COSEWIC
Assessment and Status Report

on the

Lyall's Mariposa Lily
Calochortus lyallii

in Canada

SPECIAL CONCERN
2011

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. 2001. COSEWIC assessment and status report on the the Lyall's Mariposa Lily *Calochortus lyallii* in Canada. Committee on the Status of Endangered Wildlife in Canada. Ottawa. vi + 24 pp.

M.T. Miller and G.W. Douglas. 2001. COSEWIC status report on the Lyall's Mariposa Lily *Calochortus lyallii* in Canada, *in* COSEWIC assessment and status report on the Lyall's Mariposa Lily *Calochortus lyallii* in Canada. Committee on the Status of Endangered Wildlife in Canada. Ottawa. 1-24 pp.

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COSEWIC
Assessment Summary

Assessment Summary – May 2011

Common name
Lyall's Mariposa Lily

Scientific name
Calochortus lyallii

Status
Special Concern

Reason for designation
This species is a distinctive, long-lived perennial with a small range in Canada. It is known from only 5 populations in forest openings and sagebrush grasslands in southern BC, near Osoyoos. Plants emerge from underground bulbs in late spring, but are capable of remaining dormant for one or more years. This plant was formerly designated Threatened, but most of the area where it occurs has been designated as a provincial protected area, and the main threats, related to grazing and forest management, have now been mitigated.

Occurrence
British Columbia

Status history
Designated Threatened in May 2001. Status re-examined and designated Special Concern in May 2011.

COSEWIC
Executive Summary

Lyall's Mariposa Lily
Calochortus lyallii

Species information

Lyall's Mariposa Lily (*Calochortus lyallii*) is a bulbous perennial herb in the lily family. Important diagnostic features include white to purplish-tinged petals with fringed margins and crescent-shaped glands, differentiated sepals, and erect capsules.

Distribution

Lyall's Mariposa Lily occurs along the eastern slope of the Cascade Mountains from extreme south-central British Columbia to Yakima Co., Washington. Canadian populations are known only from highlands west of Osoyoos, adjacent to the U.S. border.

Habitat

The species occurs on well-drained soils in sagebrush grasslands and grassy forest openings between 900 m and 1300 m elevation.

Biology

Lyall's Mariposa Lily is a long-lived perennial that emerges each year from a subterranean bulb and reproduces exclusively by seed. Generation time is estimated as 15 years. Flowers are insect-pollinated, and capable of outcrossing and selfing. Seeds are shed in the summer and germinate close to the parent plant the following spring. Mature plants can alternate over time between reproductive (flowering) and vegetative (non-flowering) states. Bulbs have the ability to remain dormant underground for over three years, although dormancy episodes typically last a single year. Herbage and fruits are browsed by insects and bulbs are browsed by small mammals.

Population sizes and trends

There are five populations and 15 occurrences in Canada; these can be divided into 3 locations based on common threats (see below). Subpopulations range in size from a few hundred to hundreds of thousands of individuals, with an estimated total in 2009 of over 800,000 mature (flowering and non-flowering) stems. Population trends prior to 1996 are unknown; however, from 1997 to 2009, estimates of mature plant abundance from quadrats sampled in 3 subpopulations show declines of roughly 45% over this 12-year time period. This includes a period of decline of nearly 90% (based on visual estimates) between 1997 and 2007, with subsequent increases, but not to previously documented levels. The causes of fluctuations are not fully understood, but appear to be part of a natural cycle for this species. Increased survey efforts have resulted in the discovery of additional subpopulations within the known area of occupancy, such that the number of confirmed natural occurrences has increased from 3 to 14 since 1995 (with an additional site established by seeding). Despite these new discoveries, the total known population in 2009 remains approximately what it was in 1997, i.e., roughly 855,000 mature individuals in 1997, and 812,000 in 2009.

Limiting factors and threats

Establishment of the South Okanagan Grasslands Protected Area (by the BC Ministry of Environment) in 2001 and subsequent management actions have substantially reduced anthropogenic threats (e.g., from silvicultural practices and overgrazing) at the largest location, which encompasses 3 of 5 populations, and more than 85% of known individuals. Threats from invasive alien plant species, livestock trampling, and forest ingrowth still exist at this location, but do not appear imminent. The remaining two populations are on private land and are each treated as locations. The threats from silviculture and grazing at these sites may persist, and have the greatest potential to result in declines at these locations. Observed fluctuations in the number of mature individuals are not well understood, but may be part of the natural cycle for this species. Fluctuations of these magnitudes represent a potential limiting factor for the persistence of subpopulations, but as these do not appear related to human activity, and appear to be mitigated by persistence of dormant individuals, they are not considered extreme fluctuations by COSEWIC definitions. Currently, stochastic factors such as a long fire interval, unfavourable climatic conditions, and high rates of herbivory by small mammals may be combining to limit population size. Poor seed dispersal is an intrinsic limiting factor.

Special significance of the species

The genus *Calochortus* (mariposa lilies) includes about 70 species in western North America and Central America, only three of which are found in Canada (all in British Columbia). Many *Calochortus* species, including Lyall's Mariposa Lily, are local endemics with highly restricted ranges. Their high rate of local endemism and distinctive growth habit have made them important subjects in the study of plant rarity, population dynamics and speciation. Lyall's Mariposa Lily holds strong charismatic appeal for naturalists, botanists, and photographers in British Columbia, where public interest in conserving the lily helped to propel the creation of the South Okanagan Grasslands Protected Area.

Existing protection

Lyall's Mariposa Lily is not protected internationally. Nationally, it was assessed as Threatened by COSEWIC in 2001 and is listed on Schedule 1 of the federal *Species at Risk Act*. Four of the five Canadian populations occur in a provincial protected area and are regulated by the British Columbia *Park Act*.

TECHNICAL SUMMARY

Calochortus lyallii
Lyall's Mariposa Lily — Calochorte de Lyall
Range of occurrence in Canada: BC

Demographic Information

Generation time Generation time is defined from demographic transition rates as the time G required for the population to increase by a factor R_0, satisfying $\lambda^G = R_0$ and calculated as $G = \log R_0 / \log \lambda$ (Caswell 2001; Miller 2004).	Estimated 15 years (maximum age 30-40 years)
Is there an observed or projected continuing decline in number of mature individuals? Numbers show fluctuations in population sizes, including dramatic declines and recent increases based on above-ground counts of flowering individuals, but many mature individuals may be dormant at these times. Demographic studies over 5 seasons suggest stable population sizes for 1996-2000.	Uncertain
Estimated percent of continuing decline in total number of mature individuals within 5 years.	Uncertain
Inferred percent reduction in total number of mature individuals over the last 10 years. 27-57% decline in above-ground counts at sites monitored since 1997 (12 years); however, these likely represent or are likely partly due to natural fluctuations for this species.	% change in the last 3 generations (45 yrs) unknown.
Projected percent reduction or increase in total number of mature individuals over the next 10 years. No significant increase or decline predicted according to stochastic matrix model projections using 1996-2000 demographic data (λ_s = 0.99), but declines and increases have been observed following this time period.	Uknown
Inferred percent reduction in total number of mature individuals over any 10 year period, over a time period including both the past and the future. Despite inferred 87-92% reduction from 1997 to 2007 based on above-ground observations, the ability of populations to quickly rebound suggests that many mature individuals survive unfavourable growth conditions by remaining dormant for one or more seasons.	% change over 3 generations (45 yrs) unknown.
Are the causes of the decline clearly reversible and understood and ceased? However, the most imminent anthropogenic threats are understood and have ceased.	N/A
Are there extreme fluctuations in number of mature individuals? Demographic studies indicate that annual fluctuations in mature individuals are typically much less than one order of magnitude and are usually related to short-term shifts in population structure rather than to high mortality or recruitment.	No

Extent and Occupancy Information

Estimated extent of occurrence	8.5 km²
Index of area of occupancy (IAO) Biological area of occupancy is 0.1 km^2	24 km^2 (2x2 km grid).
Is the total population severely fragmented?	No
Number of locations 3 locations are recognized. One of these encompasses most known individuals (>85%), and is in a provincial protected area. The remaining two are on private land, subject to distinct threats.	3
Is there an observed or projected continuing decline in extent of occurrence?	No
Is there an observed or projected continuing decline in index of area of occupancy?	No
Is there an observed or projected continuing decline in number of populations?	No
Is there an observed or projected continuing decline in number of locations?	No
Is there a projected continuing decline in quality of habitat?	No
Are there extreme fluctuations in number of populations?	No
Are there extreme fluctuations in number of locations∗?	No
Are there extreme fluctuations in extent of occurrence?	No
Are there extreme fluctuations in index of area of occupancy?	No

Number of Mature Individuals (in each population)

Population	**N Mature Individuals (2009; to the nearest thousand, +/- 10%)**
1	14,000
2	392,000
3	326,000
4	81,000
5	2,300 in 1997, the last year surveyed
Total	813,000

Quantitative Analysis

Probability of extinction in the wild is at least 20% within 20 years or 5 generations.	Not done

Threats (actual or imminent, to populations or habitats)

Most actual or imminent threats have now been removed or mitigated through active park management. Potential threats from invasive alien plant species, livestock trampling, and forest ingrowth still exist but are not imminent. Secondary succession in the absence of fire poses a potential long-term threat, as does climate change.

Rescue Effect (immigration from outside Canada)

Status of outside population(s)?	Stable
Is immigration known or possible?	Unknown but possible
Would immigrants be adapted to survive in Canada?	Yes
Is there sufficient habitat for immigrants in Canada?	Yes
Is rescue from outside populations likely? No adaptations for long-distance dispersal are present.	Possible, but unlikely

Current Status

COSEWIC: Special Concern (May 2011).

Status and Reasons for Designation

Status:	**Alpha-numeric code:**
Special Concern	Not applicable
Reasons for Designation: This species is a distinctive, long-lived perennial with a small range in Canada. It is known from only 5 populations in forest openings and sagebrush grasslands in southern British Columbia, near Osoyoos. Plants emerge from underground bulbs in late spring, but are capable of remaining dormant for one or more years. This plant was formerly designated Threatened, but most of the area where it occurs has been designated as a provincial protected area, and the main threats, related to grazing and forest management, have now been mitigated.	

Applicability of Criteria

Criterion A (Declining Total Population): Population trends do not cover three generations in the past, and the causes of decline are not understood. Therefore, criteria A1, A2 are not met. A3 is not met because the decline reaches into the past. Does not meet A4 because of uncertainty associated with population size estimates and the apparent ability of the species to recover from declines.
Criterion B (Small Distribution, and Decline or Fluctuation): Not met. Not met. Meets EO and IAO thresholds for Endangered under B1 and B2, but subcriteria are not met evidence of continuing declines is lacking, and populations are not severely fragmented. Fluctuations could be considered extreme, but this would then mean that the pattern was not due to decline.
Criterion C (Small Total Population Size and Decline): Does not meet the criterion.
Criterion D (Very Small Population or Restricted Distribution): Meets D2 Threatened based on fewer than 5 locations (and an IAO nearing the <20km² threshold), but susceptibility to stochastic events is unlikely to result in the species becoming endangered or extinct in a very short time period.
Criterion E (Quantitative Analysis): Not done.

PREFACE

Since the original status report (Miller and Douglas 2001), four additional subpopulations have been identified (Table 1); however, these represent extensions of known populations. There have been no notable contractions or expansions in the Canadian range of Lyall's Mariposa Lily since regular monitoring first began in 1996. No new populations have been found.

Habitat trends at East Chopaka have improved considerably since the mid-1990s, when disturbances from forestry activities such as logging and afforestation, along with unfettered livestock grazing, were judged to pose imminent threats both to the integrity of the habitat and the long-term survival of Lyall's Mariposa Lily (Miller and Douglas 2001).

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
(2011)

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.

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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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Lyall's Mariposa Lily

Calochortus lyallii

in Canada

2011

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WILDLIFE SPECIES DESCRIPTION AND SIGNIFICANCE

Name and classification

Scientific name: *Calochortus lyallii* Baker
Synonyms: none
English common names: Lyall's Mariposa Lily, Lyall's Star Tulip, Cats-ear
French common name: Calochorte de Lyall
Family: Liliaceae; Lily family
Major plant group: Monocot flowering plant

Morphological description

Lyall's Mariposa Lily is a perennial herb that grows from a bulb (Figure 1). The bulb is subtended by a single strap-shaped basal leaf. The flowering stem is unbranched, with a single bract-like leaf near mid-stem and one to 12 white or purplish-tinged, star-shaped flowers. The flowers have three petals and three sepals. The petals are 2-3.5 cm long, clawed, broadly lance-shaped, with fringed margins and a bearded, crescent-shaped gland toward the base. The sepals form a distinct series (they are narrower and greener than the petals), a feature that sets this genus apart from most other groups in the lily family. The fruit is an erect, 3-angled capsule containing numerous seeds (Ownbey 1940; Hitchcock and Cronquist 1973, Fiedler and Zebell 2002).

The size of the basal leaf varies greatly and is dependent on the age/stage of the individual. The basal leaves of flowering plants are generally as long as the flowering stem and 1-2 cm wide. In juveniles and non-flowering individuals, the basal leaf is the only aboveground structure produced. This can be as small as 4 cm x 1.5 mm, about the size of a toothpick.

Lyall's Mariposa Lily is easily distinguished from the only other locally occurring member of the genus, Sagebrush Mariposa Lily (*C. macrocarpus*), by its fringed white to purplish-tinged petals (the much larger petals of Sagebrush Mariposa Lily are lavender and have no fringe) and flat basal leaf (the basal leaf of Sagebrush Mariposa Lily is strongly channeled and v-shaped in cross-section,). The two species are distinguished in fruit by their seed capsules, which in Sagebrush Mariposa Lily are long, narrow and wingless.

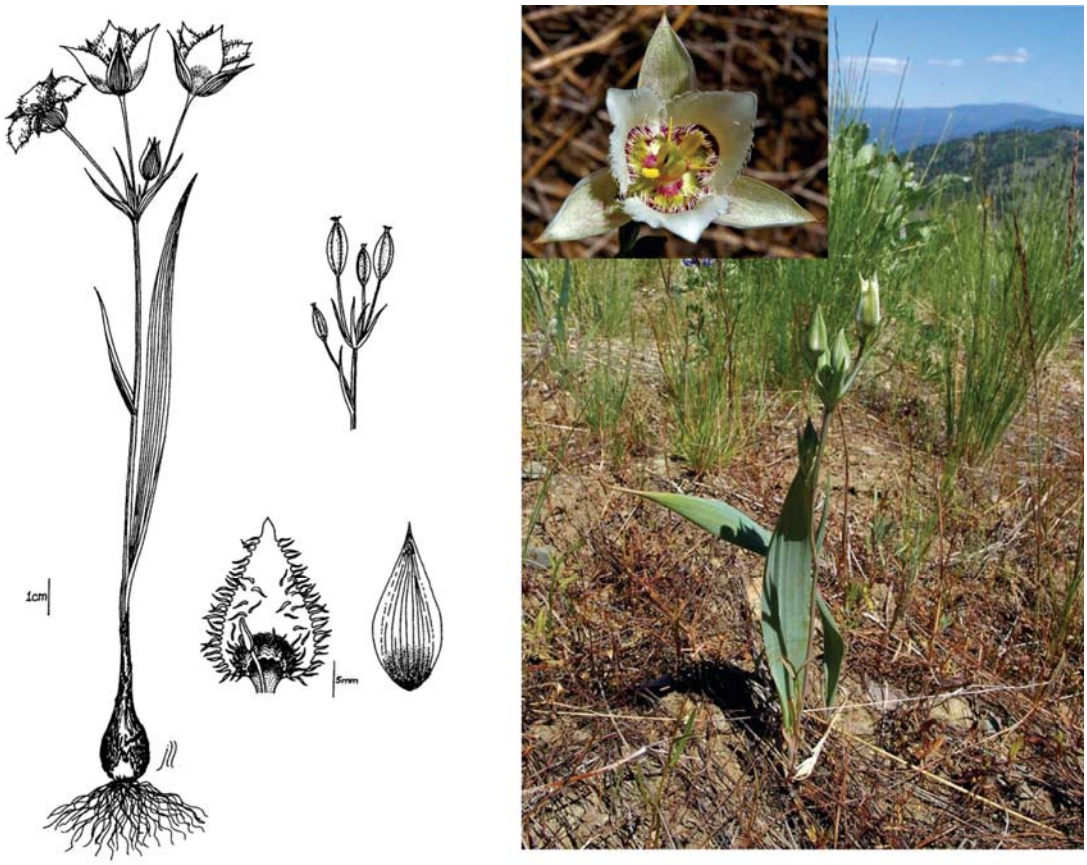

Figure 1. Lyall's Mariposa Lily. Line drawing by J.L. Ling in Douglas *et al.* (2001). Photos: M. Miller.

Population spatial structure and variability

The first comprehensive biosystematic treatment of *Calochortus* was by Ownbey (1940), who used morphological traits to subdivide the genus into three sections and numerous subsections. Subsequent molecular phylogenetic analyses (Patterson and Givnish 2004) revealed that diversification of the genus involved repeated parallel radiations in floral syndrome, habitat, and substrate type in seven major lineages, each centred in a different geographic area. Lyall's Mariposa Lily is one of 18 species in the "Pacific Northwest" group. Patterson and Givnish (2004) also concluded that differences in base chromosome number likely limit hybridization between species in different lineages. The base chromosome number of Lyall's Mariposa Lily and its allies is $x = 10$, in contrast to the inferred ancestral base chromosome number of $x = 9$. Limited seed dispersal has also likely contributed to the diversity and narrow endemism of individual species. However, to date there has been no research on the conservation genetics of Lyall's Mariposa Lily populations either in Canada or the U.S.

Designatable units

A single designatable unit is recognized for Lyall's Mariposa Lily in Canada. There are only 5 known populations in 3 locations that occur within a single ecozone (the Southern Mountain Ecological Area as recognized by COSEWIC).

SPECIAL SIGNIFICANCE

Calochortus is a genus of about 70 species of showy bulbous plants found mostly in western North America. Many species have highly restricted ranges (Fiedler & Zebell 2002), with the greatest concentration of species occurring in California, where the genus figures prominently in Rare Lilies of California (Fiedler 1996). Many *Calochortus* species are prized as ornamentals for their graceful stance, brilliant colors, and intricate markings, and both seeds and bulbs are available commercially. However, all species are difficult to cultivate since bulbs must usually be raised from seed and can take many years to flower (Gerritson and Parsons 2007).

Lyall's Mariposa Lily is taxonomically unique in British Columbia, being the only *Calochortus* species of three found in the province to belong to subsection *Nitidi*, a distinct group of species within the section *Calochortus* (Ownbey 1940).

The high rates of endemism and distinctive growth habits that characterize the genus have made it an important group for exploring questions of plant rarity and population dynamics (Fiedler 1986, 1995). From a conservation biology standpoint, *Calochortus* has become one of the most intensively studied groups of bulbous plants: to date at least ten species, most of them rare endemics, have been the subject of long term demographic studies (Fiedler 1987, Fredricks 1992, Fiedler *et al.* 1998, Miller *et al.* 2007). Recently, Lyall's Mariposa Lily and its co-occurring relative, Sagebrush Mariposa Lily (*C. macrocarpus*), were the first *Calochortus* species shown to regularly undergo extended dormancy, with some dormancy episodes exceeding three years (Miller *et al.* 2004). The occurrence of prolonged dormancy is significant as it can make population estimates and monitoring more difficult, as noted for *Calochortus flexulosus* (Panjabi and Anders 2006) and *C*. *nitidus* (Mancuso 1996), underscoring the need for long-term data sets when tracking trends in bulbous plants. Lyall's and Sagebrush mariposa lilies are also the first two *Calochortus* species for which age-based demographic parameters such as average life expectancy, generation time, and maximum lifespan have been estimated (Miller 2004).

Lyall's Mariposa Lily holds strong charismatic appeal for naturalists, botanists, and photographers in the South Okanagan-Lower Similkameen region of British Columbia, where public concern over the conservation status of the lily helped to propel the creation of the South Okanagan Grasslands Protected Area in 2001. The species has subsequently become a feature species and popular symbol for the new protected area.

Although the bulbs of many *Calochortus* species were harvested for food or medicine by Aboriginal peoples (Turner *et al*. 1980, Moerman 1998), such a use has not been reported for Lyall's Mariposa Lily.

DISTRIBUTION

Global range

Lyall's Mariposa Lily is endemic to British Columbia and Washington State (Figure 2). Its range extends from extreme southern British Columbia to the east slope of the Cascade Range and the Wenatchee Mountains (Douglas *et al.* 2001, Fiedler and Zebell 2002). In Washington it is found in Okanogan, Chelan, Kittitas, and Yakima counties, with particularly high concentrations around Methow Valley in north-central Washington. The Canadian range of Lyall's Mariposa Lily accounts for well under 10% of the species' global distribution.

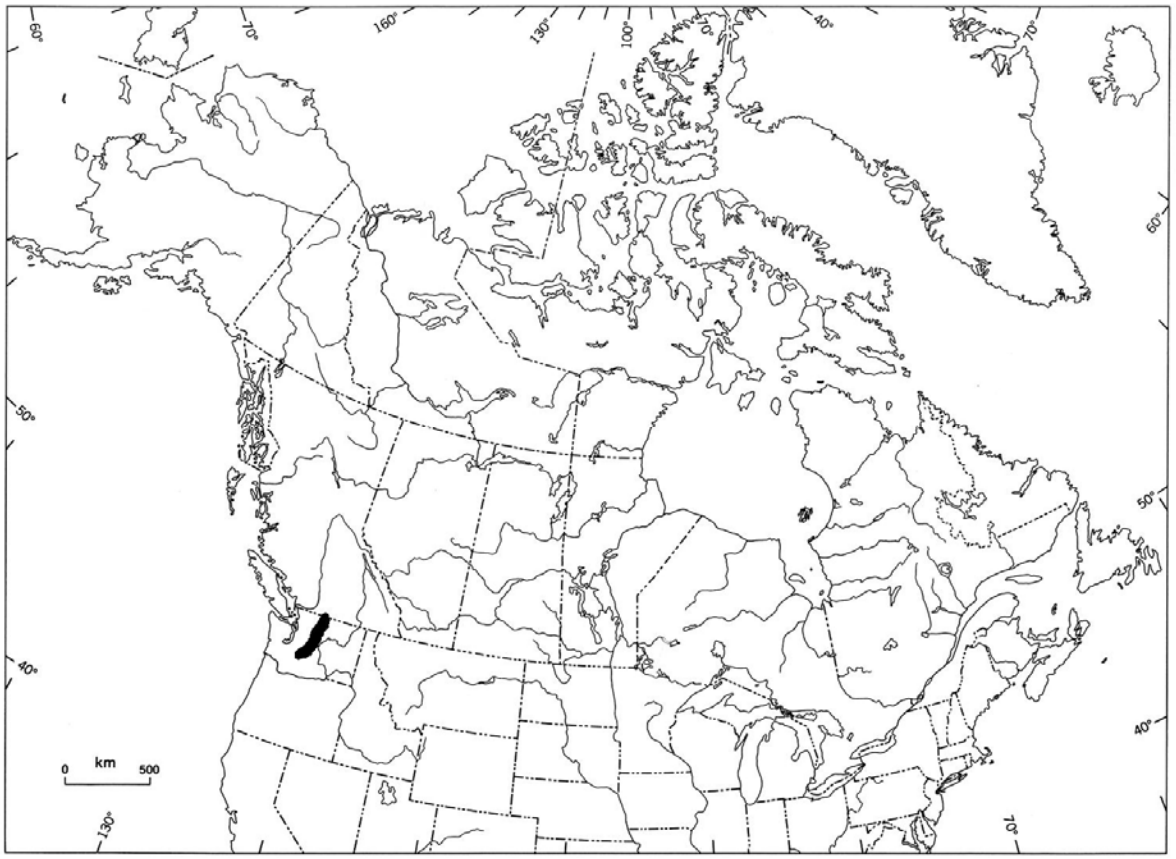

Figure 2. Approximate global range of Lyall's Mariposa Lily.

Canadian range

In Canada, Lyall's Mariposa Lily is known only from East Chopaka, an upland area west of Osoyoos between Osoyoos Lake and the Similkameen River (Figure 3). All occurrences with precise locality information are within five km of one another and within five km of the U.S. border (Miller and Douglas 1999). The localities of two additional collections are ambiguous. Ownbey (1940) refers to a single British Columbia collection (by Macoun in 1905) from "open hilltops near Similkameen River, 1050 m alt." The exact location and status of this population are unknown, although the record likely refers to one of the extant East Chopaka occurrences. Another collection (D. Fraser 1978) originates from an unspecified site on Mt. Chopaka, a neighbouring mountain that straddles the Canada-US border some 10 km west of the remaining sites. Collection notes for this specimen give as its locality the "road up to Chopaka Mt." However, the only serviceable road leading up this mountain is situated on the US side of the international border. There is thus some ambiguity surrounding the nationality of this collection. The individual who made the collection is deceased (Whittaker 2010), thus the exact locality cannot be verified.

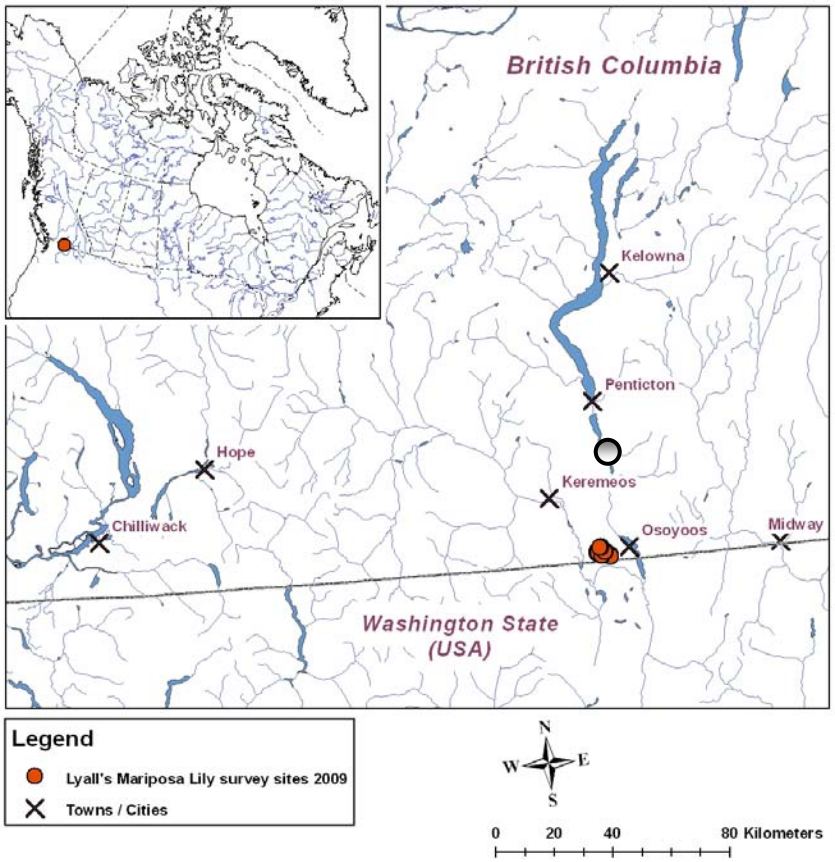

Figure 3. Canadian range of Lyall's Mariposa Lily. Open circle: unconfirmed record from Chopaka Mt. on the international border.

There are currently five confirmed populations in Canada, consisting of 15 subpopulations (Table 1). These are grouped into three locations based on threats. For Lyall's Mariposa Lily, land tenure was the primary criterion used to identify distinct locations, because the threat status of the species is closely tied to land management decisions and habitat protection. Thus, Location 1 includes populations 1-3, comprising a total of 11 subpopulations located within the boundaries of a provincial protected area, while Locations 2 (population 4) and 3 (population 5) occur on two separate private land tenures (Table 1; see **Threats and Limiting Factors**, below).

Table 1. Localities, observation dates and abundance (1997 to 2009) for populations and sub-populations of Lyall's Mariposa Lily populations in Canada.

Population[1] and Sub-population	Year discovered (observer[2])	Estimated abundance of flowering individuals and total mature individuals[7]				
		Life stage	1997 (visual estimate)[3,4]	1997 revised[5,6]	2007 (visual estimate)[4]	2009[6]
1a	1984 (SC)	Flowering: Tot. mature:	13,000 - 17,000 16,000 - 24,000	27,557 45,687	2,000 - 4,000 5,700 - 7,700	6,145 9,000
1b	1996 (MM)	Flowering: Tot. mature:	2,000 - 3,000 2,670 - 4,670		500 - 700 1,200 - 2,200	3,098 4,550
1c	2007 (SB)	Flowering: Tot. mature:	n/a	n/a	150 - 250 460 - 660	200±50 300±50
2a	1984 (SC)	Flowering: Tot. mature:	350,000 - 450,000 563,000 - 763,000	381,362 635,603	8,000 - 12,000 34,800 - 40,800	250,786 368,000
2b	1996 (MM)	Flowering: Tot. mature:	6,200 - 8,200 8,600 - 12,600		300 - 500 1,000 - 1,200	15,942 23,400
2c (artificial colony)[8]	1997 (MM)	Flowering: Tot. mature:	(0) (14)		(4) (11)	14 21
2d	2007 (SB)	Flowering: Tot. mature:	n/a		>100 >300	>100 >150
3a	1991 (MS)	Flowering: Tot. mature:	55,000 - 75,000 80,000 - 120,000	75,620 115,420	2,000 - 4,000 7,900 - 9,900	40,485 59,400
3b	1996 (MM)	Flowering: Tot. mature:	35,000 - 43,000 47,000 - 67,000		8,000 - 12,000 24,900 - 30,900	64,541 94,700
3c	1997 (MM)	Flowering: Tot. mature:	180 - 220 270 - 330		500 - 1,500 2,300 - 3,300	9,798 14,380
3d	2005 (SB)	Flowering: Tot. mature:	n/a		4,000 - 6,000 13,000 - 15,000	55,998 81,200
3e	2007 (SB)	Flowering: Tot. mature:	n/a		>200 >560	51,676 75,824
4	2000 (MM)	Flowering: Tot. mature:	n/a (200 plants in 2000)		>200 >560	55,310 81,160
5a	1997 (MM)	Flowering: Tot. mature:	1,000 - 1,400 1,300 - 2,300		n/a	n/a

Population[1] and Sub-population	Year discovered (observer[2])	Estimated abundance of flowering individuals and total mature individuals[7]				
		Life stage	1997 (visual estimate)[3,4]	1997 revised[5,6]	2007 (visual estimate)[4]	2009[6]
5b	1997 (MM)	Flowering: Tot. mature:	40 60		n/a	n/a
Total mature Population		Flowering: Tot. mature:	540,000±70,000 860,000±140,000		34,000±7,500 103,000±10,000	555,000±60,000 812,000±80,000

[1] Populations 1-3 are on BC Parks land; populations 4 and 5 are on private land.
[2] SC: S. Cannings; MS: M. Sarell; MM: M. Miller; SB: S. Bunge
[3] Data adapted from the 2001 status report.
[4] Estimates based on a visual estimate of abundance (no random sampling). Exception is site 2c, which represents an exact count, and 1c, which is a visual estimate only.
[5] Data from Miller (2004)
[6] Estimates derived from average plant densities within a random sample of 1 m^2 quadrats at each site, with a ±10% margin of error unless otherwise indicated.
[7] Estimated abundance of mature individuals takes into consideration estimates of non-flowering individuals that are likely mature and of likely dormant individuals, using information from demographic studies.
[8] Artificial colony established by M. Miller in 1996, from 50 seeds harvested from Population 2 and broadcast over a 5 m x 5 m area of apparently suitable but previously unoccupied ground within the known range of the species.

Five populations are identified based on standard one km separation, as recommended by NatureServe (2007) and the BC Conservation Data Centre. Subpopulations or occurrences represent patches of individuals within the five populations. Intervening suitable habitat exists between most of the populations, suggesting that the number of populations could actually be less than this, or could change if additional intervening sites are colonized (NatureServe 2007). Nevertheless, the species' highly clumped distribution, together with a lack of known insect pollinators capable of foraging long distances or of obvious specialized seed dispersal mechanisms, suggest that the one km separation criterion is appropriate in this case (Haber pers. comm. 2007). The five populations include 14 naturally established subpopulations and one additional occurrence (2c) that was artificially established in 1996 (Table 1).

Search effort

Surveys for the original status report occurred over three consecutive summers, from 1996 to1998, as part of a Ph.D. study on the demographic determinants of rarity in mariposa lilies (Miller 2004). During this time, intensive multi-day surveys for Lyall's Mariposa Lily were conducted in the East Chopaka highlands between Osoyoos and Nighthawk, B.C., encompassing the species' known historical range in Canada. Less intensive searches were also conducted on Mt. Kobau to the north, Anarchist Mt. to the east, Chopaka Mt. to the west, and numerous other locations in south-central BC. This research also included a week-long survey of the species' range in Washington State.

Initial fieldwork for the present COSEWIC update was conducted over a 10-day period by Miller, in May 2007. A follow-up census was conducted over three days (totaling six person-days) in June 2009. In the 2007 survey, approximately four days were spent surveying potential habitat for new populations. These searches focused on three different regions of South Okanagan Grasslands Protected Area: East Chopaka, West Chopaka, and Mt. Kobau (along summit road), and covered an area of approximately 20 km^2. Follow-up fieldwork in 2009 occurred over three days in June and focused on obtaining updated abundance estimates at known occurrences.

In addition to these studies, BC Parks staff have spent numerous person-days since 2005 surveying the South Okanagan Grassland Protected Area for Lyall's Mariposa Lily. These surveys have resulted in the discovery of four new subpopulations (1c, 2d, 3d, 3e; Table 1) and one significant extension (Bunge pers. comm. 2009).

It should be noted that the area of potentially suitable habitat is vast and, despite the above efforts, many habitats still wait to be surveyed at East Chopaka as well as on Mt. Kobau to the north and Chopaka and Snowy Mountains to the west. It is thus possible that the number of known occurrences will increase with increasing survey coverage.

Extent of occurrence and area of occupancy

The extent of occurrence (EO) in Canada is approximately 8.5 km^2, and the index of area of occupancy (IAO) is 24 km^2 (based on 2 x 2 km^2 grid, Filion pers. comm. 2009). The actual habitat area occupied is approximately 0.1 km^2. There have been no notable changes to the Canadian range of Lyall's Mariposa Lily since regular monitoring first began in 1996. Since the original status report (Miller and Douglas 2001), four additional subpopulations have been identified (Table 1); however, these represent additions to known populations.

HABITAT

Habitat requirements

Lyall's Mariposa Lily inhabits sagebrush slopes, grasslands, and open forests in the steppe and montane zones (Hitchcock and Cronquist 1973, Douglas *et al.* 2001). In British Columbia, the species is generally limited to grasslands and natural openings in Douglas-fir (*Pseudotsuga menziesii* var. *glauca*) forests at elevations ranging from 900 to 1300 m (Figure 4). The British Columbia sites fall within the IDFxh1 or "Okanagan very dry hot Interior Douglas-fir variant of the Interior Douglas-fir zone" (Lloyd *et al.* 1990). The climate is predominantly continental, with warm dry summers and cool winters.

Figure 4. Lyall's Mariposa Lily habitat at East Chopaka, British Columbia. Photos: M. Miller.

Sites are typically grassy slopes dominated by Bluebunch Wheatgrass (*Pseudoroegneria spicata*) and Idaho Fescue (*Festuca idahoensis*). Prairie Junegrass (*Koeleria macrantha*) and Pinegrass (*Calamagrostis rubescens*) are common associates (Miller 2004). Associated herbs include Death Camas (*Zygadenus venenosus*), Yellow Bell (*Fritillaria pudica*), Arrow-leaved Balsamroot (*Balsamorhiza sagittata*), Silky Lupine (*Lupinus sericeus*), and Blue-eyed Mary (*Collinsia parviflora*). On drier sites, Bitterroot (*Lewisia rediviva*) and Big Sagebrush (*Artemisia tridentata*) comprise part of the association. Shrub cover is generally sparse but includes Birch-leaved Spirea (*Spiraea betulifolia*), Squaw Currant (*Ribes cereum*), and Saskatoon (*Amelanchier alnifolia*). Similar plant associations occur throughout the area (Bryan 1996) and are considered indicative of moderately dry to dry, water-shedding sites with shallow, nitrogen-medium to nitrogen-rich soils (Klinka *et al*. 1989).

Like many *Calochortus* species (Gerritson and Parsons 2007), Lyall's Mariposa Lily is fire-adapted, and fire may have played an important role historically in maintaining sufficient open habitat for the species. British Columbia populations appear to have responded favourably to a wildfire that burned over much of the East Chopaka habitat in 1994 (Miller and Douglas 1999).

Habitat trends

Historically, there may have been some loss of suitable habitat at East Chopaka due to forest encroachment and ingrowth stemming from fire suppression practices (and possibly climate warming) during the past century. Aerial photographs from 1938 show more extensive grasslands and less forest cover at similar habitats and elevations throughout the south Okanagan region than occur at present (Lea pers. comm. 2007, Lea 2008). Nevertheless, habitat trends at East Chopaka have improved considerably since the mid-1990s, when disturbances from forestry activities such as logging and afforestation, along with unfettered livestock grazing, were judged to pose imminent threats both to the integrity of the habitat and the long-term survival of Lyall's Mariposa Lily (Miller and Douglas 2001). A wildfire that burned over East Chopaka in 1994 has temporarily reduced the canopy cover and slowed forest ingrowth. More importantly, the largest Canadian occurrences of Lyall's Mariposa Lily are now protected within the South Okanagan Grasslands Protected Area, established in 2001. Since 2001, direct human disturbance to Lyall's Mariposa Lily habitat inside the Protected Area has been minimal. No new anthropogenic threats were observed during Miller's 2007 surveys, although low densities of invasive species (e.g., Hound's-tongue (*Cynoglossum officinale*), Great Mullein (*Verbascum thapsus*)), were found in association with Lyall's Mariposa Lily at four sites. Evidence of past livestock presence, in the form of dried cow dung, was noted in about half of the subpopulations; however, grazing impacts appeared minor.

While invasive plants do not appear to be spreading rapidly into most occupied habitat patches, they have become well established in adjacent areas of East Chopaka and hence will continue to pose a long-term threat to habitat integrity. Provided timely action is taken, it may still be possible to prevent the establishment and spread of these species into critical habitat areas. Potential problem species include knapweed (*Centaurea* spp.), Canada Thistle (*Cirsium arvense*), Common Hound's-tongue (*Cynoglossum officinale*), Great Mullein (Verbascum thapsus), Toadflax (*Linaria* spp.) and Cheat-grass (*Bromus tectorum*). Infestations of knapweed, a highly aggressive competitor that forms dense monospecific stands with the potential to eliminate all or most indigenous plants in the vicinity, have advanced to within a few hundred metres of several Lyall's Mariposa Lily populations. Great Mullein is not often a significant weed of most wildlands and natural areas, as it is easily crowded out by grasses or other competing vegetation. It can be a problem, however, in the sparsely vegetated soils of the south Okanagan, where it may become abundant even in relatively undisturbed grasslands with undisturbed soils, displacing native herbs and grasses. It also establishes rapidly following forest fires.

The one population (population 5) occurring entirely on private land adjacent to the protected area has not been surveyed since the late 1990s. Habitat trends at this site are unknown. However, the site is located in a remote section of rangeland and does not appear to be under any imminent threat from development or forestry.

BIOLOGY

Life cycle and reproduction

Like all mariposa lilies, Lyall's Mariposa Lily is iteroparous, meaning that individuals can reproduce several times over the course of a lifetime. The species has a complex life cycle that includes a number of more or less discrete stages: seeds, seedlings, juveniles, mature reproductive (i.e., flowering) stems, mature vegetative (non-flowering) stems, and dormant bulbs (Miller 2004). Transitions among these different stages are not all unidirectional; a plant that produces flowers one year may be vegetative and produce a single leaf in the following year, or it may remain dormant as an underground bulb. Alternatively, a plant might produce only sterile leaves for several years before flowering (producing one flower or many flowers), after which it may either continue to flower in subsequent years or revert back to a mature vegetative state. In a typical year, a population may be composed of approximately 15% seedlings, 40% juveniles/sub-adults, 20% flowering plants, 15% mature but sterile shoots, and 10% (occasionally up to 18%) dormant bulbs (Miller 2004). Dormancy episodes typically last a single year, although episodes as long as four years have been recorded (Miller 2004, Miller *et al.* 2004). This ability of bulbs to remain dormant for prolonged periods is an important life history feature that complicates censuses or population counts (Miller *et al.* 2004).

Using recently developed analytical techniques (Caswell 2001), Miller (2004) estimated age-specific traits and lifetime event probabilities for Lyall's Mariposa Lily from stage-based census data. These included average life expectancy (six years for a newly established seedling, nine years for an established adult), maximum lifespan (30-40 years), probability that a seedling will survive to reproductive maturity (0.24), average age at first flowering (eight years), net reproductive rate R_0 (0.85), and generation time (15 years). Elasticity values, representing the relative importance of different life history events (e.g., recruitment, growth and survival) to population growth rate, were on average highest for survival of large juveniles and large flowering adults.

Although bulbifery (the asexual production of new bulb offsets) has been documented in other mariposa lilies (Fiedler 1987), asexual reproduction has not been observed in Lyall's Mariposa Lily. Instead, reproduction appears to be exclusively by seed (Miller 2004). Results of a field experiment comparing fruit set in self-pollinated and open-pollinated plants indicated that Lyall's Mariposa Lily is self-compatible. However, because the anthers shed their pollen prior to the stigma becoming receptive, a strategy that promotes outbreeding, plants probably do not self-pollinate unless pollen is transferred between flowers within an individual by pollinators (Miller *et al*. 2004).

Miller *et al.* (2004) report that percent fruit set (proportion of flowers producing a fruit) ranged from 0.10 to 0.34 (mean of 0.24) at East Chopaka from 1997 to 2000. In a random sample of one of the East Chopaka populations, seed capsules contained an average of 23 (± 14) seeds. Capsule production per adult plant (including vegetative and reproductive, but not dormant adults; measured over three sites and four years) veraged 0.29 (± 0.17). The replacement fertility level under average conditions was estimated to be 1.08 seedlings per large reproductive individual per year, well within the realm of values observed for this species (Miller 2004). Miller *et al*. (2004) report that, in general, reproductive output in Lyall's Mariposa Lily seems to be highest following years with warm, dry weather conditions.

Physiology and adaptability

Lyall's Mariposa Lily prefers partial to full sun and does not establish under dense canopy. At the microsite level, Miller (2004) found that edaphic conditions had a significant influence on several key life history parameters (recruitment rate, seedling and juvenile survival and growth), but only a weak association with others (adult survival and flowering). The two strongest relationships were a consistent positive correlation of soil depth, and a consistent negative correlation of the amount of bare soil with early survival and growth. That is, seedlings of Lyall's Mariposa Lily are most apt to establish successfully on deep soil where there is at least some vegetation or litter cover (Miller 2004). In a study of rare *Calochortus* species from Oregon (Fredricks 1992), seedlings of both *C. umpquaensis* and *C. coxii* were also more likely to establish on mossy ground or on litter than on bare soil, suggesting that desiccation may generally contribute to seedling mortality in *Calochortus*.

A proportion of individuals first tagged in 1996 were still alive and, in some instances, producing flower buds in 2007. This is evidence that the life span of Lyall's Mariposa Lily can exceed 10 years under natural conditions, and is consistent with earlier demographic projections (Miller 2004).

Lyall's Mariposa Lily occupies a variety of habitat types throughout its range, from dry sagebrush scrub to fescue grasslands to high montane forest. Given its deep-seated bulbs, it appears able to tolerate a certain amount of trampling and disturbance by livestock. It also appears to be a good competitor, as it is often found growing in dense monospecific patches. It is fire-tolerant, and because it is shade-intolerant, likely depends on periodic fires to maintain sufficient open habitat.

Like most species of mariposa lily, the bulbs of Lyall's Mariposa Lily do not easily tolerate transplanting, nor do they thrive in cultivation.

Dispersal

Lyall's Mariposa Lily possesses no specialized dispersal mechanisms. Seeds are released directly onto the ground and usually germinate close to the parent plant (Miller 2004). The species' limited dispersal ability likely accounts for its characteristically patchy distribution, as well as its very slow rate of spread into unoccupied habitat patches.

Interspecific interactions

Lyall's Mariposa Lily serves as an important local food source for Northern Pocket Gophers (*Thomomys talpoides*), fossorial rodents that harvest the plant bulbs by tunneling through the soil (Miller 2004). Bulbivory by pocket gophers has also been cited as one of the primary sources of mortality in rare mariposa lilies of southern Oregon (Fredericks 1992). In addition to directly feeding on bulbs, pocket gophers produce large soil mounds that can kill the bulbs by preventing their emergence (Miller pers. obs.). At the same time, burrowing and tunneling activities of these animals could benefit Lyall's Mariposa Lily by helping to maintain open patches of soil suitable for seed germination and establishment.

Insects (species unknown) browse occasionally on the shoots, buds and flowers, and also occasionally lay their eggs in the immature seed capsules which are subsequently consumed by the developing larvae (Miller 2004).

In Canada, flowers of Lyall's Mariposa Lily are pollinated primarily by solitary halictid bees in the genus *Dufourea* (Miller *et al.* 2004). Reproductive success appears to be closely tied to the activities of these pollinators.

POPULATION SIZES AND TRENDS

Sampling effort and methods

1996-1998

Fieldwork for the initial status report (Miller and Douglas 2001) took place over three summers from 1996 to 1998 in conjunction with an ongoing long-term study of *Calochortus* demography in the south Okanagan (Miller 2004). As part of the study, in June 1997 Miller ran five transects at 10 m intervals through the three largest subpopulations known at the time (1a, 2a and 3a). At ten random points along each transect he established 0.5 m x 0.5 m quadrats (50 quadrats per subpopulation) and counted the number of plants in each, to obtain an estimate of average plant density (Miller 2004). These data were not available for the 2001 status report but are analyzed here to provide a more accurate estimate of 1997 abundances at the three sites.

2007

Fieldwork for this update report was conducted over 10 days during the period May 10-31, 2007. In the 2007 survey, two days were spent surveying and delimiting the 10 extant habitat patches within the South Okanagan Grasslands Protected Area (two occurrences on neighbouring private land were not surveyed). Four additional days were spent conducting intensive demographic censuses of the three longest-known occurrences (1a, 2a, and 3a). This work involved enumerating individual plants (seedlings, juveniles, mature flowering, and mature vegetative) within a set of 51 permanently marked 0.5 m x 0.5 m quadrats. The quadrats were ones that had been left in place following completion in 2000 of a five-year demographic study on Lyall's Mariposa Lily (described in Miller 2004).

2009

In June 2009, a follow-up survey was undertaken in order to gain a better understanding of current population trends. This survey occurred over three days (six person days) and focused on obtaining updated abundance estimates at known occurrences.

Abundance

1997 and 2007 visual estimates

Lyall's Mariposa Lily tends to form large, dense patches where it occurs. The high plant densities, combined with the fact that different life stages may not be visible at certain times of year, make a complete enumeration of individuals impracticable. Consequently, abundance is estimated for all but the smallest subpopulations. For the 1997 and 2007 surveys, abundance was estimated visually (Table 1). Because no formal sampling protocol was employed during these surveys, the abundance estimates should be regarded as rough approximations only. In fact, the 2007 estimates are regarded as conservative; actual numbers may have been somewhat higher than reported (M. Miller, pers. obs.).

2009 estimates

To increase the certainty around population estimates, the 2009 census employed a more rigorous sampling approach. For this survey, a team of two surveyors spent one to three hours at each site counting plants in a quasi-random sample of 1 m^2 quadrats. To prevent bias in quadrat placement, a stick was tossed blindly over the shoulder at arbitrary locations within the study area; the point where the stick contacted the ground was designated as the centre of a sample quadrat. The number of quadrats sampled ranged from 10 to 72 depending on the size of the occupied patch. The average density of flowering plants per m^2 was determined; this value was then multiplied by the total area of the occupied polygon (as determined from GPS coordinates) to obtain an estimate of total flowering abundance. Total mature abundance was extrapolated from flowering abundance based on yearly observed ratios of flowering to sterile stems within permanent demographic plots (Miller 2004).

Revised 2007 estimates

To provide a valid statistical comparison between the 2009 abundance estimates and those from 1997, a similar analysis was applied retroactively to previously unanalyzed 1997 quadrat data from subpopulations 1a, 2a and 3a. The original dataset (Miller 2004) included 50 stratified-random samples of plant density from each of these three sites. For the present report, the 1997 dataset was randomly re-sampled to obtain a sample of 30 density estimates for each site. The average density of flowering plants per m^2 was determined after adjusting for the smaller (0.5 m x 0.5 m) quadrat sizes employed in the 1997 study. As was done for the 2009 data, this value was then multiplied by the total area of the occupied polygon to obtain an estimate of total adult abundance.

The resulting 1997 and 2009 abundance estimates were then compared statistically using a non-parametric Mann-Whitney *U* test. Non-parametric tests were used because in both years the data were non-normally distributed due to the strongly patchy plant distributions and correspondingly frequent “zero” counts obtained as a result of sampling with a relatively small quadrat size.

Populations 3 and 4 are both larger than previously estimated, due to recent discovery of additional subpopulations (Bunge pers. comm. 2007). A 2007 re-survey of subpopulation 3c revealed that this occurrence is also more extensive than first reported (Table 1). Population 5, which occurs on private land adjacent to the park, has not been surveyed since the late 1990s. Its present status is unknown.

Lyall’s Mariposa Lily tends to form dense patches where it occurs and hence population sizes are typically large, often exceeding 50,000 individuals (Table 1). A precise enumeration of the total Canadian population has not been attempted, but in 2009 was estimated to contain 554,000 (+/- 10%) flowering plants (Table 1), and 812,000 mature individuals (including dormant and vegetative individuals).

Fluctuations and trends

Population projection models (1996-2000)

A demographic study of Lyall's Mariposa Lily was conducted at three sites (1a, 2a and 3a in Table 1) on Black Mt. (East Chopaka), from 1996 to 2000 (Miller 2004, Miller *et al.* 2004, Miller *et al.* 2007). For five consecutive growing seasons, detailed census data were collected on individual plants inside permanently marked quadrats. These data were then used to construct transition matrix models of population growth. Projected population growth rates (λ) varied from 0.89 to 1.07, depending on site and year (Table 2). Projected growth rates across all sites were highest in 1996-97 and 1998-99, and lowest in 1997-98 and 1999-2000. Population performance was somewhat episodic, with "good" years ($\lambda > 1$) generally followed by "poor" years ($\lambda < 1$) and vice versa, although growth rates in some cases were statistically indistinguishable from 1.0 (i.e., stable).[1] Population growth rates did not differ statistically among sites in any given year, suggesting that factors operating at the regional level (e.g., climate) exert a greater influence over population dynamics than local factors (Miller 2004). Incorporating the annual pattern of variability into a stochastic projection model, Miller *et al*. (2007) estimated the stochastic growth rate for the three sites combined to be 0.99, a value indistinguishable from 1.0. Therefore, based on observed patterns of performance from 1996 to 2000, the overall population at East Chopaka is projected to remain essentially stable over the long term.

Table 2. Projected annual population growth rates for Lyall's Mariposa Lily for three sites over four years at East Chopaka, British Columbia. Values significantly different from 1.0 are shown in bold. Adapted from Miller (2004).

Year	Population growth rate λ		
	Site 1a	Site 2a	Site 3a
1996-97	**1.05**	1.03	**1.07**
1997-98	**0.93**	**0.91**	**0.89**
1998-99	0.99	**1.07**	**1.07**
1999-00	0.98	**0.90**	1.01

[1] In a stable environment, the difference between $\lambda < 1$ and $\lambda > 1$ represents the difference between exponential decline and exponential growth; hence, any change in the direction of λ will by definition have a major impact on population trajectories. However, environments are rarely stable in nature, thus λ is generally more useful as a hypothetical projection of population growth, as opposed to a prediction.

Trends based on surveys from 1997, 2007, and 2009

Despite uncertainties associated with abundance estimates, survey data from 1997, 2007 and 2009 indicate that above-ground mature plant numbers have fluctuated over the past 12 years (Table 1, Figs. 5-6). Based on visual estimates, and comparing only the 8 (of 14) subpopulations with data available for 1997 and 2007, the estimated number of flowering individuals declined by roughly 95%, and the total mature population declined by roughly 90% in this 10-year period.

Trends that include the most recent 2009 surveys also indicate that population sizes have fluctuated since 1997, and detect a substantial rebound from the lowest levels in 2007. These trends compare data from sampled quadrats in subpopulations 1a, 2a and 3a (2007 revised and 2009; Table 1). Over this time period, estimated numbers of mature individuals and flowering individuals showed declines of 45% and 39%, respectively.

Direct comparison of population size estimates based on visual versus quadrat-based approaches should however be treated with caution. Further, care should be taken when comparing total population estimates, as 2009 numbers include population extensions resulting from recent surveys.

Estimating the size of the total Canadian population

Not counting additions from recently discovered occurrences, the 2009 totals were roughly 6-fold greater than 2007 numbers, but remained roughly 30% below 1997 numbers (Figure 5). At occurrences 1a, 2a, and 3a (the three most intensively surveyed occurrences), the total number of mature plants (combined) in 2009 was an estimated 27-57% lower than in 1997, while flowering numbers were 22-51% lower (Figure 6). Calculated individually, the number of mature plants at occurrences 1a, 2a, and 3a had declined by roughly 80%, 42%, and 49%, respectively, while the number of plants in flower had declined by 78%, 34%, and 46%, respectively (Table 1). The difference in flowering abundance between 1997 and 2009 was statistically significant for all three cases as determined by Mann-Whitney *U* tests. *P*-values for occurrences 1a, 2a, and 3a were < 0.001, < 0.001, and 0.016 respectively, implying that the probability of a random sample of quadrats yielding such large differences by chance is very low (less than 2%).

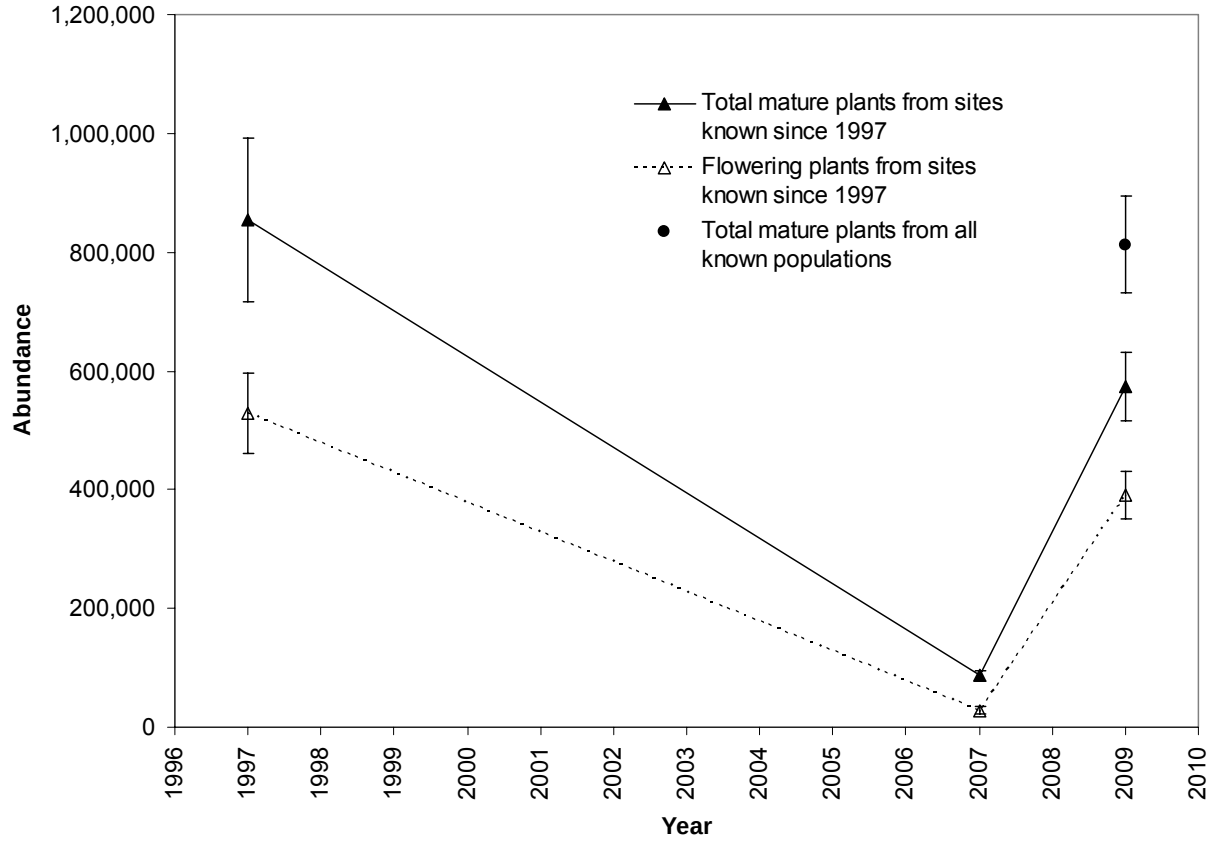

Figure 5. Total mature and flowering abundance of Lyall's Mariposa Lily at East Chopaka in 1997, 2007, and 2009. Data presented are from sites monitored since 1997. Note that 1997 and 2007 data are from visual estimates, while 2009 data are from quadrat-based surveys.

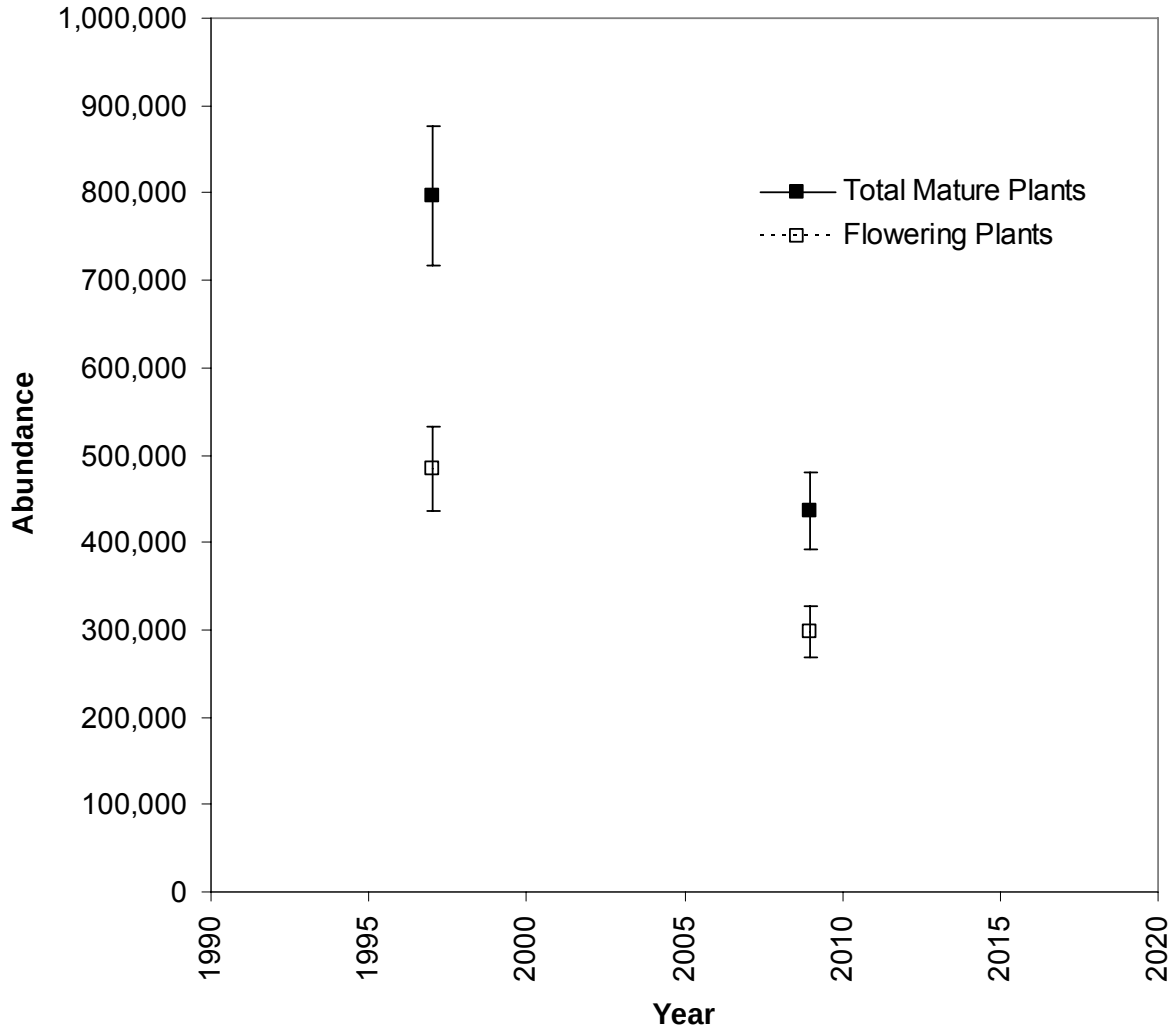

Figure 6. Total mature and flowering abundance of Lyall's Mariposa Lily at East Chopaka in 1997 and 2009. Data are from three occurrences (1a, 2a, and 3a) assessed using random quadrat counts.

Previous research (see above) suggests that the dynamics observed at occurrences 1a, 2a, and 3a (i.e., a downward trend from 1997 to 2007, followed by an upward trend from 2007 to 2009) are likely a general phenomenon and thus representative of most occupied sites at East Chopaka, including those sites discovered only recently.

As noted previously, individuals of the long-lived Lyall's Mariposa Lily often undergo marked changes in size and demographic stage from one year to the next. The relative proportion of reproductive vs. non-reproductive individuals in the population also varies from year to year, because different individuals may progress through the life cycle at different rates and may respond in different ways to prevailing environmental conditions. Between 1997 and 2007, for example, the ratio of mature flowering to sterile stems inside permanent demographic plots at occurrence 1a decreased from 3.0 to 0.81. In occurrences 2a and 3a, this ratio declined from 1.5 to 0.36 and from 1.9 to 0.51, respectively. Because past plant counts have typically emphasized flowering individuals (which are much easier to spot from a distance than the inconspicuous sterile leaves), some of the apparent decline in overall abundance between 1997 and 2007 is probably due to a reduction in flowering rates, rather than a reduction in the number of mature individuals *per se*. Comparable figures are not available for 2009, but it is also likely that some of the observed rebound in abundance from 2007 to 2009 was due to higher numbers of plants flowering rather than to an outright increase in total numbers. Further supporting this is the fact that seedlings likely require three years to reach flowering, and thus the time from 2007 to 2009 is unlikely to have resulted in the levels of recruitment necessary to account for observed increases in flowering individuals, which exceeded 16-fold (34,000 to 555,000) over this time period.

In addition, the life history of Lyall's Mariposa Lily further suggests that declines in above-ground individuals are unlikely to represent mortality of the missing set of individuals, owing to the ability of the species to undergo dormancy. Although demographic studies conducted between 1996 and 2000 estimated the relationship between the percentage of dormant individuals and observations of above-ground individuals, these ratios were estimated in years of relatively low variability in population growth rates, and it is unclear to what extent they are appropriate for years in which significant declines and increases in above-ground numbers are observed. Taken together, these factors suggest that fluctuations in estimated population sizes are likely to partially reflect the species ability to withstand stressful conditions via dormancy, and thus it is difficult to infer declines for Lyall's Mariposa Lily.

Rescue effect

Despite a global conservation rank of vulnerable to apparently secure (G3G4), Lyall's Mariposa Lily is not considered rare or at-risk in Washington (Arnett 2010), the only other jurisdiction where it occurs. At the core of its range in north-central Washington, the species is both widespread and locally abundant. In some areas, such as the Methow Valley, it forms a dominant component of the steppe vegetation (Miller pers. obs.). There thus exists a substantial seed pool south of the international border that could potentially mitigate a Canadian extirpation or population decline via a "rescue effect." Nevertheless, the British Columbia sites are separated from the closest known Washington site 20 km to the south by the deep gorge formed by the Similkameen River Valley; any dispersal into Canada from the southern part of the range would have to be effected through the air. As birds do not typically utilize the seeds of Lyall's Mariposa Lily (Miller pers. obs.), long-range colonization events of this type are probably quite rare (although possible). The limited number of occurrences in southern BC, despite an abundance of apparently suitable unoccupied habitat support this conclusion.

There does however appear to be sufficient suitable habitat available for immigrants, and were dispersal to occur, individuals from the nearest Washington populations would presumably be adapted to survive in Canada.

THREATS AND LIMITING FACTORS

For this update status report, threats could only be assessed directly for the one location (including populations 1-3) for which surveys were conducted. This location is located within the South Okanagan Grasslands Protected Area, The population trends reported here do not appear to be related to the effects of direct anthropogenic factors. For example, there is no evidence to indicate that recent declines are linked either to livestock trampling, forest ingrowth, or competition from invasive alien plants. Invasive plants will continue to pose a threat in the long run, but for this location, this threat is not imminent.

Locations 2 and 3 are on private land, and thus land management decisions, including grazing regimes, and silvicultural practices are the greatest potential threats, with the ability to affect each of these relatively discrete areas over a short time.

Previously identified threats and current management responses

The original status report (Miller and Douglas 2001) cited a number of imminent threats to Lyall's Mariposa Lily or its habitat. These included uncontrolled cattle grazing; forestry activities such as logging, tree planting and road construction; secondary succession; and encroachment of invasive alien plants.

With the establishment of the South Okanagan Grasslands Protected Area in 2001, direct threats to Lyall's Mariposa Lily from forestry activities have now largely abated. No new logging is planned, and most of the conifer seedlings that were planted into occupied habitat patches in 1995 as part of a post-fire salvage operation (Miller and Douglas 2001) have since been removed. Fencing improvements at East Chopaka have also helped limit (but not eliminate) movement and impacts from cattle trampling. The BC Parks' Management Direction Statement for the new protected area accords special consideration to the conservation needs of rare species such as Lyall's Mariposa Lily (BC MWLAP 2003). Recent management initiatives include a biocontrol program at East Chopaka aimed at controlling noxious weed pests such as Hound's-tongue (Dyer pers. comm. 2007).

The draft recovery strategy for Lyall's Mariposa Lily (Southern Interior Rare Plants Recovery Implementation Group, under review) recommends a combination of approaches to address threats, including stewardship, mitigation, inventory and monitoring, additional protection at the provincial level, and further ecological research relevant to the management of the species. Several of these recommendations have now been incorporated into a draft Stewardship Plan for Lyall's Mariposa Lily prepared by BC Parks and the Ministry of Environment (Dyer *et al*. 2007). Specific actions outlined in the Stewardship Plan include monitoring and controlling invasive alien plants, with consideration of potential impacts to Lyall's Mariposa Lily, in accordance with the Regional Invasive Plant Strategy and Pest Management Plan; monitoring cattle grazing, forest encroachment and unauthorized use/activities at known Lyall's Mariposa Lily sites; incorporating best management practices and appropriate strategies (i.e. pasture rotation schedule) into the approved range use plan to protect Lyall's Mariposa Lily; and identifying additional potential threats as they are observed (Dyer *et al*. 2007).

Beginning in 2005, BC Parks and Ministry of Environment staff have conducted semi-annual surveys of Lyall's Mariposa Lily sites within South Okanagan Grasslands Protected Area in order to monitor and manage potential threats to the species. Results of management activities to date are summarized in Klym *et al*. (2007). Klym *et al*. (2007) report that, although non-native species such as Hound's-tongue, Great Mullein and Cheat-grass occur in small numbers at several sites, as of 2007 invasive alien plant impacts at all sites appeared low. Hound's-tongue was manually removed when it was found, except for two sites that were recommended for biocontrol. Likewise, cattle grazing impacts and impacts from forest ingrowth are currently rated "low" at all sites. The report states that any trespass cattle grazing will be monitored by BC Parks on an ongoing basis (Klym *et al*. 2007).

Harvesting

Although some species of *Calochortus* are harvested from the wild for horticulture, the commercial market for Lyall's Mariposa Lily bulbs is negligible and wild-harvesting does not likely pose a threat. Of the very few bulbs sold commercially in North America and worldwide each year, almost all are grown in nurseries from seeds (Woodward pers. comm. 2008).

Post-fire effects

It is possible that microsites that were positively impacted by 1994 fires have declined in suitability somewhat as they revert to their pre-burn condition (Miller *et al*. unpubl.). Increased thatch and vegetation cover, combined with changes to the nutrient regime, could be limiting plant emergence and flowering rates relative to the post-burn flush of the 1990s. Evidence for such post-fire effects on demographic performance is anecdotal at present.

Climate change

Lyall's Mariposa Lily thrives in warm arid climates. The range of climatic conditions that it can withstand is unknown. However, the upland habitat at East Chopaka is somewhat cooler and wetter than the low-elevation sagebrush steppe in which it is typically found at the core of its range in north-central Washington. Miller *et al*. (2004) reported that flowering and fruiting rates at East Chopaka tended to be higher in years following a warm dry spring and summer. Moreover, the year with the wettest spring (1998) yielded the lowest reproductive success among emergent plants and also had the highest dormancy rates. These results suggest that marginal climatic conditions at the periphery of this species' range have the potential to limit demographic performance and hence may be a factor that has limited its spread into British Columbia (Miller *et al.* 2004).

A string of unfavourable weather years could be sufficient to tip the balance towards negative population growth and produce a population decline such as the one observed over the past decade. Although any causal relationship between climate and population performance is difficult to establish without many sequential years of time series data, it is instructive to examine recent climate trends for the region. Figure 7 shows climate normals for the closest weather station at Osoyoos (49° 1.800' N 119° 26.400' W, 300 m elev.) for the period 1975-2008. The station is situated 10 km east of and approx. 700 m elev. below the study area (near valley bottom), thus these data do not perfectly reflect conditions at the East Chopaka, which is a highland area. However, the data contain some discernable patterns with respect to temperature and precipitation that are worth noting for their regional relevance. Most notable is a steady rise in the mean annual temperature since 1975. Regression analysis indicates that this rise is statistically significant, and that it has occurred at approximately 0.44 degrees per decade (Figure 7). This finding should be validated by an appropriate expert. However, from an ecological perspective it is clear that such an increase could, if sustained over the long term, exert a significant impact on plant communities and their constituent species in the south Okanagan.

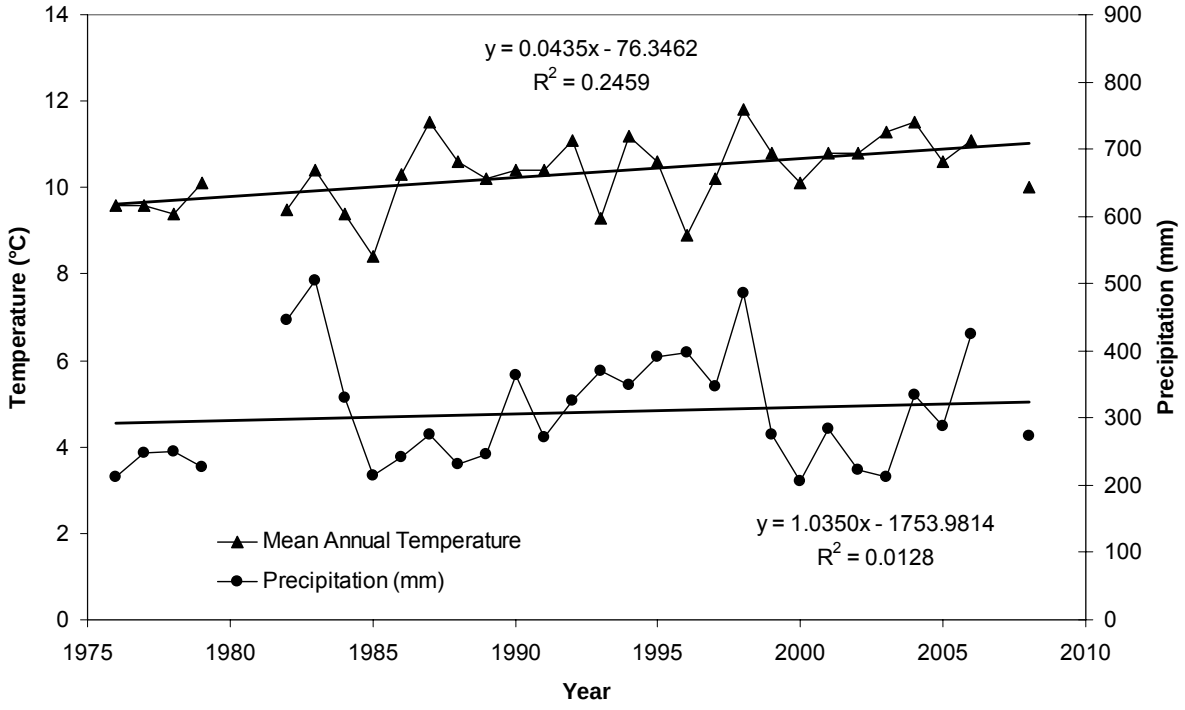

Figure 7. Climate normals (total annual precipitation and annual mean temperature) for the period 1975-2008 for the Osoyoos West climate station, with regression lines against year and R^2 values indicating the percent of annual variation explained by the regression line. Note that there are some missing data points (such as for 2007). Raw data courtesy Environment Canada (2009).

Precipitation patterns for the period are less clear; annual precipitation totals fluctuate considerably, and a regression analysis failed to isolate any long-term directional trend in this variable (Figure 7). Nevertheless, the climate normals show that the first few years of the present decade had relatively low precipitation—about 35% below average. Several drought years in a row, in concert with gradually rising temperatures, may have subjected Lyall's Mariposa Lily to physiological stresses during this period that negatively affected demographic performance during some life stages. For example, prolonged dry spells in the spring season when delicate seedlings and small juveniles are establishing could lead to increased early mortality due to premature desiccation (Miller 2004). Lower survivorship in the early life stages during the early 2000s could in turn have resulted eventually in the lower mature plant numbers observed in 2007. Total precipitation has increased again in the past few years (Figure 7), possibly helping to account for the recent observed upward trend in plant numbers. As noted above, however, overly wet conditions can also have a negative effect on Lyall's Mariposa Lily flowering and fruiting rates as well as bulb emergence.

Most analysts suggest that Canadian grassland ecosystems will enlarge because of greenhouse gas-induced climate change, because predicted warming trends and more frequent droughts will favour grasses over trees (Intergovernmental Panel on Climate Change 2001). Expansion of grasslands should in theory increase the amount of habitat available for Lyall's Mariposa Lily, a primarily grassland species. The warmer drier conditions associated with global warming could also provide physiological benefits for this species at the northern limit of its range. However, any such benefits may be neutralized by negative impacts arising from the predicted increase in extreme weather events and ecosystem state shifts. For example, if the areal extent of grasslands expands rapidly, normal successional processes may fail, leaving the new grassland areas dominated by early pioneer and invasive alien species (Gayton 2003). A similar community shift within presently occupied sites could result in altered competitive regimes for Lyall's Mariposa Lily along with a loss of important pollinators.

EXISTING PROTECTION OR OTHER STATUS DESIGNATIONS

Legal protection and status international status

In Canada, Lyall's Mariposa Lily was assessed by COSEWIC as Threatened in 2001, and is currently listed on Schedule 1 of the federal *Species at Risk Act* (*SARA*). No populations are on federal lands. The species is not covered under the Convention on International Trade in Endangered Species of Wild Fauna and Flora (CITES), the Endangered Species Act (USA) or the IUCN Red Data Book.

Non-legal status and ranks

Lyall's Mariposa Lily global rank was reviewed in May 2008 and has been downgraded from the rank of vulnerable (G3) to a rank of G3G4, defined as "vulnerable - at moderate risk of extinction due to a restricted range, relatively few populations (often 80 or fewer), recent and widespread declines, or other factors to apparently secure - uncommon but not rare; some cause for long-term concern due to declines or other factors" (NatureServe 2010).

This species is not tracked as a rare species outside British Columbia. In Washington, the only other jurisdiction in which it occurs, it is ranked SNR (NatureServe 2007) indicating that the species has not yet been assessed.

Lyall's Mariposa Lily has a NatureServe national conservation rank of vulnerable (N3). Provincially, Lyall's Mariposa Lily also has a conservation rank of vulnerable (S3) in British Columbia and has recently been downgraded from critically imperiled (S1) and from the Red List (candidate for extirpated, endangered or threatened status) to the Blue List (special concern). Because of its SARA listing, Lyall's Mariposa Lily could still be a candidate for protection in British Columbia under the provincial *Wildlife Amendment Act* (2004).

BC Parks' Management Direction Statement for the new protected area accords special consideration to the conservation needs of rare species such as the Mariposa Lily (BC MWLAP 2003).

Habitat protection and ownership

Twelve of the 15 known Lyall's Mariposa Lily subpopulations in Canada (four of five populations) exist entirely within the South Okanagan Grasslands Protected Area and are protected by provincial parks legislation. A thirteenth subpopulation lies partly within the Protected Area with the majority of the occurrence extending onto private land. Two other occurrences are located entirely on private land.

Parks Canada is currently conducting a study into the feasibility of establishing a National Park Reserve in the South Okanagan-Lower Similkameen region to represent the Interior Dry Plateau Natural Region. The Reserve would encompass what is presently the South Okanagan Grasslands Protected Area (Parks Canada 2009).

Four of the five populations of Lyall's Mariposa Lily in British Columbia occur in a provincially protected area (South Okanagan Grasslands Protected Area) and thus are regulated by the provincial *Park Act*.

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COLLECTIONS EXAMINED

The following collections were consulted:

- Royal BC Museum Herbarium (V)
- University of British Columbia Herbarium (UBC)
- Burke Museum, University of Washington (WTU)