike Plains Bison, cattle do not create blowouts by wallowing (Fox *et al*. 2012). Nonetheless, cattle disturbance by over-grazing and trampling, compounded by drought, is responsible for the only documented example of historical dune reactivation (Hugenholtz and Wolfe 2005a, b). Cattle can be a vector for establishing invasive species (Chuong *et al*. 2015), although impacts on PYDMs have not been demonstrated.

Threat		Impact[1] (calculated)	Scope[2] (next 10 Yrs)	Severity[3] (10 Yrs or 3 Gen.)	Timing[4]	Comments
3	Energy production and mining	Unknown	Large - Small (1-70%)	Unknown	Moderate (Possibly in the short term, < 10 yrs/3 gen)	
3.1	Oil and gas drilling	Unknown	Large - Small (1-70%)	Unknown	Moderate (Possibly in the short term, < 10 yrs/3 gen)	Over the past several decades there has been a dramatic increase in natural gas extraction activities and associated infrastructure (e.g., gas wells, trails, pipelines, compressors) in the sand hills in southwestern SK and adjacent AB (Hugenholtz *et al*. 2010). The footprint of these activities is relatively small, however, and typically located on level and stable ground. Although often near, none appear to have been developed on occupied PYDM habitat. Oil and gas activity, and their associated roads (see Transportation and Service Corridors) can facilitate the introduction of invasive, non-native plants (see Invasive and other Problematic Species and Genes), but the roads' verge can also provide potentially suitable semi-stabilized dune habitat. Shallow gas drilling could lower water tables, which could improve habitat for PYDM if it leads to less dune stabilization.
3.2	Mining and quarrying	Unknown	Small 1-10%)	Unknown	High (Continuing)	Large scale sand excavation for industrial use (e.g., construction, fracking) is a potential risk to PYDM Habitat, particularly on private land.
3.3	Renewable energy					Not applicable. The probability of solar energy or wind turbine construction unlikely.
4	Transportation and service corridors	Negligible	Negligible (<1%)	Slight (1-10%)	High (Continuing)	
4.1	Roads and railroads	Negligible	Negligible (<1%)	Extreme (71-100%)	High (Continuing)	There is an increasing extent of access corridors associated with natural gas extraction in southwestern SK, with more than 240 km of new access roads and trails constructed between 1991 and 2005 to access the oil and gas wells in the Great SHs (Government of Saskatchewan 2007; Hugenholtz *et al*. 2011). Given the infrequent use, relatively low vehicle speeds, and nocturnal behaviour of PYDMs, it is unlikely that vehicles pose a significant mortality risk. Although these linear disturbances may increase the risk of invasive species (see 8. Invasive and other Problematic Species and Genes), their verges can provide semi-stabilized sandy habitat that may be suitable for PYDMs.
4.2	Utility and service lines	Negligible	Negligible (<1%)	Slight (1-10%)	High (Continuing)	There is increased pipeline activity related to gas drilling in certain areas of southern SK and AB. Pipeline construction and maintenance (e.g., hydrostatic testing) can create a network of linear disturbance in sandy habitats, although actual impacts on PYDM or their host plants have not been documented. Pipelines can also be a source of invasive plants.
5	Biological resource use	Negligible	Negligible (<1%)	Extreme (71-100%)	Moderate (Possibly in the short term, < 10 yrs/3 gen)	

Threat		Impact[1] (calculated)	Scope[2] (next 10 Yrs)	Severity[3] (10 Yrs or 3 Gen.)	Timing[4]	Comments
5.1	Hunting and collecting terrestrial animals	Negligible	Negligible (<1%)	Extreme (71-100%)	Moderate (Possibly in the short term, < 10 yrs/3 gen)	Cited as a potential threat in the COSEWIC (2007b) status report and Management Plan (Environment Canada 2016). Overall mortality from targeted or inadvertent collecting is not expected to threaten Canadian subpopulations since permits are required, search effort is low, and live-trapping is often used at the few sites with repeat visits. Over the past 110+ years, only about 100 individuals have been caught and kept as specimens in all of Canada.
6	Human intrusions and disturbance	Low	Pervasive (71-100%)	Slight (1-10%)	High (Continuing)	
6.1	Recreational activities	Low	Pervasive (71-100%)	Slight (1-10%)	High (Continuing)	Sand dunes are popular with all-terrain vehicle (ATV) users and ATV tracks have been observed at a small number of dunes or blowouts that have PYDM subpopulations (COSEWIC 2007b.). There is a small risk of PYDMs (particularly larvae or pupae) being crushed by ATVs. This risk may be partially mitigated by the beneficial effect that ATV use may have by destroying vegetation and slowing the rate of dune stabilization. ATVs and other vehicles can introduce invasive plants (e.g., White Sweet Clover (*Melilotus albus*) seeds) on tires (Anderson 2013) but impacts on PYDM habitat have not been demonstrated (see IUCN Threat 8).PYDMs and their habitat could be similarly impacted by high visitor use at occupied sites at Spirit Sands (Brandon SH) in Spruce Woods Provincial Park. Most of the thousands of visitors annually at Spirit Sands likely stay on the marked self-guiding trail, but there remains a small risk of trampling during off-trail ventures. Trampling by visitors may also have a beneficial effect in helping slow the rate of dune stabilization at a local scale.
6.2	War, civil unrest and military exercises	Low	Restricted (11-30%)	Slight (1-10%)	High (Continuing)	This threat is potentially applicable at three subpopulations: CFB Shilo, CFB Wainwright, and CFAD Dundurn. PYDM habitat is potentially present in CFB Suffield (AB). Military training with heavy vehicles, the use of explosives, and disturbance from associated fires may help maintain semi-open dune habitats on these bases. These activities may also cause mortality of PYDM individuals. PYDMs continue to persist at CFB Shilo, which has been the site of military activity since 1910 (Government of Canada 2017a).
6.3	Work and other activities	Low	Large (31-70%)	Slight (1-10%)	Moderate (Possibly in the short term, < 10 yrs/3 gen)	This includes potential incidental mortality from research activities other than moth trapping (accounted for under Hunting and Collecting). Permits that stipulate capture techniques and limits are typically required (e.g., in parks and military bases) which will limit incidental mortality.
7	Natural system modifications	Medium - Low	Pervasive (71-100%)	Moderate - Slight (1-30%)	Moderate (Possibly in the short term, < 10 yrs/3 gen)	

Threat		Impact[1] (calculated)	Scope[2] (next 10 Yrs)	Severity[3] (10 Yrs or 3 Gen.)	Timing[4]	Comments
7.1	Fire and fire suppression	Unknown	Pervasive (71-100%)	Unknown	High (Continuing)	Historically, Prairie grasslands burned every 5-10 years (Wright and Bailey 1982), although it is unclear to what extent dunes burned due to the lack of fuel load in these ecosystems. Wildfire is now uncommon and actively suppressed at or near most known PYDM subpopulations in Canada. This is not necessarily the case for fires on military bases unless they threaten infrastructure or adjacent properties. Although the effects of fire suppression on PYDM habitat are not well understood, fire suppression likely exacerbates vegetation encroachment and dune stabilization, reducing habitat availability for PYDMs. Fires may kill PYDMs, but prairie wildfires tend to move rapidly, and dune habitats likely have relatively low fuel loads. Mortality may also be mitigated by the mobility of adults, and if pupae are buried in the sand a sufficient depth (e.g. surface fires may not impact buried larvae or pupae).
7.3	Other ecosystem modifications	Medium - Low	Pervasive (71-100%)	Moderate - Slight (1-30%)	Moderate (Possibly in the short term, < 10 yrs/3 gen)	Dune stabilization is the predominant threat to PYDM subpopulations and habitat, particularly at small (<1 ha) blowouts that now support most of the known occurrences. This is a pervasive and continuing threat at all known sites throughout its Canadian range and is largely driven by long-term climate trends (see Habitat Trends), natural and non-native plant succession and the lack of disturbance from fire and Plains Bison. These threats are discussed under the appropriate subheadings, however, scored under this subcategory.
8	Invasive and other problematic species and genes	Unknown	Pervasive (71-100%)	Unknown	High (Continuing)	

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	Pervasive (71-100%)	Unknown	High (Continuing)	Invasive non-native plant species can accelerate the process of dune stabilization compared to native species and may also negatively impact the larval food plants of PYDMs due to competition. Non-native plants such as Smooth Brome (*Bromus inermis*), Leafy Spurge (*Euphorbia esula*), Crested Wheatgrass (*Agropyron cristatum*), and sweet clovers (*Melilotus* spp.) are present in Canadian dunes and have the potential to out-compete native vegetation, altering ecosystem properties and ecological integrity (Schykulski and Moore 1996; Henderson and Naeth 2005; Catling and Mitrow 2012; MCWS 2012). Invasive non-native plants can rapidly colonize active dune areas, accelerating the establishment of both native and non-native vegetation (Environment Canada 2016). At present, non-native invasive plants are not abundant in dry grasslands or sand dunes with PYDM and are mainly associated with cattle grazing and infrastructure development (N. Page pers. obs. in Environment Canada 2016; Foster pers. obs.). At Spruce Woods Provincial Park (MB) Sweet Clover, Smooth Brome and particularly Leafy Spurge are considered major problems for the long-term integrity and sustainability of this habitat (Schykulski and Moore 1996) and control is ongoing (Province of Manitoba 2015). Nearby farmsteads, gas wells, roads, and associated infrastructure in the sand hills near extant subpopulations likely increase the likelihood of non-native species invading PYDM habitat. Invasive plant species are scored in 7.3.
8.2	Problematic native species	Unknown	Pervasive (71-100%)	Unknown	High (Continuing)	Native plants (including trees such as aspens and pines) encroach and stabilize dunes due to the climate regime that is wetter and warmer than historically. This is likely to continue within the coming decades. Encroachment is coming from the edges of the habitat, but not happening throughout the entire habitat and is not equally distributed. Problematic native species are scored in 7.3.
9	Pollution	Unknown	Large - Small (1-70%)	Unknown	High (Continuing)	
9.3	Agricultural and forestry effluents	Unknown	Large - Small (1-70%)	Unknown	High (Continuing)	It is unlikely that pesticides or herbicides are sprayed by ranchers on native prairie near PYDM habitat. PYDMs, as well as their larval food plants could potentially be impacted by the drift of agrochemicals used to control pest insects or weeds on adjacent agricultural fields or hayfields (e.g., Davis *et al*. 1991). However, most known PYDM occurrences are more than 1 km from adjacent agricultural fields, so it appears that there is a negligible risk. Chemical control methods were used from 1983 to 2009 in Spruce Woods Provincial Park to control Leafy Spurge (MCWS 2012). Impacts, if any, on PYDMs are unknown.
9.4	Garbage and solid waste					CFB Dundurn and CFB Shilo have their own garbage dumps, although the scope is negligible, and the debris is contained.

Threat		Impact[1] (calculated)	Scope[2] (next 10 Yrs)	Severity[3] (10 Yrs or 3 Gen.)	Timing[4]	Comments
11	Climate change and severe weather	Unknown	Pervasive (71-100%)	Unknown	Moderate (Possibly in the short term, < 10 yrs/3 gen)	
11.1	Habitat shifting and alteration	Unknown	Pervasive (71-100%)	Unknown	Moderate	The potential impact of climate change on Canadian PYDMs and their habitats is unknown and unlikely to be demonstrated in the short term but may be beneficial over the long term (>10 years). Decreased precipitation and increased mean annual temperatures and aridity associated with climate change could slow stabilization of dune habitats, particularly if there are prolonged and/or severe droughts (Hugenholtz *et al*. 2010). The impacts are difficult to predict, however, and the long-term impact of climate change on future PYDM habitat may depend on the unknown interplay of temperatures, aridity, and vegetation dynamics (Wolfe and Torpe 2005).
11.2	Droughts					Not applicable. An increase in droughts would likely benefit PYDM due to reduced dune stabilization
11.3	Temperature extremes	Unknown	Pervasive (71-100%)	Unknown	Moderate (Possibly in the short term, < 10 yrs/3 gen)	In the short-term, small, isolated subpopulations of PYDM are likely 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 and flooding					Not applicable. No evidence of impacts on PYDM.

[1]**Impact** – The degree to which a species is observed, inferred, or suspected to be directly or indirectly threatened in 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 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.

Threat 2: Agriculture and Aquaculture (Medium – Low)

2.1 Annual and perennial non-timber crops (Medium – Low).

Due to the very dry and sandy soils of Pale Yellow Dune Moth habitat and surrounding areas, conversion to agricultural crop or forage production is not likely. However, some irrigated potato farming and haying occurs in marginal adjacent areas in southern AB and MB.

Threat 7: Natural System Modifications (Medium - Low)

7.3 Other ecosystem modifications (Medium - Low).

Dune stabilization is the predominant threat to Pale Yellow Dune Moth subpopulations and habitat, particularly at small (<1 ha) blowouts that now support most of the known occurrences. This is a pervasive and continuing threat at all known sites throughout its Canadian range and is largely driven by long-term climate trends (see Habitat Trends), natural and non-native plant succession and the lack of disturbance from fire and Plains Bison. These threats are discussed under the appropriate subheadings, however, scored under this subcategory.

Threat 6: Human Intrusions and Disturbance (Low)

6.1 Recreational activities (Low).

Sand dunes are popular with all-terrain vehicle (ATV) users and ATV tracks have been observed at a small number of dunes or blowouts that have Pale Yellow Dune Moth subpopulations (COSEWIC 2007b.). There is a small risk of Pale Yellow Dune Moths (particularly larvae or pupae) being crushed by ATVs. This risk may be partially mitigated by the beneficial effect that ATV use may have by destroying vegetation and slowing the rate of dune stabilization. ATVs and other vehicles can introduce invasive plants (e.g., White Sweet Clover (*Melilotus albus*) seeds) on tires (Anderson 2013) but impacts on Pale Yellow Dune Moth habitat have not been demonstrated (see IUCN Threat 8).

Pale Yellow Dune Moths and their habitat could be similarly impacted by high visitor use at occupied sites at Spirit Sands (Brandon SH) in Spruce Woods Provincial Park. Most of the thousands of visitors annually at Spirit Sands likely stay on the marked self-guiding trail, but there remains a small risk of trampling during off-trail ventures. Trampling by visitors may also have a beneficial effect in helping slow the rate of dune stabilization at a local scale.

6.2 War, civil unrest and military exercises (Low).

This threat is potentially applicable at three subpopulations: CFB Shilo, CFB Wainwright, and CFAD Dundurn. Pale Yellow Dune Moth habitat is potentially present in CFB Suffield (AB). Military training with heavy vehicles, the use of explosives, and disturbance from associated fires may help maintain semi-open dune habitats on these bases. These activities may also cause mortality of Pale Yellow Dune Moth individuals. Pale Yellow Dune Moths continue to persist at CFB Shilo, which has been the site of military activity since 1910 (Government of Canada 2017a).

6.3 Work and other activities (Low).

This includes potential incidental mortality from research activities other than moth trapping (accounted for under Hunting and Collecting). Permits that stipulate capture techniques and limits are typically required (e.g., in parks and military bases) which will limit incidental mortality.

Threat 8: Invasive and Other Problematic Species and Genes (Unknown)

8.1 Invasive non-native/alien species (Unknown impact).

Invasive non-native plant species can accelerate the process of dune stabilization compared to native species and may also negatively impact the larval food plants of Pale Yellow Dune Moths due to competition. Non-native plants such as Smooth Brome (*Bromus inermis*), Leafy Spurge (*Euphorbia esula*), Crested Wheatgrass (*Agropyron cristatum*), and sweet clovers (*Melilotus* spp.) are present in Canadian dunes and have the potential to out-compete native vegetation, altering ecosystem properties and ecological integrity (Schykulski and Moore 1996; Henderson and Naeth 2005; Catling and Mitrow 2012; MCWS 2012). Invasive non-native plants can rapidly colonize active dune areas, accelerating the establishment of both native and non-native vegetation (Environment Canada 2016).

At present, non-native invasive plants are not abundant in dry grasslands or sand dunes with Pale Yellow Dune Moth and are mainly associated with cattle grazing and infrastructure development (N. Page pers. obs. in Environment Canada 2016; Foster pers. obs.).

At Spruce Woods Provincial Park (MB) Sweet Clover, Smooth Brome and particularly Leafy Spurge are considered major problems for the long-term integrity and sustainability of this habitat (Schykulski and Moore 1996) and control is ongoing (Province of Manitoba 2015). Nearby farmsteads, gas wells, roads, and associated infrastructure in the sand hills near extant subpopulations likely increase the likelihood of non-native species invading Pale Yellow Dune Moth habitat. Invasive plant species are scored in 7.3.

8.2 Problematic native species (Unknown).

Native plants (including trees such as aspens and pines) encroach and stabilize dunes due to the climate regime that is wetter and warmer than historically. This is likely to continue within the coming decades. Encroachment is coming from the edges of the habitat, but not happening throughout the entire habitat and is not equally distributed. Problematic native species are scored in 7.3.

Threat 9: Pollution (Unknown)

9.3 Agricultural and forestry effluents (Unknown).

It is unlikely that pesticides or herbicides are sprayed by ranchers on native prairie near Pale Yellow Dune Moth habitat. Pale Yellow Dune Moths, as well as their larval food plants could potentially be impacted by the drift of agrochemicals used to control pest insects or weeds on adjacent agricultural fields or hayfields (e.g., Davis *et al.* 1991). However, most known Pale Yellow Dune Moth occurrences are more than 1 km from adjacent agricultural fields, so it appears that there is a negligible risk. Chemical control methods were used from 1983 to 2009 in Spruce Woods Provincial Park to control Leafy Spurge (MCWS 2012). Impacts, if any, on Pale Yellow Dune Moths are unknown.

Threat 11: Climate Change and Severe Weather (Unknown)

11.1 Habitat shifting and alteration (Unknown).

The potential impact of climate change on Canadian Pale Yellow Dune Moths and their habitats is unknown and unlikely to be demonstrated in the short term but may be beneficial over the long term (>10 years). Decreased precipitation and increased mean annual temperatures and aridity associated with climate change could slow stabilization of dune habitats, particularly if there are prolonged and/or severe droughts (Hugenholtz *et al.* 2010). The impacts are difficult to predict, however, and the long-term impact of climate change on future Pale Yellow Dune Moth habitat may depend on the unknown interplay of temperatures, aridity, and vegetation dynamics (Wolfe and Torpe 2005).

11.3 Temperature extremes (Unknown).

In the short-term, small, isolated subpopulations of Pale Yellow Dune Moths are likely 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.

Limiting Factors

Limiting factors are generally not human-induced and include characteristics that make the species less likely to respond to recovery/conservation efforts. Limiting factors for Pale Yellow Dune Moth are not well documented.

The distribution and abundance of Pale Yellow Dune Moths are inherently limited by the scarcity of semi-stabilized sand dunes in Canada. Dune fields within its Canadian range are often isolated and separated, making successful dispersal, migration, and re-colonization unlikely (Environment Canada 2016). Dispersal distances are unknown but are likely less than 10 km for this species (COSEWIC 2007b) and may limit dispersal among patches of suitable habitat within and among sand hills. Isolated subpopulations can be vulnerable to local extinction, reducing the subpopulation’s potential to persist.

Number of Locations

A location is defined "a geographically distinct area in which a single threatening event can rapidly affect all individuals of the species". Dune stabilization is the greatest single threat to Canadian Pale Yellow Dune Moth subpopulations. However, dune stabilization is ultimately driven by longer-term trends in regional climate and fire suppression, and non-climatic factors such as cattle grazing, fire, and other disturbance factors at the local scale thereby initiating dune activity (Hugenholtz *et al.* 2010). Dune stabilization is outside of the ten-year assessment time frame.

Some of the extant Pale Yellow Dune Moth subpopulations may be at risk of extirpation within the next ten years, specifically those subpopulations in smaller sand dune/hill habitats. A case for severe fragmentation may be possible; however, there is not enough spatial information for each extant subpopulation's habitat to accurately assess the projected habitat loss and inferred habitat decline.

Local variation in land management may therefore be important in mitigating dune stabilization and reducing the threat to Pale Yellow Dune Moth subpopulations. In addition, many Pale Yellow Dune Moth sites are relatively isolated from each other and are unlikely to be affected by a single threatening event. Based on these factors, each of the 13 extant Pale Yellow Dune Moth subpopulations/habitats in Canada may represent a separate location.

PROTECTION, STATUS AND RANKS

Legal Protection and Status

Pale Yellow Dune Moth is listed as Special Concern under Schedule 1 of the federal *Species at Risk Act* and Endangered under the Manitoba *Endangered Species and Ecosystems Act* (Manitoba Wildlife Branch 2017). The species is not protected under the *Wildlife Acts* of Alberta (AEP 2017) or Saskatchewan (Government of Saskatchewan 2017).

Non-Legal Status and Ranks

Pale Yellow Dune Moth conservation status ranks (NatureServe 2017) are:

- Global: Apparently Secure – Secure (G4G5) (NatureServe 2017)
- Canada: Imperilled (N2) in Canada.
- Manitoba: Critically Imperilled (S1) (Manitoba Conservation Data Centre 2017), Alberta: Critically Imperilled to Imperilled (S1S2) (Alberta Conservation Information Management System 2017).
- Saskatchewan: Imperilled (S2) (Saskatchewan Data Centre 2017).

- United States: status not ranked at both the national and state levels (NatureServe 2017).

Pale Yellow Dune Moth is not listed under the US *Endangered Species Act* or the Convention on International Trade in Endangered Species of Wild Fauna and Flora.

Habitat Protection and Ownership

Most Canadian sites with known or suspected Pale Yellow Dune Moth subpopulations occur on publicly owned lands, primarily provincial lands that are leased for cattle grazing. Pale Yellow Dune Moths at Wainwright (Wainwright Dunes Ecological Reserve) and Spirit Dunes (Spruce Woods Provincial Park) occur in protected areas. A small portion of the subpopulation in the Suffern Lake area is within Suffern Lake Regional Park; however, park activities focus on recreation rather than conservation (COSEWIC 2007b).

Two sparsely vegetated ecological communities in which Pale Yellow Dune Moth occurs are ranked by Alberta Natural Heritage Information Centre (2017): 1) sand grass–sand dropseed–hay sedge herbaceous vegetation and 2) creeping juniper / sand grass–sun-loving sedge dwarf shrubland. Both are ranked as imperilled/vulnerable (S2S3); however, this designation does not provide habitat protection (COSEWIC 2007b).

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COLLECTIONS EXAMINED

The following collections were searched for new or overlooked Canadian specimens of Pale Yellow Dune Moth:

Canadian National Collection of Insects, Arachnids and Nematodes (CNC), Ottawa, ON (Owen Lonsdale)

Chicago Field Museum, Chicago, IL. (on-line search)

E.H. Strickland Entomological Museum, University of Alberta, Edmonton, AB (on-line search)

J. B. Wallis / R. E. Roughley Museum of Entomology (Jason Gibbs)

Olds College, AB (Ken Fry)

Manitoba Museum of Man and Nature (Randall Mooi)

Museum of Zoology, Department of Biological Sciences, University of Calgary (John Swann)

Royal Alberta Museum, Edmonton, AB (Matthias Buck)

Royal British Columbia Museum, Victoria, BC (Claudia Copley)

Royal Saskatchewan Museum, Regina, SK (Cory Sheffield)

Spencer Entomological Collection, Beaty Biodiversity Museum, University of British Columbia, Vancouver BC (on-line search)

Yale Peabody Museum of Natural History, New Haven, CT, USA (on-line search)