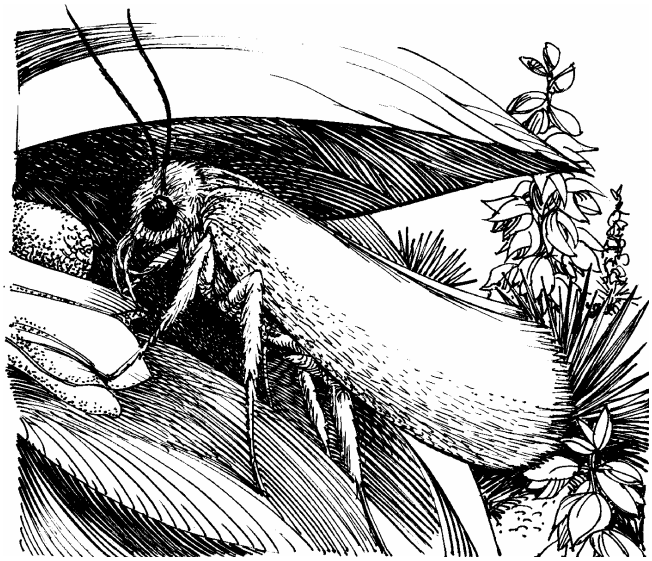
COSEWIC
Assessment and Status Report

on the

Yucca Moth
Tegeticula yuccasella

in Canada



ENDANGERED
2002

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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COSEWIC would also like to acknowledge Donna D. Hurlburt for writing the status report on the yucca moth *Tegeticula yuccasella* prepared under contract with Environment Canada.

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Yucca Moth — Brian Hoffman courtesy of the Alberta Conservation Association and the Alberta Sustainable Resource Development.

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COSEWIC
Assessment Summary

Assessment Summary – May 2002

Common name
Yucca Moth

Scientific name
Tegeticula yuccasella

Status
Endangered

Reason for designation
Only one viable population of the moth persists in an extremely small and restricted area; another small population has been lost recently. The moth has an obligate mutualism relationship with its host plant, the soapweed, which is threatened by ungulate herbivory and loss of plants to human activities.

Occurrence
Alberta

Status history
Designated Endangered in May 2002. Assessment based on a new status report.

COSEWIC
Executive Summary

Yucca Moth
Tegeticula yuccasella

Species information

Yucca Moths (*Tegeticula yuccasella*) are small white moths with a wingspan of 18-27.5 mm. They are most easily identified by their presence within *Yucca* flowers. The different closely related species, all of which are generally referred to as yucca moths, are difficult to distinguish without examination under a microscope. For clarity, Yucca Moth (capitalized) will be used throughout to refer specifically to *Tegeticula yccasella*.

Yucca Moths are members of the family Prodoxidae. They are characterized by a mutually beneficial association with Soapweed (family Agavaceae), and have specialized mouth parts with which to actively pollinate their host species.

Distribution

The Yucca Moth is found in Soapweed populations throughout the Great Plains from southern Texas to southern Canada, and in all regions to the Eastern seaboard. In Canada, the only sustainable population exists in Alberta at Onefour in one of only two native populations of Soapweed. In addition to Onefour, there is another native population of Soapweed in the Pinhorn Grazing Reserve, also in Alberta, that has next to no Yucca Moths.

Habitat

Yucca Moths are restricted to Soapweed populations in Canada. Soapweed occupies well-drained, sparsely vegetated, south-facing coulee slopes on the Milk River drainage in southeastern Alberta. In the more central and southern parts of the species' range, Soapweed flourishes on flat prairie grasslands.

Biology

Adult Yucca Moths pollinate and then lay eggs in Soapweed flowers; these moths are the sole pollinators of Soapweed. As moth larvae develop, they consume a portion of the fruit's developing seeds. Shortly before the fruit dry out and crack open to disperse seeds, moth larvae emerge from the fruit, burrow into the soil and enter a state of prepupal diapause. Most stay in this state from one to four years, before emerging from the soil as an adult moth. Adult moths live for approximately four days.

Population sizes and trends

In 1998, a complete census revealed 255 Yucca Moth larvae at the Onefour site, about 75-90 of which became adults. The Pinhorn population has not produced any new larvae from 1997-2002. There are no long-term data available to assess population decline and no trends were apparent from indices measured between 1998 and 2002. Populations of this species undergo dramatic fluctuations.

Limiting factors and threats

The greatest factor limiting Yucca Moths in Alberta is limitation in the interactions of emerging adult moths with flowering Soapweed plants. Factors limiting the interaction include browsing on Soapweed flowers and stalks by mule deer and pronghorn antelope. Levels of Soapweed flowering and moth emergence are highly variable among years and also act as limiting factors. Other potential concerns include application of agricultural herbicides and insecticides, changes in cattle grazing patterns, off-road travel, and horticultural and medicinal collection of Soapweed plants.

Special significance of the species

Albertan Yucca Moths exist in very isolated populations of Soapweed at the very northern edge of both species' ranges. Isolation and extreme environmental and biological conditions may have introduced unique selective pressures on these populations, generating higher genetic divergence than expected and potential pre-adaptation to anthropogenic disturbance or climate change. There has been no genetic analysis of Yucca Moths in Canada. However, when compared to more southern populations, Canadian Yucca Moths exhibit unique behavioural characteristics which appear to enhance their survival under low-density conditions.

Existing protection or other status designations

The Alberta Endangered Species Conservation Committee has recommended that the Yucca Moth be listed as endangered in Alberta. It is ranked globally as G4 (apparently secure). There is no recovery team or plan currently in place for the Yucca Moth or its host, the Soapweed.

Summary of status report

Yucca Moths in Canada appear to be undergoing a decline as indicated by the following characteristics of the Pinhorn population: 1) the failure of Soapweed to produce fruit, 2) the near absence of moths in flowers, and 3) the lack of moths in diapause in the soil from 1997-2002. The Onefour population shows no sign of decline. Canadian populations are small, have a small area of occupancy, are highly isolated and experience large population fluctuations which make Yucca Moths susceptible to existing extrinsic pressures, such as browsing of Soapweed by wild ungulates, plant collection and off-road traffic.

COSEWIC MANDATE

The Committee on the Status of Endangered Wildlife in Canada (COSEWIC) determines the national status of wild species, subspecies, varieties, and nationally significant populations that are considered to be at risk in Canada. Designations are made on all native species for the following taxonomic groups: mammals, birds, reptiles, amphibians, fish, lepidopterans, molluscs, vascular plants, lichens, and mosses.

COSEWIC MEMBERSHIP

COSEWIC comprises representatives from each provincial and territorial government wildlife agency, four federal agencies (Canadian Wildlife Service, Parks Canada Agency, Department of Fisheries and Oceans, and the Federal Biosystematic Partnership), three nonjurisdictional members and the co-chairs of the species specialist groups. The committee meets to consider status reports on candidate species.

DEFINITIONS

Species	Any indigenous species, subspecies, variety, or geographically defined population of wild fauna and flora.
Extinct (X)	A species that no longer exists.
Extirpated (XT)	A species no longer existing in the wild in Canada, but occurring elsewhere.
Endangered (E)	A species facing imminent extirpation or extinction.
Threatened (T)	A species likely to become endangered if limiting factors are not reversed.
Special Concern (SC)*	A species of special concern because of characteristics that make it particularly sensitive to human activities or natural events.
Not at Risk (NAR)**	A species that has been evaluated and found to be not at risk.
Data Deficient (DD)***	A species for which there is insufficient scientific information to support status designation.

* 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.

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.

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

COSEWIC Status Report

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2002

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SPECIES INFORMATION

Name and classification

Yucca Moths were first reported by Engelmann (1872a, b), who pointed out their association with *Yucca* plants to Charles Riley, the State Entomologist for Missouri at the time. Riley (1892) and William Trelease (1893) described the moths in the genus *Tegeticula* (Prodoxidae; Lepidoptera) first as *Pronuba* spp. in the late 1800s. After Walsingham (1903) and Coolidge (1909) found that the name *Pronuba* was preoccupied, the moth was renamed *Tegeticula yuccasella,* although some literature still retains the original genus name.

Historically, the genus *Tegeticula* was described as a species complex consisting of three species: *Tegeticula synthetica* which is monophagous on *Yucca brevifolia*, *T. maculata* on *Hesperoyucca whipplei*, and *T. yuccasella* as the pollinator for the other 30+ *Yucca* species north of Mexico. Despite this classification, most researchers reported considerable morphological and behavioural variation within T. *yuccasella* and as a result, some researchers artificially separated coexisting species by oviposition behaviour (e.g. Wilson & Addicott 1998). Using morphological and molecular data, Pellmyr (1999) completed a systematic revision of the yucca moths in the *T. yuccasella* complex and described ten new pollinator species and two non-pollinating cheater species of yucca moths. The term "yucca moth" may be used generically to refer to any of the species within this complex. For clarity, “Yucca Moth” (capitalized) is used throughout this report to refer to *Tegeticula yuccasella* specifically, while “yucca moth” is used to refer to other members of the complex. Using specimens collected from Onefour, Alberta and housed at the Canadian National Collection in Ottawa, Pellmyr (1999) identified the species of pollinating yucca moth residing in Soapweed (*Yucca glauca*) populations in southeastern Alberta as *Tegeticula yuccasella* (Riley).

Description

Moths of the genus *Tegeticula* are relatively small (wingspan 15-35 mm), non-descript, white or silvery, and have slender forewings. Females of pollinating species have maxillary tentacles with large numbers of sensory hairs; tentacles are absent in males of pollinating species and in both sexes in non-pollinating species, or "cheaters". Although there are subtle differences in body morphology and coloring among species, examination of genitalia provides a more definitive identification.

Tegeticula yuccasella is the most widespread member of its genus and has a moderate wingspan of 18-27.5 mm (Pellmyr 1999). The forewings are white dorsally and mostly dark brown ventrally; the hindwings are brownish gray dorsally, and light brown ventrally (Pellmyr 1999). The head has white scales. Females have a maxillary palp with a specialized maxillary tentacle. The tentacles are tubular and membranous with numerous short, hooked hairs which help retain pollen (Pellmyr & Leebens-Mack 2000). Males may have a rudimentary tentacle. Antennae are composed of 42-50 segments with the terminal segment droplet-shaped and shorter than in other species.

The thorax has white scales in most individuals, and the legs are yellow. The abdomen is pale brown dorsally and white ventrally (Pellmyr 1999).

T. yuccasella males are characterized by relatively small valvae with a broadly tapering cucullus and a slightly asymmetric pectinifer of 6-12 fused spines (Pellmyr 1999). Females have a 0.35-0.50 mm long ovipositor with a high keel of fine teeth rising behind the tip. When the female ovipositor is withdrawn, the tip of the abdomen is truncate, and the terminal joint is bluntly rounded at the tip with a corrugated ridge running dorsally before the tip (Riley 1892).

Immature stages are poorly known, and no morphological traits have been found useful to identify individuals to species (Pellmyr 1999). Immature stages of the genus *Tegeticula* can be described as follows: The pupa has an acute spine on the head and spines on the back (Riley 1892). Larvae are less than 1 mm long when newly hatched and reach 14 mm at maturity. At first they are translucent white but turn yellowish, then reddish. They have no pro-legs, but thoracic legs are developed. Larvae undergo three moults (Riley 1892). Eggs are club-like, mostly translucent and about 2 mm in length (Hurlburt, unpubl. data).

In Alberta, *T. yuccasella* adults may be confused with two other white moths that coexist within Soapweed flowers and fruit. *T. corruptrix* is a non-pollinating species of yucca moth that lays eggs in early stage Soapweed fruit. The species is larger than *T. yuccasella* with a wingspan of 22.5-35 mm (Pellmyr 1999). Both sexes have a maxillary palp without a rudimentary tentacle. These moths often appear after the flowering peak of its host and are frequently the only inhabitants of late-opening flowers. In the fourth instar, larvae are several millimetres longer than those of *T. yuccasella* and tend to be white to greenish in color; larvae coexist with *T. yuccasella* larvae within Soapweed fruit.

Prodoxus quinquepunctellus (Chambers) is a small moth with a wingspan of 13-19 mm. It inhabits Soapweed flowers from early June to mid-July. Its forewings are pure white and have 1-14 small spots. Its hindwings range from gray to near white, but are always darker than the forewings. The body is less robust than in *Tegeticula* (Davis 1967). Females oviposit in the flowering stalks of Soapweed, so *P. quinquepunctellus* larvae are not apt to be confused with those of *T. yuccasella*.

DISTRIBUTION

Global range

T. yuccasella is found in *Yucca* populations throughout the Great Plains from the southern boundary of Texas to southern Canada, and in all regions east of the plains northward to Michigan and Connecticut (Pellmyr 1999). The species is known to pollinate several different species of *Yucca* and as a result has a much wider North American distribution than its Canadian host, the Soapweed (Figure 1).

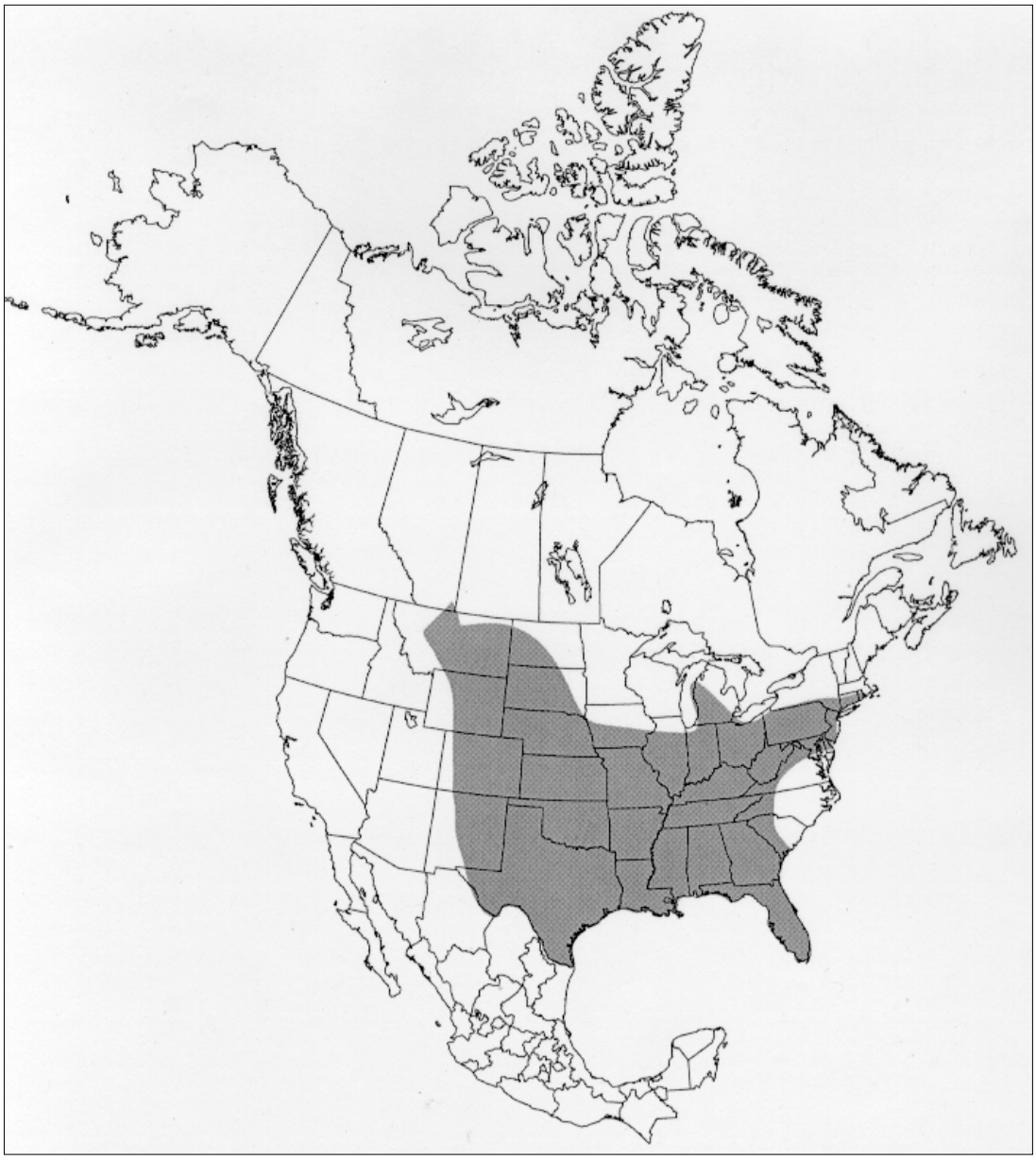

Figure 1. Distribution of the Yucca Moth, *Tegeticula yuccasella*, in North America.

Canadian range

Yucca Moths exist in sustainable numbers at only one of two naturally occurring Soapweed populations in southeastern Alberta (Figure 2). The Lost River (Alberta) population is primarily distributed along a 2-km stretch of south-facing coulee slope of a tributary of the Milk River on land owned by the Lethbridge Agricultural Research Substation in Onefour, Alberta. In the last four years, only a single pollinating female was recorded from the Pinhorn Grazing Reserve along a 0.05-km stretch of southwest-facing coulee on the Milk River drainage, and no larvae were found in prepupal

diapause upon sifting 20 2-liter samples of soil from around the bases of Soapweed clones (D. Hurlburt, unpubl. data). Soapweed has not sexually reproduced (i.e. produced fruit) in this area for a minimum of five years, and there has been no evidence of pollination or oviposition in abscised flowers. The moths in this population appear to be undergoing extirpation through the herbivory of Soapweed flower stalks by wild ungulates (Hurlburt 2001). Although small numbers of Soapweed plants are found in several other locations in Alberta, these were likely transplanted by people, and there has been no sign of fruit set or oviposition, indicating that adult moths are not present (Hurlburt 2001).

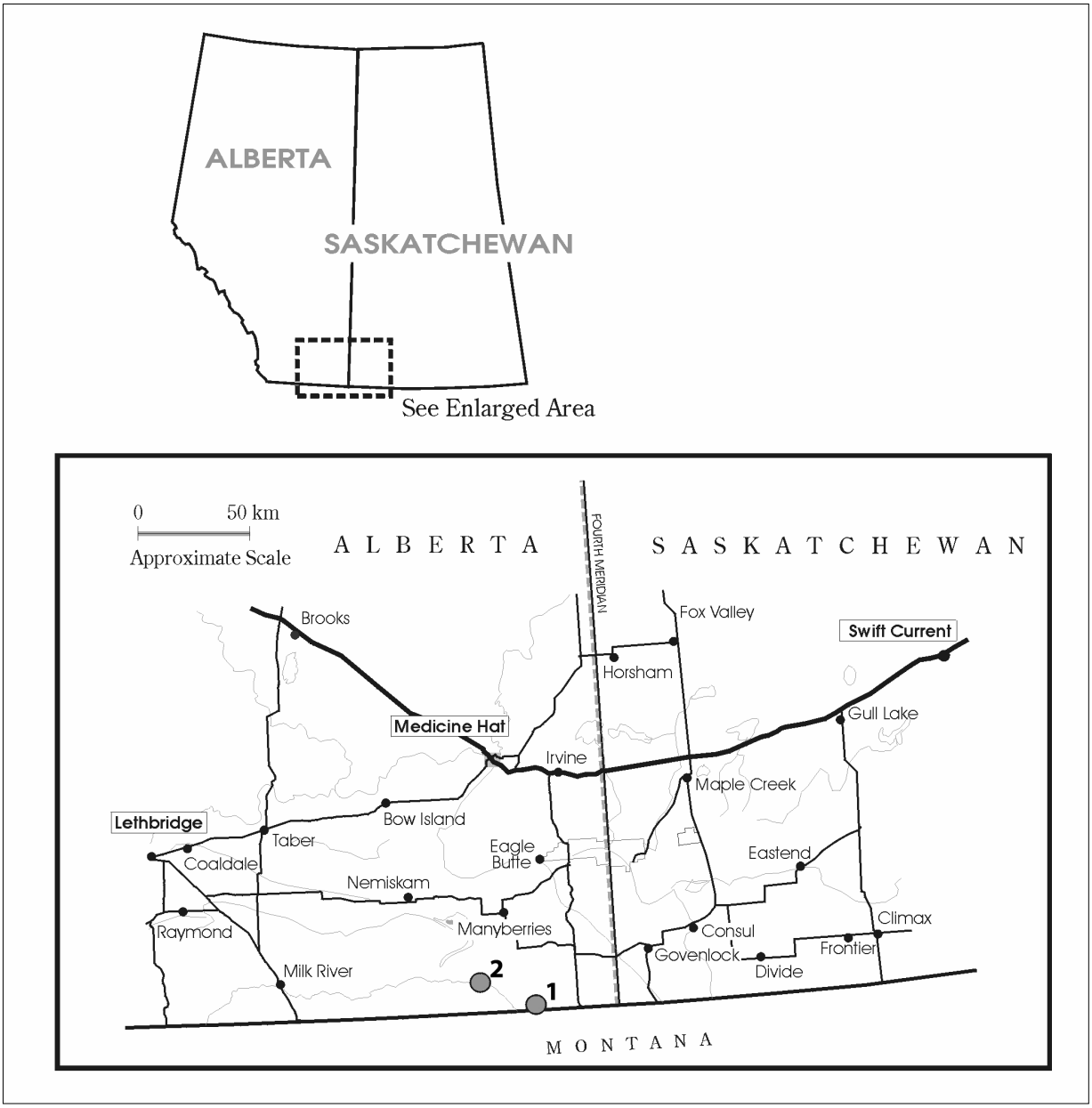

Figure 2. Known occurrences of the Yucca Moth (*Tegeticula yuccasella*) in Canada (Alberta).

HABITAT

Habitat requirements

In Alberta, Yucca Moths are restricted to the Dry Mixed Grass Subregion (ANHIC 2001). This semi-arid subregion has a continental climate with extremes of weather and large daily and seasonal variations in temperature characterized by low precipitation, hot summers and a high rate of evaporation. The rate of evaporation is exacerbated by a high average wind speed, often approaching 100 km/hr.

At the northern edge of its range in Alberta and Montana, the Yucca Moth uses only Soapweed for oviposition and for larval feeding. There is no other *Yucca* sp. naturally occurring within Canada that could act as a host plant for the Yucca Moth. This plant grows in sparsely distributed populations on well-drained, mostly south-facing coulee slopes. Typically, these slopes are eroded, dry and sparsely vegetated with prickly pear cactus (*Opuntia polyacantha*) and sagebrush (*Artemisia cana*). The aspects of slopes supporting Soapweed in Alberta range from 34º (northeast) to 200º (south-southwest), and generally face away from prevailing southwest winds, except in cases where slopes are protected by adjacent slopes. Soils tend to be alkaline and regosolic without shallow hardpan (Milner 1977, Fairbarns 1984). In areas further south (northern Wyoming), Soapweed grows on flatter ground and occurs in sand dunes, pine forests and glades in the east and grassland in the southwest, and ranges in altitude from 0 to 1920 m (Pellmyr 1999).

Trends

Appropriate habitat for Yucca Moths is naturally limited at the northern edge of the species' range in Alberta. Although there are numerous south-facing coulee slopes throughout the southeastern part of Alberta, many of these locations are grass-covered rather than eroded and are not inhabited by either the Soapweed or the Yucca Moth. Available habitat has not been reduced by agricultural practices (other than the negligible effects of cattle grazing) because Soapweed grows on steep coulee slopes that are unusable for crop production.

Protection/ownership

Although the Soapweed is designated as Threatened by COSEWIC and the Yucca Moth is recommended to be listed as Endangered by the provincial government in Alberta, neither the Yucca Moth nor the Soapweed has any formal protection. Preliminary planning for a recovery team and plan for both species is underway. Fortunately, both populations occur in relatively isolated, undisturbed sites. The largest population of the Yucca Moth occurs on the Lost River, near Onefour, AB on land owned and managed by Agri-food and Agriculture Canada. The smaller, declining population, is located on a public grazing reserve managed by the province of Alberta.

BIOLOGY

General

There is little literature available on the general biology and conservation of the Yucca Moth, even though *Yucca* plants and their pollinators are common throughout the United States and Mexico. Aspects of the moth's life cycle, population dynamics of the Soapweed, and the obligate relationship between the two species must be considered to assess the status of the moth. Further, isolated populations of Yucca Moths at the northern periphery of their range appear to demonstrate unique strategies for survival that would have important implications for the management and preservation of the Yucca Moth and its host in Canada.

Moth Biology — Most adult moths emerge from the soil from the second week in June through to the second week in July (D. Hurlburt, unpubl. data). Shortly after emergence, they gather and mate in freshly opened Soapweed flowers (Riley 1892, Baker 1986, Addicott et al. 1990). Adult female Yucca Moths actively collect pollen from one plant and then usually fly to another inflorescence. Upon finding a fresh flower, a female first inserts her ovipositor through the carpel wall and lays an egg next to the developing ovules (Aker & Udovic 1981; Addicott & Tyre 1995). She then climbs to the tip of the style, and using her maxillary tentacles, appendages unique to yucca moths, she actively transfers pollen into the stylar canal. Moths do not feed as adults and die after three to five days (Kingsolver 1984). Moth eggs hatch after 7 to 10 days, and larvae feed on developing Soapweed seeds. After approximately 50-60 days, fourth-instar larvae chew their way out of the Soapweed fruit and drop to the ground via a silken thread (Riley 1892). Larvae burrow 5-20 cm into the soil (Fuller 1990), spin a cocoon of silk and sand particles (Davis 1967), and enter a prepupal diapause (Riley 1873, Keeley et al. 1984). After a minimum diapause of one year, larvae pupate and adults emerge from the soil within several weeks, usually coinciding with Soapweed flowering.

Host Biology — Soapweed, a relative of century plants (*Agave* spp.), is the only *Yucca* species native to Canada. It is an arid-region perennial that flowers every 2-3 years in Alberta. The growth form of the plant is a single rosette or cluster of rosettes of narrow, spear-shaped leaves that are 25 to 40 cm long. An inflorescence 30 to 85 cm tall can grow from the center of each rosette and produce 15 to 75 large, fleshy, white flowers that mature from the base toward the apex of the inflorescence. Individual rosettes start to die immediately after producing an inflorescence and cannot produce future inflorescences (Kingsolver 1984).

In Soapweed, sexual reproduction or fruit production can only take place if flowers are pollinated by Yucca Moths. In Alberta, the Pinhorn population has failed to reproduce sexually (no seed production) for at least five years, and the Onefour population has shown low fruit set during three of four years studied (Hurlburt 2001). However, the Soapweed is also capable of asexual or clonal reproduction. New rosettes are produced in late summer from lateral buds from the rhizome near

senescing rosettes. Kingsolver (1984) found the rate of asexual reproduction increased during times or in locations where little sexual reproduction was taking place. In Alberta, the Pinhorn population has significantly more rosettes (i.e. higher levels of asexual reproduction) than other populations in the north (D. Hurlburt, unpubl. data), supporting Kingsolver's observations. Although individual rosettes die after flowering (and do not produce more inflorescences), clones can persist for many years. Longevity data for Soapweed clones are not available, but there is anecdotal evidence to suggest that plants live for 25-50 years (J. Addicott, pers. comm.). In Alberta, Soapweed only reproduces after 15-20 years of age (D. Hurlburt, unpubl. data).

At the northern edge of the Soapweed's range, inflorescences are capable of maturing five or six fruit. Soapweed fruit contain six locules (rows) of 30-50 seeds that are flat and easily dispersed by wind when the fruit dehisces in September. Seeds over-winter and germinate the following spring; however, recruitment is very low, with less than 1% of each Canadian population comprised of seedlings less than 10 cm tall. Of 1000 seeds planted in 1999, only three germinated successfully (D. Hurlburt, unpubl. data). Recruitment for populations throughout the Soapweed's range is normally low (1-2%); however recruitment in Alberta is significantly lower than that in the rest of the species' range (D. Hurlburt, unpubl. data). Seeds contain no endosperm and cannot lay dormant for longer than a year (J. Addicott, pers. comm.); therefore, the seedbank is not relevant to the persistence of the species.

In Canada, Soapweed is recognized as 'Threatened' by the Committee on the Status of Endangered Wildlife in Canada because of population isolation, the species' limited, peripheral distribution and its obligate reliance on the Yucca Moth for pollination (Fairbarns 1984, Csotonyi & Hurlburt 1999).

Physiology

Fuller (1990) was the first to demonstrate that *T. yuccasella* are capable of prolonging diapause for at least four years. Most larvae terminated diapause during or before their second year. This ability to extend diapause for a minimum of three years was confirmed in Alberta populations; however, up to 50% of observed larvae failed to pupate, and of those that pupated, half died in the cocoon (D. Hurlburt, unpubl. data). Diapause may be prolonged for up to 30 years in a closely related species, *Prodoxus y-inversus* (Powell 2001); however, there are no data to support such prolonged diapause in *T. yuccasella*.

Prolonged diapause is suggested to have favorable adaptive value in habitats where resources are available for short periods of time per season or vary considerably from year to year (Powell 1989). Since yucca moths must be closely synchronized with the development of inflorescences of their host plants to reproduce, and because Soapweed flowering at the northern limits of the species' range is highly variable among years, the existence of prolonged diapause in Yucca Moths is likely. However, it is suspected that only a few individuals will demonstrate extended diapause and that most Yucca Moths will emerge in less than two years, i.e. most moths will have a generation

time of less than two years. Fuller (1990) found that only 9% of moth larvae in diapause were alive at the end of his third year of study and that approximately 50% tended to die in their cocoons each winter. Nonetheless, the persistence of a few individuals in the soil may be a bet-hedging strategy for moths to bypass unfavorable climatic or biological conditions such as poor flowering.

Interspecific interactions

Of crucial importance to the survival of the Yucca Moth is the survival and sexual reproduction of its host, the Soapweed. The plant and the moth have an obligate mutualistic relationship where neither species can survive without the other. Obligate mutualistic systems are those relationships in which each partner requires the other to survive or reproduce, and as a result, both species benefit from the interaction (Addicott 1995). This interaction is obligate for both Soapweed plants and Yucca Moths, because there is no other consistently successful mechanism of pollen transfer for the plants and because Yucca Moth larvae feed only on Soapweed seeds.

The maintenance of the mutualism is dependent upon the degree of overlap of relevant life-history stages of the plant and its pollinator. In this case, pollinating moths must be active when flowers are receptive to pollen. Soapweed plants in Alberta have developed several unique strategies for dealing with this problem. Their flowering is highly asynchronous, having the longest flowering season (approx. 83 days in 1998) of any documented Soapweed population or any population of *Yucca* spp. (D. Hurlburt, unpubl. data). In species of *Yucca* with similar numbers of flowers, flowering typically lasts around 30-35 days (J, Addicott, pers. comm). Further, moth density is relatively constant throughout the flowering season. Data suggest that flowers have an even chance of being pollinated at any point during the flowering season (D. Hurlburt, unpubl. data).

In most populations, the Soapweed is predominantly an out-crossing species, and selective abscission (abortion) of flowers occurs in response to self-pollination. However, at the northern edge of the species' range, neither the presence of moths nor the presence of other individual plants in flower is reliable, and data suggest that Soapweed plants were selected to be tolerant of a self-pollinating mating system (D. Hurlburt, unpubl. data). In Alberta and parts of Montana, if Soapweed plants have a choice between cross-pollinated and self-pollinated flowers, they will “choose” to retain cross-pollinated flowers. However, if not given a choice, they will retain self- and cross-pollinated flowers equally, with no apparent loss in seed viability (D. Hurlburt, unpubl. data). Despite the ability of the Soapweed to retain self-fertilized flowers, Yucca Moths are still necessary as a pollen vector (Hurlburt, unpubl. data).

POPULATION SIZES AND TRENDS

Alberta

Yucca Moth and Soapweed populations in Alberta were the subject of a complete census for the first time in 1998 (Csotonyi and Hurlburt 1999). Every clone and fruit at both naturally occurring sites was documented, and emergence holes were counted. Each emergence hole is made by a single Yucca Moth larva. Pollinators have been monitored at these sites for three additional years (1999, 2000, 2001) using estimates or indices as it was not always practical to collect data on every fruit. Moth abundance was assessed directly and indirectly in a proportion of fruit and plants in each population via 1) moth counts in fresh flower surveys, 2) larval counts within fruit, 3) fruit set per inflorescence, and 4) numbers of oviposition marks per fruit. These measures were not assessed every year because of high variation in flowering, moth abundance and herbivory; for example, there were few to no fruit produced in some years and/or locations.

Two native populations of *Y. glauca* exist in Alberta, representing a total potentially reproducing population of 29,557 rosettes in 8,903 clones (Csotonyi and Hurlburt 1999). The Onefour population was estimated at 28,174 rosettes distributed among 8,499 clones (Csotonyi and Hurlburt 1999) along coulee slopes and adjacent prairie. The Pinhorn population was comprised of approximately 1,383 rosettes among 404 clones (Csotonyi and Hurlburt 1999).

In 1998, there were only 255 Yucca Moths (including males, which do not pollinate) produced at Onefour from 29,557 rosettes of Soapweed, an average of 4.397 $\pm$ 0.350 larvae per fruit. A similar census at Pinhorn in 1998 revealed no fruit and no evidence of pollinators. During four years of study in Pinhorn, only one female pollinating moth was observed, no pollinators were found in diapause in the soil, and there was no oviposition or fruit set (D. Hurlburt, unpubl. data). Data for measures of Yucca Moth abundance in Canada are presented in Table 1. Moth abundance in the Onefour population (Table 1) appears to be similar to moth abundance throughout the United States.

Table 1. Indices of Yucca Moth (*Tegeticula yuccasella*) population size in Albert from 1998-2000.

	Fruit / Inflorescence	Moths / flower	# Larvae / fruit	Ovipositions/fruit
Onefour				
1998	2.034 $\pm$ 0.279	Not monitored	4.397 $\pm$ 0.350*	Not monitored
1999	3.102 $\pm$ 0.161	0.456 $\pm$ 0.259	3.560 $\pm$ 0.470	9.552 $\pm$ 1.261
2000	0.322 $\pm$ 0.156	0.563 $\pm$ 0.259	5.920 $\pm$ 0.508	18.317 $\pm$ 2.075
2001	1.411 $\pm$ 0.115	0.388 $\pm$ 0.235	4.396 $\pm$ 0.576	14.755 $\pm$ 1.489
Pinhorn				
1998	0.000 $\pm$ 0.000	Not monitored	N/A - No fruit	Not monitored
1999	0.000 $\pm$ 0.000	0.003 $\pm$ 0.000	N/A - No fruit	0.000 $\pm$ 0.000
2000	0.000 $\pm$ 0.000	0.000 $\pm$ 0.000	N/A - No fruit	0.000 $\pm$ 0.000
2001	0.000 $\pm$ 0.000	0.000 $\pm$ 0.000	N/A - No fruit	0.000 $\pm$ 0.000

*Based on # emergence holes per fruit in 1998. Actual counts of moth larvae per fruit are presented for 1999-2001.

With the exception of reports on a single moth population in Colorado (Dodd 1989; Dodd & Linhart 1994), all other reports of moth abundance are substantially higher than those at Pinhorn. Dodd (1989) and Dodd and Linhart (1994) suggested that the population in Colorado suffered from an absence of moths because of the inability of the larvae to complete development at high elevations and a low density of host plants; a similar response would be expected in small, northern-edge populations such as at Pinhorn.

Without long-term data, it is not known whether moth populations are increasing, decreasing or stable at Onefour. Considerable variation in moth abundance exists in all Soapweed populations within and among flowering seasons, and only long-term studies will provide insight on the viability of populations. Other insect populations are known to be sustainable despite experiencing huge swings in numbers; however, there is no literature to suggest that similar dynamics occur in Yucca Moths or in the Prodoxidae. Further, small populations may be less able to recover from dips in population numbers than larger populations, and may be more susceptible to decline in response to stochastic events.

Other areas

There are no long-term estimates of population size from Saskatchewan Soapweed populations of unknown origin or from US states within the range of the Yucca Moth. It is suspected that moth abundances are sustainable throughout most of the species range (around and south of the Missouri River) as a result of their close proximity to other *Yucca* populations, with the exception of ecologically marginal populations such as those at high elevations (Dodd & Linhart 1994).

LIMITING FACTORS AND THREATS

There are a number of natural and anthropogenic factors that may limit the distribution of Yucca Moths in Alberta. Most factors concern the reduction of moth access to Soapweed which limits the interaction between the two species.

Natural limiting factors

<u>Peripheral Distribution and Isolation</u>

Yucca Moth distribution in Alberta is limited to locations where Soapweed exists, reproduces sexually and retains fruit. Further, the moth is apt to be physiologically limited by temperature and probably can only survive on south-facing, highly eroded, dry slopes, similar to the habitat characteristics preferred by its host. At the northern edge of their range, moths in less than ideal locations exhibit lower fecundity; Soapweed plants not located on south-facing slopes have fewer ovipositions, fewer fruit and lower larval production than those in ideal locations (D. Hurlburt, unpubl. data). Further, the plant exists beyond the most northern location of the moth (up to 200 km north in Fox Valley, SK) (Hurlburt 2001); hence it is possible that the moth is more restricted by latitude than

the plant and cannot use the plant right to the edge of its range. The Fox Valley population was transplanted from a native population of Soapweed in the United States and it is highly likely that diapausing moths were transferred to Fox Valley in the soil, but did not survive at the new site. There could be several reasons for this lack of larval survival, but it is possible that the larvae were unable to tolerate Fox Valley's climatic conditions.

Alberta populations of Soapweed are isolated from other populations in the main range to the south by a minimum of 200 km, with little intervening native habitat in which Soapweed could live (D. Hurlburt, unpubl. data). Isolation of Alberta's Soapweed populations could prevent re-colonization of Yucca Moths in these sites should they become extirpated because Yucca Moths are particularly weak flyers, are short-lived and are likely incapable of dispersing long distances over inhospitable terrain (Kerley et al. 1993, Marr et al. 2000; J. Addicott, pers. comm). Although other insects, such as aphids, ride storm fronts and can expand their distribution considerably, there is no evidence to suggest that similar activity could occur with Yucca Moths. During bouts of windy weather, Yucca Moths cling to the inside of Soapweed flowers and do not fly among plants. There are no records of moth-depauperate populations being recolonized by Yucca Moths. Further, there is evidence to suggest that small, declining peripheral populations of Soapweed may not contain enough plants to sustain Yucca Moths (Dodd & Linhart 1994, D. Hurlburt, unpubl. data).

Ungulate Herbivory

Floral and inflorescence herbivory by pronghorn antelope (*Antilocapra americana*) and mule deer (*Odocoileus hemionus*) appears to play a large negative role in the recruitment of Yucca Moths and Soapweed seeds in some years and on some sites. Pronghorn eat individual Soapweed flowers, whereas mule deer most often eat the entire flowering stalk. When the number of inflorescences was low because of small population size or low flowering, herbivory has been high (between 80-100% of flowers). In episodes of high flowering, herbivory has been low (less than 1% of flowers). The interactions between Soapweed plants and Yucca Moths that normally would determine the outcome of the mutualism are over-ridden in times of high herbivory; that is, the nature of the interactions between the Soapweed and Yucca Moth has little effect on their reproductive success because the deer and pronghorn consume most of the flowers and/or fruit. Low fruit production can lead to complete reproductive failure of moths (D. Hurlburt, unpubl. data).

The date and type of herbivory of individually marked inflorescences, flowers and fruit were recorded to evaluate the magnitude and timing of herbivory on the success of the mutualism between years and sites. In 2000, herbivory by antelope caused a major loss of flowers during the peak flowering season at the Onefour site (Hurlburt 2001). Over the entire flowering season, 1328 of 2943 flowers were consumed; 47% of eaten flowers were newly opened (less than one day of age). However, in 1999, less than 2% of flowers were consumed at the same site even though the abundance of antelope appeared to be similar in both years (Hurlburt 2001). Several populations in Montana exhibited the same patterns (D. Hurlburt, pers. obs.).

In 1998, Csotonyi and Hurlburt (1999) discovered that 80% of inflorescences at the Pinhorn site were clipped or entirely consumed by large herbivores. During the summer of 1999, less than 1% of flowers at Pinhorn were eaten during the flowering season, although an increase in herbivory did occur later in the season after unpollinated flowers were shed. Mule deer destroyed 100% of inflorescences flowering at the Pinhorn site in 2000. Removal of flowers by herbivores in an unpredictable population of flowering plants causes a decline in fruit production and moth survival and has the potential, through decreased recruitment, to lead to long-term population decline in isolated peripheral populations (Kerley et al. 1993). Apparently, this problem was exacerbated in recent years by drought and the resulting absence of other vegetation for ungulates to feed on in the area (D. Hurlburt, pers. obs.).

Insect Herbivory

The mutualistic relationship between the Soapweed and the Yucca Moth at the northern edges of their ranges is also confounded by the presence of a newly recorded, non-pollinating moth, (*Tegeticula corruptrix*) (a closely related species to the Yucca Moth) (Perry 2001, D. Hurlburt, unpubl. data). It does not pollinate, but lays eggs in early-stage Soapweed fruit. Non-pollinators may have a large impact on the Soapweed/Yucca Moth mutualism by laying enough eggs in the Soapweed fruit that their larvae consume all the seeds (Addicott 1996), competing with Yucca Moth larvae for food and limiting sexual reproduction of the plant. In *Y. kanabensis*, the larvae of pollinating Yucca Moths play a large role in limiting exploitation by non-pollinators because the Yucca Moth larvae out compete the exploiter larvae (James 1998). Yucca Moth larvae hatch several weeks earlier than non-pollinating larvae and have the capacity to consume many of the Soapweed plants' seeds before the non-pollinators commence eating. When Yucca Moth larvae occur in high numbers, they can have a negative impact on non-pollinator survival. On average, despite limitation by pollinators, non-pollinators ate 30% of seeds in *Y. kanabensis*. In fruit with few or no pollinator larvae, all seeds were occasionally consumed by non-pollinators (James 1998). In southern Alberta, these non-pollinating larvae are abundant in some years and localized areas and can consume up to 40% of seeds (D. Hurlburt, unpubl. data). Non-pollinators may have the capacity to consume greater numbers of seeds at the northern edge of their range because their numbers are not limited by high densities of pollinating larvae.

Additionally, ants can significantly reduce the availability of Soapweed flowers in which moths can oviposit, and may kill moths that reside in flowers in which the ants are patrolling. Ants reduce the availability of Soapweed flowers by chewing on buds and subsequently causing the premature abscission of those buds. Some plants lose up to 90% of their buds through ant damage (D. Hurlburt, pers. obs.). Ants are also attracted to Soapweed plants by aphids, but ants tend to be present on Soapweed even in the absence of aphids. When ants encounter any insect that is not an aphid on a Soapweed plant, they either disturb the insect so that it moves away or catch the insect and consume it (Perry 2001).

Wind

Periodic intense winds of up to 100 km/hr greatly affect the availability of Soapweed flowers to moths or eliminate developing larvae in early stage fruit through premature removal of fruit from the stalk. During extreme windy days in 1999, over half of the flowers and young fruit at the Onefour site, and 100% of uneaten flowers at the Pinhorn site, were blown off. Individual plants located at the tops of coulee slopes or on the prairie flats were particularly susceptible. This kind of wind damage has not been recorded for any other location of Soapweed plants (J. Addicott, pers. comm.) and as a result, wind is thought to be a major limiting factor during some years. Windstorms that occur during the peak of flowering can destroy 25-35% of flowers produced in a single 24-hour period (D. Hurlburt, unpubl. data). It appears that the Yucca Moth is further negatively affected during such adverse conditions because the wind makes it more difficult for moths to fly among inflorescences to collect pollen or to pollinate; moths have been observed to remain in tightly closed Soapweed flowers during extreme periods of wind (Hurlburt, D., pers. obs.).

Anthropogenic Limiting Factors

Agricultural Activities

Agricultural practices have restricted the Soapweed to unarable land in many areas of Montana (D. Hurlburt, pers. obs.). Although, with the exception of grazing, agricultural activity is not a prevalent threat to Soapweed or the moth at this time in Alberta, it is possible that an increase in such activity may take place in the future.

In both Alberta locations, Soapweed and their moths must coexist with cattle and current grazing practices. Fortunately, most plants occur on steep, rocky slopes that are not preferred by cattle; however, those at the tops of slopes and on prairie in Onefour are particularly susceptible, and most of their flowers and fruit were eaten by cattle in 2001. In the past, the Onefour Research Substation has not pastured cattle in the area of the Soapweed during flowering and fruiting; however, during periods of drought, such as in 2001, such a luxury can not be afforded as feed for cattle is in short supply (I. Walker, pers. comm.). Although the plants in Pinhorn are reachable by cattle, grazing has not been a problem in recent years - typically mule deer consume all of the stalks shortly before or upon the beginning of flowering (D. Hurlburt, pers. obs.). Flowering stalks of *Yucca* populations in the southwestern United States are routinely destroyed by grazing cattle (J. Addicott, pers. comm.), and it is plausible that grazing could become a substantial threat in Alberta.

Within Alberta, an estimated two-thirds of original grasslands have been lost to cultivation (Samson & Knopf 1994); however most areas inhabited by Soapweed and its pollinator are not ideal for cultivation and are in no immediate threat of such activity. Strip-farming and irrigation is prevalent in Montana immediately across the coulee from the Soapweed, and there is no reason to assume that such activity could not take place on the flats immediately adjacent to the plants in Alberta. In the past 25 years,

Soapweed has spread onto these flats in a northerly direction (Csotonyi & Hurlburt 1999), and these clones and the spread of the population would be immediately threatened by intensive agricultural practices.

Although currently herbicides are only used to eliminate individual weedy plants near the Onefour Soapweed site, widespread use of herbicides and insecticides could cause plant and moth mortality and reduce reproductive success. Soapweed throughout the Great Plains is routinely killed through tilling and by the use of Round-up (D. Hurlburt, pers. obs.). In Montana, Soapweed plants along roadsides sprayed for weeds tend to have fewer ovipositions and produce few fruit (D. Hurlburt, pers. obs.).

Traffic

Both Alberta sites are well known and directly reachable by road. As a result, both locations are visited daily during the summer and fall by naturalists, hunters, ranchers, border patrol and archeologists. Plants have been destroyed at both locations by off-road traffic, and in one case a vehicle was noted to be deliberately running over Soapweed plants on the prairie at Onefour (D. Hurlburt, pers. obs.). It should be noted that Soapweed seedlings are more likely to occur on the disturbed soil of roads than in other locations; however, rarely do these seedling survive more than one growing season (D. Hurlburt, unpublished data). Further, off road traffic has destroyed cryptogamic soil crusts and caused an increase in erosion (D. Hurlburt, pers. obs.). A more concerted effort needs to be made to make the public aware of the problem.

Horticultural and Medicinal Uses

There are numerous examples of Soapweed in household gardens in southern Alberta, transplanted from both the Onefour and Pinhorn populations (Hurlburt 2001). One ranch in the area has well over a dozen Soapweed plants in its garden, all from the declining Pinhorn population (D. Hurlburt, pers. obs.). None of the transplanted Soapweed plants have shown any sign of oviposition or pollination by the moth (Hurlburt 2001). Transplanting of Soapweed, although discouraged, probably will not affect the long-term success of the plant or the moth. During digging the roots of the Soapweed plant are often partially removed from the original site and the remaining roots will send up new shoots in subsequent years.

Other species of *Yucca* (e.g. *Yucca elaphantipes*) that are commercially available in greenhouses are found in household gardens across Canada. There has been no documentation of these plants having ovipositions or fruit or of observations of moths among their flowers. Although it is plausible that these small, isolated plants (native and non-native) could experience visitation by Yucca Moths, it is unlikely that they could support moth populations in large numbers or for any length of time. *Yucca* flowers usually need several visits from moths to ensure successful pollination (D. Hurlburt, unpublished data), and most species and populations require cross-pollination for fertilization. Further, these commercial *Yucca* species may not be pollinated by *T. yuccasella*.

There has been interest in the collection of Soapweed seed for the development of nursery stock and the collection of roots and petals for herbal remedies in Canada. Fruit production is extremely low some years, and when combined with seed collection, could very well jeopardize the viability of Alberta populations. To date, the relative importance of the few high fruiting years to the more frequent low fruiting years in maintaining Soapweed populations is unknown. Although Alberta populations of Soapweed will never be harvested by large commercial operations because of their small population size, they could be threatened by smaller, grass-roots based harvesting (Hurlburt 2001).

SPECIAL SIGNIFICANCE OF THE SPECIES

The patchy distribution of northern Soapweed populations, coupled with the limited dispersal ability of Yucca Moths, may reduce gene flow among Yucca Moth populations compared to that of more continuously distributed populations (Massey and Hamrick 1998). Isolation and extreme environmental effects may introduce selective pressures to the population that are unique or more severe (Lesica and Allendorf 1995), leading to more rapid genetic divergence than expected. Peripheral populations of Yucca Moths may be adapted to a greater variety of environmental conditions than are populations occupying the range centre. Thus, peripheral populations could be pre-adapted to anthropogenic disturbance or climate change that may threaten populations across the remainder of the species range (Lomolino and Channell 1998). Although genetic evidence to support this possibility does not exist, Yucca Moths in Alberta exhibit unique behavioural characteristics. These moths have a longer flight season and apparently lay their eggs in different locations of the flower than do moths residing further south (D. Hurlburt, unpublished data).

Although there are no recorded uses of the Yucca Moth by aboriginal people, some tribes did make frequent use of the insect's host, the Soapweed, in the more southern parts of the species' range. Many *Yucca* species were used for food, beverages, detergents, medicines, clothing and household articles (Webber 1953), and it is probable that the Blackfoot (Alberta) / Blackfeet (Montana) may have used Soapweed for some of these purposes as well (Johnston 1987). Despite records of Soapweed use in other parts of the range, there are no definitive records of use or artifacts containing Soapweed fiber found in Alberta (J. Brink, pers comm.).

EXISTING PROTECTION OR OTHER STATUS

The host of the Yucca Moth, the Soapweed (*Y. glauca*), was uplisted by COSEWIC from Vulnerable (Special Concern is the currently used equivalent) to Threatened in 2000 because of characteristics that make it particularly sensitive to human activities or natural events, its reliance on a sole pollinator species, and because it occurs naturally in only two locations, one of which is in apparent decline (COSEWIC 2002). The uplisting by COSEWIC resulted from the reassessment of the species using new criteria

based on those developed by the IUCN (COSEWIC 1999). In Alberta, both Soapweed and the Yucca Moth have been recommended by the Endangered Species Conservation Committee (ESCC) to be listed as endangered at the provincial level. Soapweed is listed as Exotic in Saskatchewan. In the United States, the Yucca Moth has not been assessed and has no ranking within the Endangered Species system. Soapweed is described as N5 and is listed as secure by the IUCN (NatureServe 2003).

There are currently no recovery plans for the Soapweed or Yucca Moth in Alberta or Canada. A joint provincial recovery team, including Alberta Sustainable Resource Development and other stakeholders, will prepare a recovery plan to set goals, objectives, strategies, and actions to guide management of existing native populations of both species over the next five years. Since the overall North American populations of both species appear healthy, initial recovery efforts for these species will likely focus on the identification and conservation of existing populations, rather than reintroduction. Protection of all Soapweed sites will have to be implemented to prevent losses from industrial, agricultural, recreational or plant collection activities. Ongoing scientific research will continue to assess the unique survival strategies exhibited by both species in the face of the highly variable conditions found at the northern edge of their ranges. These findings will be used as a guide for suitable management practices.

SUMMARY OF STATUS REPORT

The limited distribution and small effective population size (low numbers of plants and low flowering levels) of Soapweed at the northern edge of the species' range makes the Yucca Moth susceptible to population declines in Alberta. Recent studies in Alberta indicate moth abundance in the Onefour population is similar to that of the main range, but the moth in the Pinhorn population is in severe decline (possibly being extirpated through herbivory of Soapweed inflorescences by wild ungulates). However, there is little available literature on northern populations of *T. yuccasella.* We know neither the species' historic distribution nor its long-term population trends in Alberta. Nor does this type of information exist on most populations in other parts of the plant’s range. Only in recent years has there been a vested interest in the preservation of non-agricultural invertebrate species, and as a result, few insect populations have been monitored from a conservation perspective over the long-term.

TECHNICAL SUMMARY

Tegeticula yuccasella
Yucca Moth Teigne du Yucca
Alberta

Extent and Area information	
• *extent of occurrence (EO)(km²)*	< 400 km^2
• *specify trend (decline, stable, increasing, unknown)*	Declining
• *are there extreme fluctuations in EO (> 1 order of magnitude)?*	No
• *area of occupancy (AO) (km²)*	< 1 km^2
• *specify trend (decline, stable, increasing, unknown)*	Declining
• *are there extreme fluctuations in AO (> 1 order magnitude)?*	No
• *number of extant locations*	1 (or 2)
• *specify trend in # locations (decline, stable, increasing, unknown)*	Declining – One population may be extirpated
• *are there extreme fluctuations in # locations (>1 order of magnitude)?*	No
• *habitat trend: specify declining, stable, increasing or unknown trend in area, extent or quality of habitat*	Stable
Population information	
• *generation time (average age of parents in the population) (indicate years, months, days, etc.)*	1 - 4 yrs
• *number of mature individuals (capable of reproduction) in the Canadian population (or, specify a range of plausible values)*	225 to 1000s depending on Soapweed fruit production
• *total population trend: specify declining, stable, increasing or unknown trend in number of mature individuals*	Unknown
• *if decline, % decline over the last/next 10 years or 3 generations, whichever is greater (or specify if for shorter time period)*	NA
• *are there extreme fluctuations in number of mature individuals (> 1 order of magnitude)?*	Yes - Annual fluctuations up to 15-20 orders of magnitude
• *is the total population severely fragmented (most individuals found within small and relatively isolated (geographically or otherwise) populations between which there is little exchange, i.e., ≤ 1 successful migrant / year)?*	Yes
• *Lost River population, Onefour, AB* • *Milk River population, Pinhorn Grazing Range, AB*	1000s of adults, annual recruitment varies from 225 to 1000s depending on Soapweed fruit production 0 adults, 0 recruitment
• *specify trend in number of populations (decline, stable, increasing, unknown)*	Declining, Pinhorn population may be extirpated
• *are there extreme fluctuations in number of populations (>1 order of magnitude)?*	No
Threats (actual or imminent threats to populations or habitats) - In Canada	
- herbivory - off-road traffic - horticultural & medicinal uses	

Rescue Effect (immigration from an outside source)	
• *does species exist elsewhere (in Canada or outside)?*	Yes
• *status of the outside population(s)?*	Probably stable and secure
• *is immigration known or possible?*	Not possible naturally as other populations are too distant, easily transported by researchers for reintroduction
• *would immigrants be adapted to survive here?*	Yes
• *is there sufficient habitat for immigrants here?*	Yes, if herbivory is reduced
Quantitative Analysis	Insufficient data

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BIOGRAPHICAL SUMMARY OF CONTRACTOR

Donna Hurlburt graduated with a B.Sc. in Agriculture from Nova Scotia Agricultural College, Truro, Nova Scotia in 1993. She then acquired an M.Sc. in biology from Acadia University, Wolfville, Nova Scotia in 1997, while working as a Wetlands Biologist for the Wildlife Division of the Nova Scotia Department of Natural Resources. Donna is presently completing a Ph.D. in Environmental Biology and Ecology (expected completion - Fall 2003) at the University of Alberta, Edmonton, Alberta under the

supervision of Dr. John F. Addicott (now at University of Calgary, Calgary, Alberta). She has spent the last five years assessing how the interaction between Soapweed plants and Yucca Moths persists and remains beneficial at the northern edge of range in Alberta and Montana, and has the most extensive dataset on these species in Canada.

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COLLECTIONS EXAMINED

Bowman Collection, University of Alberta, CW405 Biological Sciences Bldg, University of Alberta, Edmonton, AB T6G 3E9.

Canadian Musuem of Nature, PO Box 3443, Stn. D, Ottawa, ON, Canada K1P 6P4.

Collections of the former United States National Museum, now deposited in the National Museum of Natural History, Smithsonian Institution, Washington, D.C., USA.

Invertebrate Zoology Collection, The Provincial Museum of Alberta. 12845-102 Avenue, Edmonton, Alberta, T5N 0M6, Canada.