

Conservation Evaluation of the Bog Bird's-foot Trefoil, *Lotus pinnatus*, in Canada*

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In Canada, Bog Bird's-foot Trefoil, *Lotus pinnatus*, is confined to vernal wet meadows, creek margins, ditches and seepages, where underground water comes to the surface. Seven localities, within a small area on the east coast of Vancouver Island near Nanaimo, British Columbia, have been confirmed in recent years. At two others it is considered extirpated. The lack of protection on private land, alterations to hydrology, and erosion arising from intensive recreational use of primary habitat by off-road vehicles as well as the appearance of invasive species are the main concerns for British Columbia populations.

Key Words: Bog Bird's-foot Trefoil, *Lotus pinnatus*, endangered species, distribution, conservation, British Columbia.

Bog Bird's-foot Trefoil, *Lotus pinnatus* Hook[†], is a low-growing, short-lived perennial of the pea family (Fabaceae) with many erect to spreading stems ranging from 15 to 60 cm long (Figure 1). The pinnately compound leaves are 4–8 cm long, with 5–9 elliptic, oblong or narrowly egg-shaped leaflets. The inflorescence is a compact, stalked, axillary umbel of 3 to 12 flowers. The corollas are 10–15 mm long with a yellow banner and keel and creamy-white wings. The keel petals are fused along one edge that is elongated into a well-defined beak towards the outside of the inflorescence. The calyx is tubular and lobed, with two upper lobes that are joined most of their length. The linear seed pods are 3–6 cm long and 1.5–2 mm wide and contain 5–20 cylindrical, glossy, dark-coloured seeds (Pojar 1999). In the field, several species superficially resemble *L. pinnatus*. Vetches (*Vicia* species) are often present in similar habitats, but the leaves are smaller than those of *L. pinnatus* and the terminal leaflet in *Vicia* spp. is a tendril. Seaside Birds-foot Trefoil (*Lotus formosissimus*) looks similar to *L. pinnatus* except the wing petals of *L. formosissimus* are pinkish-purple, while those of *L. pinnatus* are cream-colored. In addition, though a trifoliate bract usually subtends the flowers of *L. formosissimus*, bracts were sometimes absent in field specimens or only a unifoliate bract was present (Ryan and Douglas 1994*). *Lotus pinnatus* and *L. formosissimus* could be confused if the plants are immature or not in flower, but the two species do not overlap in their distribution in British Columbia. *Lotus formosissimus* is known only from the Victoria area and nearby islands, where it occurs in various xeric habitats, ranging from open grass-dominated meadows

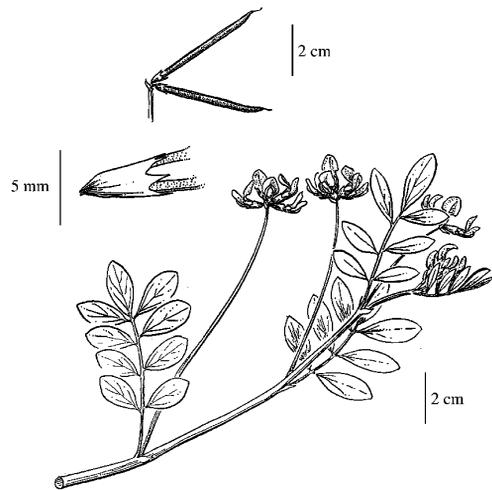


FIGURE 1. Illustration of *Lotus pinnatus* (line drawing in Hitchcock et al. 1961; Pojar 1999).

to exposed steep rocky sites with Garry Oak (*Quercus garryana*) (Ryan and Douglas 1994*). *Lotus pinnatus* is found only in the Nanaimo area on Vancouver Island, where it occurs in moist soil on exposed, coastal lowland areas. Bird's-foot Trefoil (*Lotus corniculatus*) could also be confused for *L. pinnatus* as it occasionally grows in wet places, but it is usually found in drier, disturbed sites. Also, *L. corniculatus* has completely yellow flowers and its leaflets are smaller and more blunt than the other trefoils.

The information, gathered during field surveys in 2003 formed the basis for a Committee on the Status of Endangered Wildlife in Canada status report (Donovan 2004) and the subsequent assessment of *Endangered* (COSEWIC 2004*). This paper includes more recent information that did not appear in the original status report.

[†] Taxonomy and nomenclature follow Douglas et al. (1999).

Distribution

Lotus pinnatus occurs in western North America from Vancouver Island, south to northwest Washington, western Oregon and the Columbia River Gorge, to central California and sporadically eastward to Idaho (Figure 2; Isely 1993; Pojar 1999). In Canada, *Lotus pinnatus* is known from seven extant populations within a small area on the east coast of Vancouver Island near Nanaimo (Donovan 2004*).

Habitat

The British Columbia populations of *L. pinnatus* occur within the moist maritime subzone of the Coastal Douglas-fir (CDF) biogeoclimatic zone (Meidinger and Pojar 1991) in the Nanaimo Lowlands Ecoregion of the Georgia Depression Ecoprovince (Demarchi 1996*). In this region, the Olympic Mountains in Washington State to the south and the Insular Mountains on Vancouver Island to the west produce a rain shadow effect resulting in a Mediterranean-type climate with warm, dry summers and mild, wet winters. Most of the rainfall occurs during the winter months, and limited precipitation and high temperatures during the summer months result in pronounced summer moisture deficits (Meidinger and Pojar 1991).

Lotus pinnatus grows in open, springy meadows, along the margins of creeks, or in seepages, where underground water comes to the surface and the plants are in close physical contact with cool, flowing water (H. Roemer, personal communication). In all cases, the soils are shallow (< 15 cm), over gently sloping sandstone or conglomerate bedrock with abundant moisture during the growing and blooming period. *Lotus pinnatus* is most commonly associated with Yellow Monkey-flower (*Mimulus guttatus*), Sea Blush (*Plectritis congesta*), White Triteleia (*Triteleia hyacinthina*), Small-leaved Montia (*Montia parvifolia*), Scouler's Popcornflower (*Plagiobothrys scouleri*) and American Speedwell (*Veronica beccabunga* ssp. *americana*). Stands of Douglas-fir (*Pseudotsuga menziesii*) and dense thickets of Nootka Rose (*Rosa nutkana*), Ocean Spray (*Holodiscus discolor*), Nine-bark (*Physocarpus capitatus*) and willow (*Salix* spp.) exist on the margin of some seepages but *Lotus pinnatus* does not occur in the shaded understory of these sites, suggesting that the species is shade-intolerant. Prolonged moisture, edge habitat along streams and meadows and shallow soils derived from sedimentary rock are key habitat components. Other factors, such as slope and aspect are variable and do not appear to be critical in defining suitable habitat. In British Columbia, the elevation for this species ranges between 40 m and 150 m.

Biology

Zandstra and Grant (1968) studied the biosystematics of native and introduced *Lotus* species in Canada and reported that although many of the Old World species are polyploids, none of the North American

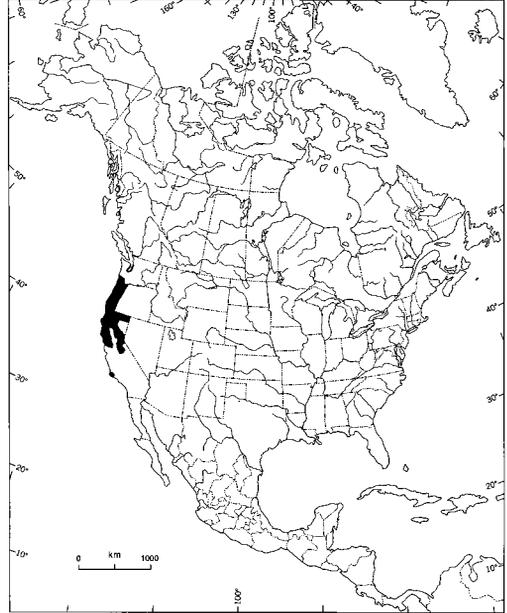


FIGURE 2. Distribution of *Lotus pinnatus* in North America (from Donovan 2004*).

species examined exhibited the same trait. North American *Lotus* species have a base chromosome number of 6 or 7. Of the species native to Canada, *L. pinnatus* and *L. formosissimus* are considered to be the most closely related, based on morphological, habitat, and cytological characteristics. A chemotaxonomic study using thin-layer chromatography further supported the general relationships among Canadian *Lotus* species with *L. formosissimus* and *L. pinnatus* demonstrating the greatest degree of similarity (Grant and Zandstra 1968). These species differed from other native Canadian species in that both were perennial outcrossers with large flowers on long pedunculate umbels. The other three native species were self-fertile annuals with small flowers. Evolution in angiosperm reproduction has frequently occurred with a decrease in basic chromosome number, a shift from an outcrossing (cross-pollinating) to an inbreeding (self-pollinating) reproductive system and a shift from a perennial to an annual habit (Stebbins 1957). On this basis, Zandstra and Grant (1968) considered *L. pinnatus* and *L. formosissimus* to be more primitive than the annual species.

Lotus pinnatus germinates in the late winter or early spring when soil moisture and temperature conditions are most favourable, and seedling survival appears to be dependent on continuous surface moisture during this period. Though the specific timing of events will depend on local habitat conditions, flowering in *L. pinnatus* generally occurs between May and the end of June.

The pea-like, bisexual flowers are borne at the end of a long peduncle arising from the leaf axil, and the umbellate inflorescences are produced sequentially throughout the growing season. As the flowers senesce, some become progressively more reddish (Isely 1981). During July, when drought conditions are prevalent, seed maturation and dispersal begin, followed by die-back of the stems to the rootstock, which is located several centimetres below the soil surface. The seeds lack any strong adaptations for long-distance dispersal by wind or animal vectors. Most seeds are gravity-dispersed and generally land in the immediate vicinity of the parent plant. The plant's habitat along stream channels may permit the legumes and seeds to be transferred by water during times of seasonal flooding. However, germination and seedling survival appear to depend upon continuous surface moisture, and the species does not appear to be a strong competitor with native shrub species or with invasive alien plants. The chances of a healthy population returning to Canada if local populations become extirpated are highly unlikely. The nearest population in Washington State, from which collections were made in 1940, is 240 km away in Bremerton. Whether this population is extant is unknown.

As with other perennial species in the genus *Lotus*, Zandstra and Grant (1968) suggested that the flowers of *L. pinnatus* required cross-pollination to set viable seed. Given the bright yellow appearance of the flower and the wide keel that serves as a suitable landing platform, flowers of *L. pinnatus* appear to be adapted to bee pollination. Although the importance of the bumblebee to the flower (and vice versa) is yet to be specifically determined, bumblebees were observed visiting flowers of *L. pinnatus* at Harewood Plains during field observations made in 2003. Although bees are capable of dispersing pollen over short distances, cross-pollination between most populations in Canada is unlikely in view of the distances involved.

Like many other legumes, *L. pinnatus* appears to be associated with nitrogen-fixing *Rhizobium* bacteria that occupy root nodules and provide the plants with a source of reduced nitrogen in exchange for a supply of carbon and other nutrients. Specific strains of *Rhizobium* bacteria are required for effective nodulation of *Lotus* species grown as forage crops, such as *L. corniculatus* and *L. tenuis*. To maximize establishment in areas that have never produced *Lotus*, inoculation of seeds with the appropriate rhizobia is necessary (Blumenthal and McGraw 1999).

An examination of root nodules collected from *L. pinnatus* at Harewood Plains indicated the presence of bacteria, most likely of genus *Rhizobium* (S. Berch, personal communication).

Population Attributes

Lotus pinnatus has been reported from nine sites in British Columbia (Figure 3; Table 1), all in the Nanai-

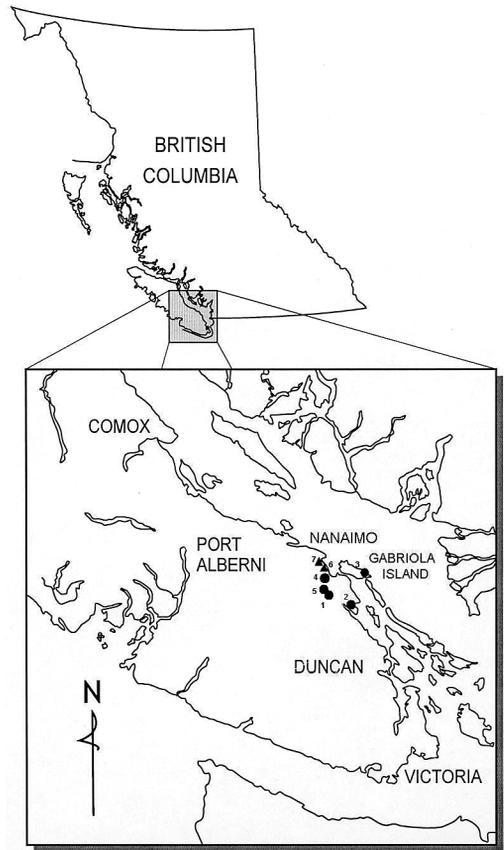


FIGURE 3. Distribution of *Lotus pinnatus* in British Columbia (from Donovan 2004*) ● confirmed; ▲ unconfirmed.

mo area on Vancouver Island and on nearby Gabriola Island. Of the nine reported records, seven populations were verified in recent years. The remaining two sites have been extensively disturbed and it is unlikely that these populations currently exist. Between 1500 and 2000 individual plants were counted in Canada in 2003 over an area of 650 square metres. Relatively little is known of demographic characteristics and population trends of *L. pinnatus* due to a lack of long-term monitoring. Estimates of population trends in *L. pinnatus* are currently unreliable as the clumped, sprawling habit makes it difficult to identify separate individuals and counting methods have varied with different investigators. Until counting methods are standardized, population numbers should be considered rough estimates.

Provincial, National and Global Ranks

The British Columbia Conservation Data Centre has ranked *L. pinnatus* as "S1" and placed it on the "Red list". A rank of "S1" indicates that the species is "critically imperiled because of extreme rarity (often

TABLE 1. Locations and Population Sizes for *Lotus pinnatus* in British Columbia.

Populations	Observation Date	Collector/ Observer	Number of Individual Plants	Apparent Status
Harewood Plains North*	7 July 2003	M. Donovan	1500 in 500 m ²	Extant
Harewood Plains South 1	12 July 2003	M. Donovan	25 in 4 m ²	Extant
Harewood Plains South 2	12 July 2003	M. Donovan	10 in 2 m ²	Extant
Woodley Range	1 June 2003	M. Donovan	120–140 in 90 m ²	Extant
Gabriola Island, off Peterson Road, on Perry Road	25 May 2003	Donovan/Penny	65–70 in 10.5 m ²	Extant
Nanaimo, west of Cinnabar Valley	15 June 2003	M. Donovan	40 in 25 m ²	Extant
Nanaimo, south of Extension	23 June 2003	M. Donovan	30 to 45 in 17 m ²	Extant, but declining
Waddington & Departure Bay Roads Nanaimo	2 June 1939	J.W. Eastham	N/A	Extirpated
Departure Bay Road and Island Highway, Nanaimo	20 June 1965	K. Beamish	N/A	Extirpated

* The collection by W. R. Carter at Mt. Benson in 1 June 1918 is included with this population as Harewood Plains may be considered the foothills of Mt. Benson.

5 or fewer occurrences) or because of factors making it especially vulnerable to extirpation.” This is the most critical status that can be applied to a species at the provincial level. Though it currently lacks formal protection in British Columbia, *Lotus pinnatus* is a potential candidate for listing under the provincial *Wildlife Amendment Act* (2004).

At the national level, *Lotus pinnatus* has been assessed as Endangered by the Committee on the Status of Endangered Wildlife in Canada (COSEWIC 2004*) and appears on Schedule 1 of the federal *Species At Risk Act* (Environment Canada 2006*).

Globally, *Lotus pinnatus* has a rank of G4G5 which indicates that the plant is apparently secure in most of its range (NatureServe Explorer 2006*).

Threats and Protection

Habitat loss presents a serious and urgent threat to *Lotus pinnatus* in Canada. Over 90% of the extant population of *L. pinnatus* is located on land that is privately owned, making this species vulnerable to habitat loss as a result of urban expansion and residential development.

In addition to potential commercial and residential development, the population of *L. pinnatus* at Harewood Plains is under direct and immediate threat of habitat degradation and fragmentation resulting from intensive, unauthorized use of recreational off-road vehicles; including ATVs, 4 × 4s and dirt bikes (C. Thirkill, personal communication). In some areas at this site, the thin and fragile soils have been rutted down to bedrock and plants have been dislodged on to bare rock where they cannot re-establish (Figure 4). There is high potential for further impacts as vehicles continue to access the site, despite efforts by the former landowner (Weyerhaeuser Canada) to block access to off-road vehicles with boulder placements, ditches and the installation of several cement barriers along the access road (C. Thirkill, personal communication). In

an effort to minimize the disturbance of sites designated as “Environmentally Sensitive Areas” the City of Nanaimo has established a Development Permit Area on a portion of the property at Harewood Plains (Rob Lawrance, personal communication). As the habitat at Harewood Plains supports several other species at risk such as Dense-spike Evening Primrose (*Epilobium densiflorum*), Green-sheathed Sedge (*Carex feta*), Foothill Sedge (*Carex tumulicola*), Slim-leaf Onion (*Allium amplexens*) and Nuttall’s Quillwort (*Isoetes nuttallii*), a working group comprised of representatives from industry, non-governmental organizations and local and provincial governments has been established in order to develop proactive communication with the different land owners, managers and stakeholders at this location.

At the site south of Extension, near Nanaimo, at least some portions of the population have been reported extirpated due to recreational off-road vehicle use and residential development (A. Ceska, personal communication).

Other than habitat destruction, competitive exclusion from native and non-native vegetation represents the most significant ongoing threat to *L. pinnatus* at all sites. Encroachment of native shrub species in potential habitats may prevent this species from occupying new sites. Invasive alien grass species that threaten the persistence of *L. pinnatus* include Sweet Vernalgrass (*Anthoxanthum odoratum*), Orchard Grass (*Dactylis glomerata*), Kentucky Bluegrass (*Poa pratensis*) and Barren Brome (*Bromus sterilis*). Scotch Broom (*Cytisus scoparius*) is the most dominant invasive alien shrub. Logging operations close to (within 50 m of) populations of *L. pinnatus* at Harewood Plains increase the potential for the spread of aggressive native and non-native plant species. By disturbing soils and carrying seeds, off-road vehicles are also a major factor in the spread of invasive non-native plants in sensitive areas.

The population located in the Woodley Range Ecological Reserve is protected, to a certain extent, by its



FIGURE 4. Destruction of habitat caused by all-terrain vehicles at Harewood Plains (Photo George Douglas, 2003).

location within an ecological reserve, but this represents only 7% of the total Canadian population. In addition, plants at this location are vulnerable to adjacent land uses including all-terrain vehicle use, logging and other land clearing activities which could impact on the hydrological features that provide seepage to the location.

A national multi-species strategy that addresses the recovery of *Lotus pinnatus* and five other endangered plant species of vernal pools and other ephemeral wet areas has been completed. This strategy outlines recovery goals for each species, suggests strategic approaches for meeting the recovery goals and recommends that a draft recovery action plan (RAP) be completed by October 2009, which includes proposing Critical Habitat for this species under the *Species At Risk Act* (Parks Canada Agency 2005*).

Evaluation

The British Columbia Conservation Data Centre considers *Lotus pinnatus* to be endangered in British Columbia (Donovan 2004*) and the Committee on the Status of Endangered Wildlife in Canada has assessed the species as Endangered (COSEWIC 2004*). Only a few small fragmented populations remain, and these are restricted to wet meadows of limited occurrence that are considerably disjunct from the main range of the species in the north-western United States. The

populations are at risk from continued habitat loss, encroachment of invasive species and recreational off-road vehicle use. Development of the habitat supporting the only sizeable remaining population could result in significant losses to the population (COSEWIC 2004*).

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Documents Cited (marked * in text)

- COSEWIC.** 2004. COSEWIC assessment and status report on the bog bird's-foot trefoil *Lotus pinnatus* in Canada. Committee on the Status of Endangered Wildlife in Canada. Ottawa, Ontario. 33 pages. www.cosewic.gc.ca
- Demarchi, Dennis A.** 1996. An Introduction to the Ecoregions of British Columbia. Wildlife Branch, Ministry of Environment, Lands and Parks, Victoria. (Available at http://srmwww.gov.bc.ca/ecology/ecoregions/title_author.html [Accessed 22 June 2006])
- Donovan, M.** 2004. COSEWIC status report on the bog bird's-foot trefoil *Lotus pinnatus* in Canada. In COSEWIC assessment and status report on the bog bird's-foot trefoil *Lotus pinnatus* in Canada. Committee on the Status of Endangered Wildlife in Canada. Ottawa, Ontario. 33 pages.

Environment Canada, Schedule 1: List of species at risk. Website: http://www.sararegistry.gc.ca/species/schedules_e.cfm?id=1 [Accessed 22 June 2006].

NatureServe Explorer. 2006. NatureServe Explorer: An online encyclopedia of life. Version 1.7. Arlington, Virginia, USA. Web site: <http://www.natureserve.org/explorer> [Accessed 22 March 2006].

Parks Canada Agency. 2005. Recovery Strategy for Multi-species at Risk in Maritime Meadows Associated with Garry Oak Ecosystems in Canada (proposed) in *Species at Risk Act Recovery Strategy Series*. Edited by Parks Canada Agency. Ottawa, Ontario. 98 pages.

Literature Cited

Blumenthal, M. J., and R. L. McGraw. 1999. Lotus adaptation, use and management. Pages 97–119 in *Trefoil: The science and technology of Lotus*. Edited by P. R. Beuselinck. Crop Science Society and the American Society of Agronomy. Madison, Wisconsin.

Douglas, G. W., D. Meidinger, and J. Pojar. 1999. Illustrated Flora of British Columbia. Volume 3. Dicotyledons (Diapensiaceae through Onagraceae). British Columbia Ministry of Environment, Lands and Parks and British Columbia Ministry of Forests, Victoria, British Columbia. 423 pages.

Grant, W. F., and I. I. Zandstra. 1968. The biosystematics of the genus *Lotus* (Leguminosae) in Canada. II. Numerical cytotaxonomy. *Canadian Journal of Botany* 46: 585–589.

Hitchcock, C. L., A. Cronquist, M. Ownbey, and J. W. Thompson. 1961. Vascular Plants of the Pacific Northwest. Part 3: Saxifragaceae to Ericaceae. University of Washington Press, Seattle, Washington. 614 pages.

Isely, D. 1981. Leguminosae of the United States. III. Subfamily Papilionoideae: tribes Sophoreae, Podalyriaceae, and Lotaeae. In: *Memoirs of the New York Botanical Garden*. 25(3): 181.

Isely, D. 1993. *Lotus*. Pages 616–622 in *The Jepson Manual: Higher Plants of California*. Edited by J. C. Hickman. University of California Press, Los Angeles, California.

Meidinger, D., and J. Pojar (editors). 1991. *Ecosystems of British Columbia*. Special Report, Series 6, British Columbia Ministry of Forests, Victoria, British Columbia. 330 pages.

Pojar, J. 1999. Fabaceae. Pages 64–180 in *Illustrated Flora of British Columbia*. Volume 3. Dicotyledons (Diapensiaceae through Onagraceae). Edited by G. W. Douglas, D. Meidinger, and J. Pojar, British Columbia Ministry of Environment, Lands and Parks, British Columbia Ministry of Forests, Victoria, British Columbia.

Ryan, M., and G. W. Douglas. 1994. Status report on the Seaside birds-foot lotus, *Lotus formosissimus* Greene. Unpublished report submitted to the Committee on the Status of Endangered Wildlife in Canada, Ottawa. British Columbia Conservation Data Centre, Victoria, British Columbia. 25 pages.

Stebbins, G. L. 1957. Self-fertilization and population variability in higher plants. *American Naturalist* 91: 337–353.

Zandstra, I. I., and W. F. Grant. 1968. The biosystematics of the genus *Lotus* (Leguminosae) in Canada. I. Cytotaxonomy. *Canadian Journal of Botany* 46: 557–583.

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