

COSEWIC
Assessment and Status Report

on the

Streambank Lupine
Lupinus rivularis

in Canada



ENDANGERED
2002

COSEWIC
COMMITTEE ON THE STATUS OF
ENDANGERED WILDLIFE
IN CANADA



COSEPAC
COMITÉ SUR LA SITUATION
DES ESPÈCES EN PÉRIL
AU CANADA

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COSEWIC Assessment Summary

Assessment Summary – November 2002

Common name

Streambank Lupine

Scientific name

Lupinus rivularis

Status

Endangered

Reason for designation

A highly restricted species with very few populations extant and extremely low numbers of plants remaining. Populations are all close to industrial and other development and at risk from impacts such as habitat loss, herbicide spraying, predation by exotic slugs and subject to genetic swamping through hybridization with a non-native lupine species.

Occurrence

British Columbia

Status history

Designated Endangered in November 2002. Assessment based on a new status report.



COSEWIC
Executive Summary

Streambank Lupine
Lupinus rivularis

Species Information

Lupinus rivularis Dougl. ex. Lindl. (streambank lupine) is a particularly beautiful species of lupine that stands between 4 and 6 dm. It has an erect habit and lovely lavender flowers that bloom from May until September. While taxonomy and nomenclature for North American lupines is particularly confusing, this species is readily identifiable, particularly when adding features of habitat and elevation to morphological features. It can be separated readily from other lupines in our area by a combination of delicate leaves, erect habit, and early flowering, and by its occurrence at low elevations.

Distribution

Globally, *Lupinus rivularis* is found only along the Pacific Coast, from northwestern California to southwestern British Columbia. To date in British Columbia, it has been confirmed only in the extreme southwestern corner of the province, with a single population on southern Vancouver Island, and five populations in the lower Fraser Valley.

Habitat

This species occupies open sandy or gravelly, moist riverbank sites at low elevations proximal to the coast. These are generally sites with little ground cover, though it occasionally occurs under an open canopy. Sites are generally flood prone and, prior to dyking, would have flooded with some regularity. Like other lupines, *L. rivularis* displays a preference for disturbed, though not weedy, sites.

Biology

Lupinus rivularis is a perennial, primarily herbaceous species, with a long taproot. It is a nodulated species of impoverished sites. Hybridization, a common feature of North American lupines, is reported in this species, and includes hybridization with the invasive *L. arboreus* (yellow bush lupine), as well as other native lupines (e.g., *L. littoralis*, seashore lupine). Like other lupine species, it appears to produce abundant amounts of large heavy seeds that can be thrown up to 26 feet from the parent plant when the pods explode.

Population sizes and trends

Only six natural populations of *Lupinus rivularis* have been confirmed in Canada and British Columbia. Present populations range from 100 plants at one station to only one plant at another station. All populations reported in the Fraser Valley in the late 1980s and early 1990s are still extant. It is speculated that the species might have been more widespread prior to the industrial development and extensive dyking of its riverbank habitat in the coastal reaches of the lower Fraser Valley.

Limiting factors and threats

Lupinus rivularis is a species that occurs at the extreme northern limit of a fairly restricted global range along the Pacific Coast. This may indicate that the species was initially rare in our region and is sensitive to climatic fluctuations. It is also limited in occurrence to a narrow band of habitat along creeks and riverbanks within this range. This is habitat that has been substantially altered by extensive dyking of the river systems in the lower Fraser Valley, as well as by industrial development in floodplain sites that may originally have provided more extensive habitat for the species. Habitat loss for this species is thought to be significant.

Several factors threaten the continued survival of this species both in Canada and throughout its US range, including hybridization and genetic swamping by *Lupinus arboreus*. Predation by invasive invertebrates poses a threat. Ground maintenance in several sites, including herbicide spraying, also poses extreme threat to our populations. In addition, this particularly beautiful lupine is threatened by wildflower collecting by the general public—as we have witnessed—and is now advertised for use in herbal essences.

Special significance of the species

It is possible that our populations of *Lupinus rivularis* represent some of the most “pure” populations that remain for this species throughout its range, potentially making our populations highly significant. Further investigation is required here. In addition, the growing interest in lupines as a food crop indicates that preserving as many species’ gene pools as possible may be important agriculturally.



COSEWIC MANDATE

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

COSEWIC MEMBERSHIP

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

DEFINITIONS

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

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

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

*** Formerly described as “Indeterminate” from 1994 to 1999 or “ISIBD” (insufficient scientific information on which to base a designation) prior to 1994.

The Committee on the Status of Endangered Wildlife in Canada (COSEWIC) was created in 1977 as a result of a recommendation at the Federal-Provincial Wildlife Conference held in 1976. It arose from the need for a single, official, scientifically sound, national listing of wildlife species at risk. In 1978, COSEWIC designated its first species and produced its first list of Canadian species at risk. Species designated at meetings of the full committee are added to the list.



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Lupinus rivularis

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2002

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SPECIES INFORMATION

Name and classification

Lupinus rivularis Dougl. ex. Lindl. (Lindley's diagnosis came from cult. plants and Douglas' notes. (USDA 2001)).

Bibliographic citation: Bot. Reg. 19: t: 1595. 1833.

Type: *America Boreali-occidentalis*, Douglas 263, 1825. CGE. Figures 55 and 56.

Synonymy: *L. lignipes* Muhlenbergia 8: 66. Fig. 8. 1912. (Type: Eugene, Lane Co., Oregon, Heller 10042 RENO, POM, MIN.)

Common names: streambank lupine, riverbank lupine.

Family: Fabaceae alt. Leguminosae. Also placed in: Papilionaceae. Edward's Bot. Reg. 19: t. 1595. 1833.

Sources: Dunn and Gillett 1966; Kartesz and Kartesz 1994

Comment

The genus *Lupinus* is considered one of the most taxonomically difficult groups in the Pacific Northwest (Phillips 1955, Hitchcock et al. 1961, Ceska 2001 pers. comm., Sholars 2001 pers. comm., Ainouche and Bayer 1999, Nicholls and Bohm 1983, and others). Confusion surrounds the taxonomy and nomenclature to the point that a widely varying number of North American species are recognized by different experts: from as few as 100 species to as many as 600 taxa (Nicholls and Bohm 1983). The genus has been explored by several researchers, including Heller (1912), Phillips (1955), Dunn and Gillett (1966), Mikolajczyk (1964), Bisby (1981), Nicholls and Bohm (1983), and Ainouche and Bayer (1999). However, this has not yet allowed a clear picture to emerge. As Nicholls and Bohm (1983, 708) state, "while *Lupinus* is easily distinguished from other genera, comparatively few characters avail themselves for clear distinctions between species."

Hybridization and introgression, play a significant role in this confusion, and are commonplace, while "phenotypic plasticity seems the rule rather than the exception" (Nicholls and Bohm 1983, 708). Phillips (1955), who examined lupines of North America exclusive of the southwestern United States and Mexico, indicates that the natural variation in the genus is high, and that this is a result of the considerable amount of hybridization that is taking place, with many of the hybrids producing fertile offspring. Hybridization is increased today in many regions by the active planting of lupines for gardens and highway maintenance. For example, the spread up the Pacific Coast of the highly aggressive *Lupinus arboreus*, mainly as a result of planting, complicates the picture. This is a species that readily genetically swamps other lupines (Sholars 2001 pers. comm.). All of this has led to some confusion in classification of lupines in general and in our local species.

The taxonomy and nomenclature of *Lupinus rivularis* does not escape these complexities. In Hitchcock et al. (1961), *L. rivularis* Lindl. is equated with *L. amphibium*

Suskd. Phillips (1955) considered *L. rivularis* Dougl. ex Lindl. as synonymous with *L. albicaulis*, while Dunn and Gillett (1966) treat *L. rivularis* as a separate species. These last authors mention that it shows morphological affinity to *Lupinus arcticus* ssp. *subalpinus*, the two being separated by altitude. Douglas et al. (1998) recognize it as a separate species with no synonymy given. In the US, Riggins and Sholars (1993) describe it as grading into blue-flowered *L. arboreus*. Sholars (2001 pers. comm), who is presently working on a new treatment of *Lupinus* for Flora North America, has indicated that in the US it is generally lumped with *L. latifolius*, although she feels it is a good and separate species. Only one synonym, *L. lignipes*, is legitimately recognized by Kartesz and Kartesz (1994) for *Lupinus rivularis*.

Lupinus rivularis is known to hybridize extensively with the aggressive *L. arboreus* (Riggins and Sholars 1993, Sholars 2001 pers. comm.), and *L. arboreus* in general is known to hybridize with other lupines species (Rhymer and Simberloff 1996), producing hybrid swarms. In addition to complicating the identification of *L. rivularis*, this is raising concerns about the survival of *L. rivularis* and other lupine species (Sholars 2001 pers. comm., Rhymer and Simberloff 1996). Concerns have been raised about the disruption of the gene pool in other lupine species where contact with *L. arboreus* is occurring (US National Park Service 2001).

Sholars hopes to clarify the situation with North American lupines, including *L. rivularis*. In the interim, she has indicated that *L. rivularis* shows strong similarity to *L. latifolius*, although it is frequently swamped by *L. arboreus*. She does believe that it is a good species, although pure populations may now be rare, and that it can be separated readily from this and other lupine species by morphological features such as woodiness of the stem, hairiness of the keel, etc., as well as by characteristics such as habitat. She also indicates that they are elevationally distinct.

Given this, in spite of this general confusion with North American lupines, and following preliminary field investigations, specimen examination, and discussion with Sholars and others, we feel that *Lupinus rivularis* in BC is readily identifiable and fits the description provided by Douglas et al. (1999) (*The Illustrated Flora of British Columbia*, Volume III). Generally, growth habit, habitat, floral features and elevation of occurrence are distinct and easily separate this species from other coincident lupine species. The work of Kartesz and Kartesz (1994) is followed for nomenclature and synonymy.

Description

Lupinus rivularis is an attractive perennial lupine that reaches heights of between 4 and 6 dm. It is an erect herbaceous plant (though sometimes slightly woody at the base) with lovely lavender flowers that generally takes on a beautiful "bouquet" form (Figure 1). Superficially, the stems and leaves appear glabrous, though small hairs are apparent when magnified. The leaves occur primarily on the stem, and consist of a palmately whorled, delicate-looking, set of 6-9 leaflets that are hairy beneath but usually hairless above, with mucronate tips. The keel of the flower is hairy along most of its length. Seedpods appear black, or with black mottling. Leaves curl slowly inwards on picking.

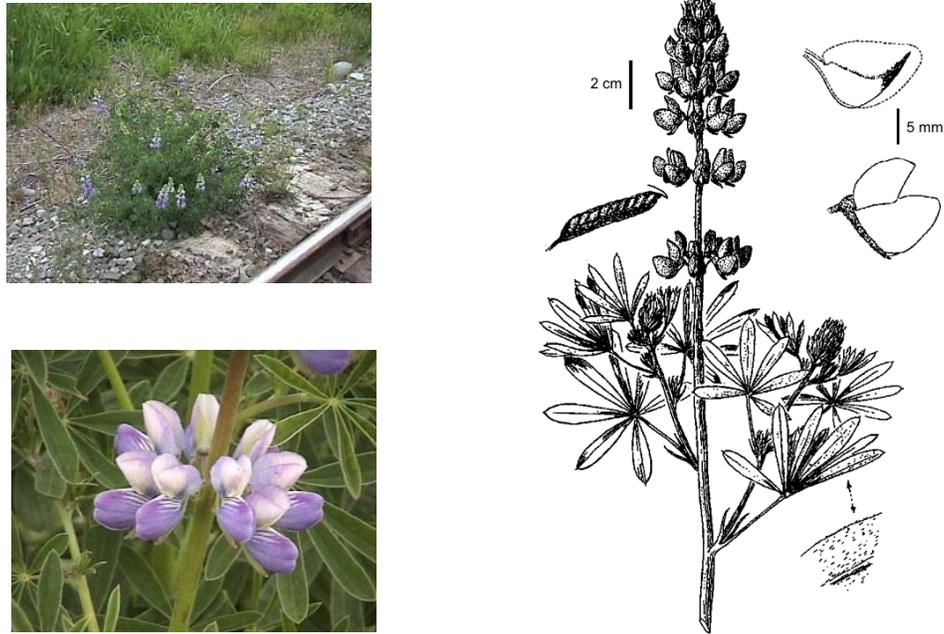


Figure 1. *Lupinus rivularis*: Photos by Brian Klinkenberg, illustration courtesy of University of Washington Press.

However, because of the confusion in lupine identification, particularly in our region between *Lupinus rivularis*, *L. arboreus*, *L. littoralis* and others, further elaboration is necessary here. Taxonomically, several authors have described *L. rivularis*, including Taylor (1974), Dunn and Gillett (1966), Douglas et al. (1999), Hickman (1993), Riggins and Sholars (1993), and others. Illustrations are provided by each of these authors. Although there is some difference in key characters (i.e., Douglas et al. (1999) describe the species as solid stemmed, while Riggins and Sholars (1993) describe it as generally hollow-stemmed), these are likely differences resulting from variability in moisture, etc. (Sholars 2001 pers. comm.). *L. rivularis* leaflets can also be slightly hairy above, and petiole length can vary (Sholars 2001 pers. comm.). In addition, Sholars (2001 pers. comm.) notes that *L. rivularis* is generally herbaceous or only slightly woody at the base, while *L. arboreus* is usually woody.

In our region, *L. rivularis* appears distinct in the field because of its combined features which include early flowering (May), generally herbaceous hollow stem, delicate looking leaves, erect habit, distinctive lavender flowers, glabrous appearance, and its occurrence in dry gravelly or sandy habitats proximal to river or creek banks at low elevations.

The similarly coloured *Lupinus littoralis* is easily separated from this species in the field by its abundance of long silky hairs on the stems and leaves, and its sprawling appearance. In addition, while *L. rivularis* is always found proximal to river or creek banks, *L. littoralis* is found in coastal areas in the fog zone, on low dunes and sandy substrates, but not necessarily proximal to creek or river banks.

The very similar *Lupinus arcticus* ssp. *subalpinus* is also readily separated from *L. rivularis* by its occurrence at high elevations. Dunn and Gillett (1966) discuss the morphological similarity between these two species.

Hybrids and intermediate forms have been reported between *L. rivularis* and *L. arboreus* (yellow bush lupine) in California and elsewhere on the coast (Riggins and Sholars 1993), and hybridization complicates the picture here. We have observed and collected what we believe to be hybrids between *L. rivularis* and *L. arboreus* in the Fraser Valley. These plants were more robust than *L. rivularis* and showed colour gradations from pale yellow to light blue—features more similar to *L. arboreus*. However, leaf shape and characteristics resembled *L. rivularis*. Plants with similar intermediate features were observed in the collections we examined from California, Oregon and Washington. We have also found populations of *L. rivularis* that show some traits of *L. littoralis*, such as long silky hairs, although in the absence of other hybrid traits, this might fall within the variation of the species.

Hybridization features in lupines, and problems with classifications, are discussed by Mikolajczyk (1964), Nicholls and Bohm (1983), and Bisby (1981). Mikolajczk (1964) has demonstrated that visually large morphological differences in lupines are often the result of a single recessive gene, indicating the difficulty that lies in placing too much emphasis on single traits (Ganders 2001 pers. comm.). And Kazimierski (1961b) has noted that in hybrid plants, the seedpods resemble the ‘paternal’ species in crosses between *L. mutabilis* and *L. douglasii*, perhaps providing a clue for tracing parent plants in apparent hybrids.

Ensuring that populations studied here were “pure” *rivularis*, or close to it, was important in the face of hybridization, particularly hybridization between *L. rivularis* and *L. arboreus*, and because of the presence in the region of planted wildflower seed packages that may contain plants from California where hybrid swarms are common.

Although not published at this point in the literature, we have noticed a leaf characteristic in the field that, in combination with other features, we believe readily separates these two species, and may be an indicator of the presence or absence of hybrid genes. There is what we believe to be a major difference in leaf/leaflet behaviour between *L. rivularis* and *L. arboreus* that is noticeable both in the field and on herbarium specimens.

When freshly picked, the leaflets of *L. rivularis* exhibit a distinctive pattern of curling response. That is, the leaflets curl inwards from the tip towards the centre of the leaf, and do so relatively slowly. This is consistent in populations which we feel are good *L. rivularis*. Contrastingly, leaflets from hybrid plants between *L. rivularis* and *L. arboreus*, as well as from pure *L. arboreus* plants, fold up fan-like when picked, do not curl towards the central leaf point but rather the leaflets fold in towards the mid-vein, and fold up very quickly. This fan-like folding of the leaflets is particularly noticeable when pressing fresh specimens. Those that are *L. arboreus*, or which contain what we believe are *L. arboreus* genes, are more difficult to press in a flat manner. *L. rivularis* leaves readily press flat. We believe this reflects the distinctive evolutionary response to moisture retention that may be typical of *L. arboreus*, a species that grows in xerophytic environments, while *L. rivularis* has not

developed this response, as its natural habitat is generally more moist. This is a feature that Sholars will explore in her work for Flora North America.

DISTRIBUTION

Global range

This species is found globally only along the Pacific coast of North America, from southern British Columbia (Canada) to northern California (Henry 1915, Scoggan 1978, Riggins and Sholars 1993, and others) (Figure 2). Scoggan (1978) indicates that Hulten considers reports of *Lupinus rivularis* occurring in the Aleutian Islands erroneous. Some web-based maps that show the distribution of this species further inland in California, and in areas of higher elevations, are considered erroneous, and are likely based upon other species (Sholars 2001 pers. comm.). Our examination of specimens from California would support this.

Canadian range

Populations determined to be *Lupinus rivularis*

In Canada, *Lupinus rivularis* occurs at the northern limits of its range, and is known from only six stations in southern British Columbia: one station on Vancouver Island (near Sooke), and five stations in the lower Fraser Valley: Surrey, Delta, and Port Coquitlam, one of which supports three small subpopulations (Figure 3).

The extent of occurrence of *L. rivularis* in Canada is approximately 70 km². This represents two disjunctive polygons—one very small, located on Vancouver Island, of less than 1 km², and one of 70 km² located in the lower Fraser Valley. Given the lack of information on this species over time, and the fact that all of the previously known populations were rediscovered this year, our only conclusion can be that the extent of occurrence is stable. Nonetheless, given the industrial development and dyking in the lower Fraser Valley, it is probable that over the past century the extent of occurrence for *L. rivularis* has decreased substantially.

The area of occupancy is less than 1 km². Again, the lack of temporal knowledge on the local populations of *L. rivularis* prevents us from making any factual statements about trends in the area of occupancy, other than to state that it appears to have been stable over the past decade. However, it is probable that the area of occupancy has declined substantially over the past century in light of the industrial developments and extensive dyking along the Fraser River.



Figure 2. Distribution of *Lupinus rivularis* in North America.

Planted populations

An additional three obviously or reportedly planted lupine/wildflower populations that contain some *rivularis*-like plants have been observed in Vancouver (2) and New Westminster (1), and there are likely others. These populations appear to be plants from popular wildflower seed packages and were growing with California poppy and other non-native species. In general, they exhibited some hybrid traits similar to *L. arboreus* and *L. polyphyllus*, and plants ranged in appearance. Some appeared very “*rivularis*-like” however, and may represent a seed source from California where hybrids of these species are common.

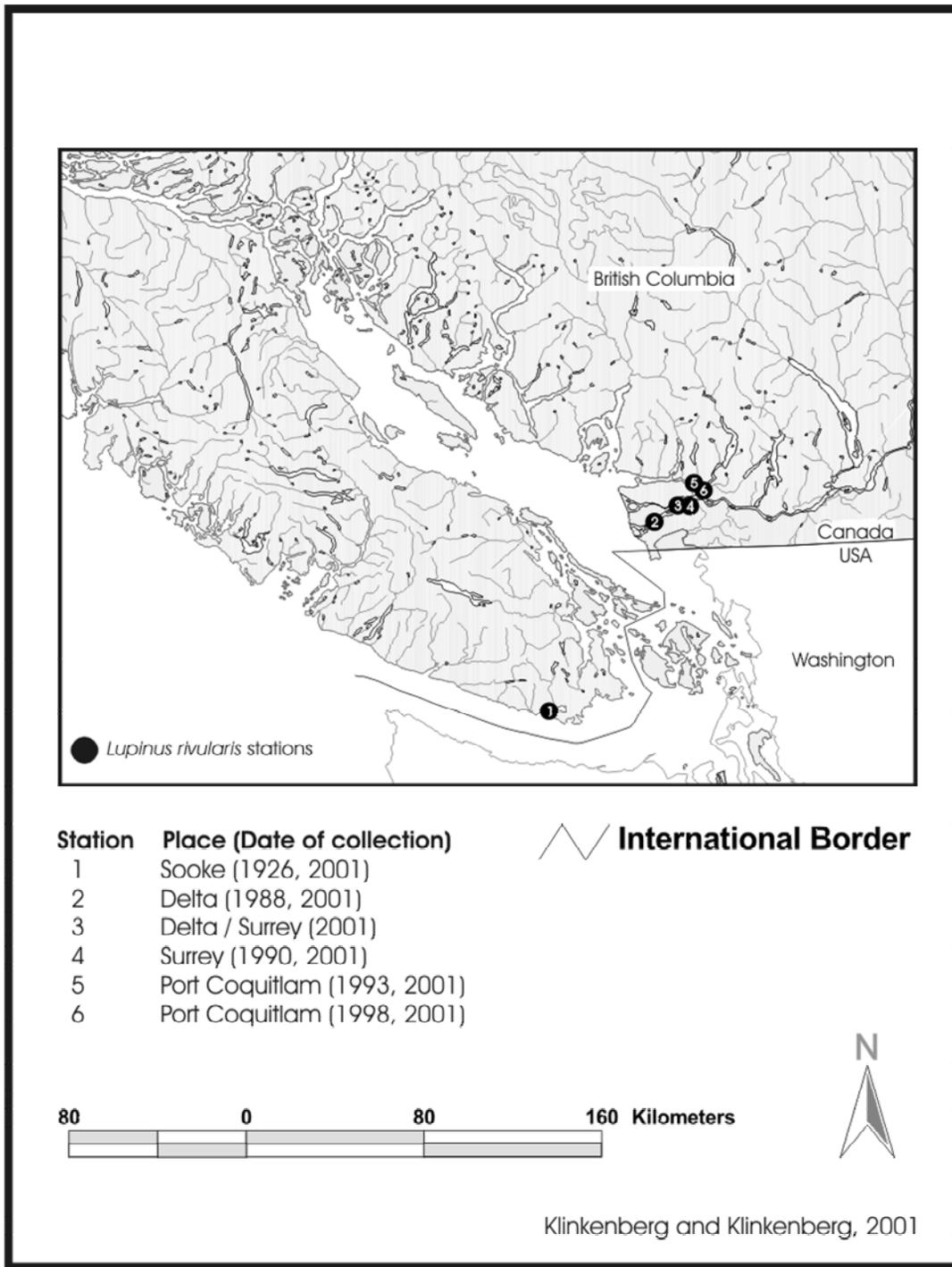


Figure 3. Distribution of *Lupinus rivularis* in Canada.

Previously reported stations which have been re-determined or are erroneous

1. One specimen report of the species from Richmond in the lower Fraser Valley has been re-determined as *L. littoralis*.
2. Previous specimen reports of *L. rivularis* from Bute Inlet and Knight Inlet have been re-determined. They are not *L. rivularis* and appear to be based on specimens of *Lupinus arcticus*.
3. A specimen report from the UBC herbarium database from Mt. Copley near Arrowsmith has been determined to be erroneous, a data entry error.
4. The reports of the species from Spence's Bridge and Shawnigan by Henry (1915) have been determined not to be *L. rivularis*.

Hybrid populations, not apparently planted

One hybrid population was observed in Surrey that is proximal to the Fraser River, and this may be *Lupinus rivularis* x *arboreus*. However, these plants are much closer to *arboreus* in appearance, and should not be construed as a *L. rivularis* population. (A large hybrid population was also discovered on Annacis Island that appears to support hybrids between *L. arboreus* and *L. littoralis*.)

Potential sites for further investigation

We believe that habitat for *L. rivularis* in the lower Fraser Valley might have been more extensive prior to dyking. However, not all creek bank/floodplain sites have been dyked, and flooding still occurs in some areas (this species prefers floodplain areas proximal to waterways). It is possible that other small populations of *L. rivularis* will be found in pockets of suitable habitat. Also, the opportunistic use of dykes by the species in what was likely the vicinity of previous populations indicates that other populations may occur elsewhere on the dykes proximal to the coast. Dykes may also offer some opportunities for recovery of this species, although this is unknown.

HABITAT

Habitat requirements

This species occupies open sandy or gravelly, moist, river or creek bank sites subject to flooding and proximal to the coast with generally little ground cover. Scoggan (1978) and others describe it as occurring in gravelly prairies, streambanks and open wood, always at low elevations. Like other lupines, it shows a distinct preference for nutrient-poor sites in disturbed, but not weedy, situations, including dykes and railway tracks adjacent to waterways (Sholars 2001 pers. comm.). Because these are disturbed sites, associated species vary but include *Plantago lanceolata*, *Solidago canadensis*, *Juncus tenuis*, *Hypericum perforatum*, and *Epilobium angustifolium*.

In British Columbia we have observed that *Lupinus rivularis* grows preferentially within a short distance from a stream or creek, most frequently within 30 meters. It occurs in both natural riverbank situations and on gravelly railway beds and dykes that have been located proximal to natural creek or riverbanks sites. Where it occurs in these man-made situations, we believe that this is coincident, and that the species opportunistically invades from already present populations. In fact, the railway beds and dykes might well have allowed survival of some populations in the face of immense habitat destruction. In natural unaltered situations, it occurs on gravel or sandy/gravelly sites that are located behind low banks. Only one population of *Lupinus rivularis* has been found on a completely unaltered site. This is a natural site that occurs in a gravel bed behind a low “beach” ridge on a riverbank that might lie within a provincial park.

At one site, a sub-population of the plant was found about 300 metres from the Fraser River, growing along the roadside. However this site appears to be comprised of river dredging material, and is substantially disturbed due to subdivision preparation. A relatively new subdivision occurs just across the road. It is possible that a natural creek once ran through the area. This population may be either a relict, or has resulted from seed dispersal during equipment or dredging material transport and is effectively non-viable. No seedlings were observed here.

Prior to dyking, *L. rivularis* likely occurred more frequently along the banks of creeks and rivers in the coastal reaches of the lower Fraser Valley. Today in this area only remnant pockets of suitable natural habitat for this species occur along the Fraser River, Pitt River, Coquitlam River, and other creeks and rivers in the area, although dykes may provide an alternative. However, natural habitat either has been heavily developed for industrial use, or has been buried by the extensive dyking system now present. The dyking has probably eliminated many populations of the plant. Natural floodplain sites, while heavily industrialized, still retain fragments of suitable natural habitat for this species and, thus, are critical for species recovery.

In situations where the sites are unaltered by the building of dykes or railway beds, the species shows preferences for floodplain sites. Sites appear to be moister than the adjacent landscape, as is indicated in the more disturbed stations by the frequent presence of *Juncus spp.*

Although this species is a pioneer species that shows preference for open sites with low soil nutrients, it does occur in two stations in shade or partial shade.

- a) It shows persistence in one location where some plant succession has occurred along a roadside, adjacent to a fence: the site supports substantial tree growth with a canopy cover of approximately 75%.
- b) It also occurs in a second location on a shaded riverbank (morning sun, afternoon shade).

As a perennial species, it is well adapted to persisting under such adverse conditions and, in fact, may benefit from other disturbances, such as mowing, where the

mowing aids in a somewhat broader seed dispersal than might otherwise be the case, especially where mowing occurs after seed set. Part of one site is regularly mowed, and another site has been sprayed. In both instances, however, healthy seedlings have been observed, both in the early spring, and in the fall.

Additional suitable habitat for the species appears to occur on the gravel bars/islands that become more frequent in the Fraser River closer to the town of Mission. However, no populations have yet been discovered in these sites.

Trends

Lower Fraser Valley

A cluster of records (five of six) for *Lupinus rivularis* occurs in the lower Fraser Valley, and all are unprotected, leaving the future of the species in Canada in jeopardy. In this region, we believe significant habitat loss has occurred as a result of the extensive dyking of our river system, and heavy industrialization of floodplains in the lower, more coastal, reaches of the Fraser. We can see some evidence of gravel pockets along the banks of the Fraser where erosion has exposed the substrate. If these were more extensive before dyking, they undoubtedly would have supported some populations of this rare species.

However, although this trend may well be responsible for the presently perilous existence of this species, it was likely already an uncommon or rare species in our region because of its occurrence at the northern limits of its range.

While more extensive gravel substrate is found further upriver, closer to Mission, including several gravel bar systems in the river, no populations of the plant have so far been discovered in this region. As it is primarily a coastal species, this may be expected. Harsher conditions further inland may be beyond the environmental capability of the species.

A further potentially restricting factor for a more inland distribution may be the impact of spring flooding. Spring melt flooding further upstream on the Fraser River and its tributaries is more intensive, and flood water levels in the Mission to Hope area are higher, resulting in greater and more frequent scouring of riverbanks and gravel bars that may inhibit the establishment of any permanent populations.

Today, abundance of the species may be also partly limited by maintenance practices, such as spraying, along the railway tracks where it occurs. While this spraying reduces competition and opens up habitat where seedlings can establish, it also eliminates the parent plants. If it occurs next year before seed set, then this will impact seriously on the two railway bed populations. These populations will be entirely dependent, then, on a buried seed bank.

Southern Vancouver Island

Field work to date in the southern portion of the Island has not turned up any other records for this species besides the Sooke station. Further investigations should be undertaken, however. An abundance of yellow bush lupine (*Lupinus arboreus*) grows along the Sooke coastline less than two kilometres from the single station for *L. rivularis*, and hybridization is a real concern here.

Protection/ownership

Only one population of *Lupinus rivularis* might be occurring in a protected site (provincial park), however, as the population was previously unreported, no active protection measures are in place. The other populations occur on railway beds, dykes, and along roadsides in private industrial lands, areas where disturbances are regular. Spraying occurred in 2001 along all railways lines in the vicinity.

BIOLOGY

General

Lupine species are found in North and South America, southern Europe, the Mediterranean and North Africa, and are commonly found on dry sites, stony slopes, and calcareous and sandy loam soils (Allen and Allen 1981). The greatest number of lupine species are found in North America, where this genus can be grouped into two clades based on ITS sequencing: an eastern New World clade, and a western New World clade (Ainouche and Bayer 1999).

Estimates of the number of North American species vary from 100 to 600 taxa (Nicholls and Bohm 1983), a result of the high degree of variability in the genus that in part stems from the large amount of hybridization and introgression that occurs. Complicating this is the continued discovery of new species such as the recently discovered 30 foot tree lupine (*Lupinus jaimehintoniana*) found in the high plateaus of Mexico (Turner 1995). In addition, lupines are known to germinate successfully even after burial for thousands of years (Sholars 2001 pers. comm.).

While there is a great deal of literature available on the biology of legumes, and on the biology of lupines in general (e.g. the lack of nectar glands in lupines), there is very little information available on the biology of *Lupinus rivularis*. Some details have been found, however:

- Some lupines are considered toxic, particularly to cattle, and toxicity varies both seasonally and geographically (Allen and Allen 1981). The active toxin may be one or more of 25-30 quinolizidine alkaloids (Allen and Allen 1981). It is not known if *Lupinus rivularis* is toxic.

- Descriptions of lupine nodules are provided by Allen and Allen (1981), who indicate that *Lupinus rivularis* is a nodulated species of lupine.
- *Lupinus rivularis* is a perennial, primarily herbaceous species with a long taproot. O'Dell and Trappe (1992) report that most of the lupines they examined, which included *L. rivularis*, had taproots that were often more than one foot deep with few fine roots, an ideal survival trait in droughty and disturbed conditions.
- Because of their ability to fix nitrogen in the soil, lupines are often species of disturbed or impoverished sites, a feature that enhances their survival and persistence (Dunn and Gillett 1966). It is noteworthy that the first plant to occur on Mount St. Helens following the eruption was a lupine (Morris and Wood 1989, Thinkquest 2000). *Lupinus rivularis* is no exception to this, often occurring on impoverished sites that are also highly disturbed, and where competition is minimal. However, all sites are proximal to creek / riverbanks along the Pacific coast.
- Hybridization is a common feature in lupines and this is true with *Lupinus rivularis*. This species is reported to hybridize with *L. arboreus* and *L. littoralis* (Rhymer and Simberloff 1996, Riggins and Sholars 1993, and others).
- Moisture levels and spring and summer temperatures play a role in lupine survival and flower persistence (Dunn 1956), although no specific information for *L. rivularis* was found.
- Based on reports of other lupine species (Breedlove and Ehrlich 1968, Breedlove and Ehrlich 1972), mutualism should be investigated for *Lupinus rivularis*, however no information on this was found.

Reproduction

Lupinus rivularis is a perennial species of lupine. Little information specific to the biology of this species was found, but it is suspected that it, like many other perennial lupine species, is capable of both self-pollination and cross-pollination (Ganders 2001 pers. comm). Cross-pollination is evident in the presence of hybrid plants. No vegetative reproduction is likely.

Although reported by Dunn and Gillett (1966) as flowering in July, BC lower mainland populations have been collected in flower in May and they continue flowering until September, thus allowing for a continuous production of seed. Dunn (1956) reports that high spring temperatures may cause some flowers to abort.

Lupines in general set prolific, heavy seed that tend to fall in the vicinity of the parent plants, resulting in the colonial appearance of many populations. This is true in the case of *Lupinus rivularis*. Numerous seedlings were found at most sites, all within 3 meters of the parent plant, except where clearing of vegetation and brush along the railway sites has dispersed the seed to a distance of about 100 meters. However, there is no way of knowing if seed production in our populations matches expected seed production for the species.

In spite of what seems like prolific seed set, the populations for the most part do not cover a large area. We speculate that maintenance work along the railway lines and dykes (i.e. repeated mowing, brush cutting, spraying), eventually kills off the mature plants. However, because replacement in the immediate vicinity is apparently high, the populations persist.

No information on germination in *L. rivularis* was found; however, Dunn (1956) studied germination in the group *micranthi*, and reports that seeds in this group do not necessarily germinate every year, and colonies may disappear at intervals depending on weather. Seed coats in this group require abrasion or decomposition for germination to occur.

Hybridization and introgression are significant components of lupine biology and reproduction (Kazimierski 1961a & b, Phillips 1955, and others). Hybridization may be a major factor in the reproduction of *Lupinus rivularis* today. Hybrids have been reported with *Lupinus arboreus* and *L. littoralis* (Rhymer and Simberloff 1996, Riggins and Sholars 1993, Wozniak 2000, Sholars 2001 pers. comm.). Hybridization in this species is a complicating factor in protection and conservation throughout its range and is clearly a factor in our Canadian populations. Where *L. rivularis* comes in contact with *L. arboreus*, it is in danger of genetic swamping and complete eradication of the species (Sholars 2001 pers. comm.). In the Fraser Valley, we observed a population of mixed *Lupinus rivularis* and *L. arboreus*. A collection made in the Sooke area by A. Ceska in 2001 may contain some hybrid genes, possibly *L. rivularis* x *littoralis*, though this is uncertain and requires verification. An interesting additional note, as mentioned above: lupine seeds are known to be viable for thousands of years, thus increasing the gene pool available in a startling way (Sholars 2001 pers. comm.).

An additional complicating factor comes from planting programs in municipalities and along roadways, where new populations of *L. rivularis* have been established from wildflower seed packages. Many of the lupines that are planted from seed packages appear to be hybrid stock. We have observed at least three planted *L. rivularis* x *arboreus* stands, and there are no doubt many more as dispersal of wildflower seeds has become popular, both with the public and with municipal and highway workers.

Some species of annual lupines are reported to be pollinated by bees, and lupines in general are frequently capable of self-pollinating (Dunn 1956). Further investigation of pollination in *Lupinus rivularis* is required, although we observed several species of Hymenoptera visiting plants at all of our sites. Presence of pollinators alone, however, may not be sufficient to allow spread of this species. Concern has been raised by some researchers for the survival of rare species, in general, when existing populations are small and isolated, even when adequate pollination is occurring (Michaels 1999). Michaels is presently studying this, and indicates that she has evidence that "lupine plants in small populations have low reproductive success, but adequate pollinator visitation" (Michaels 1999, np). Her work on lupines should be followed closely in the next few years.

Additional concerns about the long-term survival capability of small fragmented populations because of inbreeding depression have been raised by Menges (1991) and many others, and are well discussed in population genetic theory. Menges indicates that small and isolated populations may suffer several disadvantages, including greater vulnerability to outside forces. Most of this relates to an increase in inbreeding, which may or may not apply in this instance as *L. rivularis* clearly hybridizes. The downside to this hybridization is loss of the genetic pool for this species. Menges (1991) also discusses population bottlenecks that arise in some fragmented small populations. While some researchers indicate that small population size has been associated with reductions in seed set, Costin et al. (2001) indicate that this is not always the case as pollinators can be attracted to a site by other flowering plants, thus bringing them to the species in distress. A high diversity of other flowering species in the vicinity thus plays a role. Additionally, van Treuren et al. (1991) indicate that genetic erosion in small populations can be counteracted. In this case, it would be a simple matter to manually exchange seeds from each of our populations as part of a recovery plan.

Pollination mechanisms

Lupinus rivularis has not been studied specifically in this regard; however, detailed information on the pollination mechanisms of lupines in general is given by Dunn (1956). This species clearly cross-pollinates, and likely also self-pollinates. Individual populations are not likely close enough for gene exchange.

Survival

Several key factors affect the survival of this species. In the past, we believe that direct habitat loss has resulted in increasing rarity of this species. In addition, where it occurs in secondary floodplains, railways beds, and dykes, survival is precarious and dependent on happenstance. Finally, the very real threat of genetic swamping by the invasive and introduced *Lupinus arboreus* requires immediate attention. Even in natural sites, disturbance is a key element. Survival of the populations seems very tenuous.

As they exist at present, the populations are reproducing. There seems to be high germination with more than a hundred seedlings recorded at some stations we visited. In addition, there are some young plants present at most sites, as well as older plants. There is no way of knowing if populations are stable as no past work has been done on this species in BC/Canada, although its persistence in some sites since the first discovery of the stations may indicate some long-term stability.

Predation is unknown, although, in the literature, other lupine species suffer from predation by various caterpillar species. Weevils and/or bruchid beetles, and possibly other insects, are probably seed predators.

While large numbers of aphids were observed on many plants, no attendant ants were observed. At two stations, an unidentified species of *Ctenucha* moth was present in the adjacent grasses in great numbers.

Our observations would indicate that natural expansion of the existing populations is unlikely. However, it is possible that the number of stations could be increased through management and active intervention. The maintenance of low competition through mowing or brushing probably aids the species. However, it would be important for long term survival to ensure that brushing does not occur until seed set.

Physiology

This perennial species of lupine shows strong preference for low nutrient sites with little competition. It appears to be hardy within its restricted habitat, and exhibits a long flowering period (May to September) that would appear to be adaptive to maximizing pollination. The presence of a long taproot would indicate that it is drought hardy, although it occurs in moister areas within the sandy/gravelly riverbank habitats it prefers.

Observations in areas where it is mowed on a roadside verge indicate that it can withstand such disturbance and still flower and set seed.

Movements/dispersal

Lupines are described by Dunn (1956) as being dispersed by birds and rodents. In our case, they can also spread by mowing along railway tracks and dykes. This can disperse the seeds further from the mother plant than might otherwise have been the case.

Past use of populations as food sources by Aboriginal peoples may account for some dispersal, although there is no solid evidence of this occurring, and the very limited occurrence of the species would indicate that it has not been widely spread if such use did occur. Turner (1998) does not mention this species specifically as a food source, although she does cite "lupine species". Only one mention of *L. rivularis* S. Wats. use by Aboriginals was found in Teit and Steedman (1930). However, this is not *L. rivularis* Dougl. ex Lindl., and it is clearly out of range.

Our field observations indicate that high numbers of seeds drop and germinate within the vicinity of the parent plant. However, we also observed two stations with single plants. These may represent dispersal or they could be plants released from the seed banks during spring flood scouring.

One observer has noted that this species can throw its seeds up to 26 feet when the pods open (Erickson 1999), while Dunn (1956) reports that, because of the highly explosive nature of the pods, lupine seeds can be thrown 15-20 feet, and the colony can therefore spread up to 20 feet in a year. The main limitation for successful dispersal is the availability of suitable habitat.

Nutrition and interspecific interactions

At this time, nutrition and interspecific interaction of *Lupinus rivularis* is unknown but should be investigated. However, lupines are frequently planted as cover crops to enrich soils because of their nitrogen fixing capabilities (Dunn and Gillett 1966). Lupines are well known as pioneer species that occur on impoverished ground, where they improve growing conditions for other species.

In addition, co-evolution of lupines with other species is reported (Whipple 1998, Breedlove and Erlich 1968, 1972). This includes the role of lupines (*Lupinus perennis*) as a food plant for the Karner Blue Butterfly in eastern North America (Balogh 1980), and suggests that other mutualistic relations between butterflies and lupines should be investigated. The butterfly Host Plant Database (XOXEARTH 2001) does not list *L. rivularis* as a host plant for butterflies in California, although other lupines species, such as *Lupinus densiflorus*, are listed.

In spite of mycorrhizal relationships in legumes, lupine species appear to be less frequently colonized by mycorrhizal fungi and some species are never colonized by fungi (O'Dell and Trappe 1992). O'Dell and Trappe (1992) could not be certain if *L. rivularis* was mycorrhizal or not: they examined only root portions and not the complete root systems.

Behaviour/adaptability

Our observations in 2001 indicate a few traits that this species exhibits that seem to show promise for its continued survival. It is a species that does well in disturbed situations and where competition is eliminated.

In some sites where it occurs, this adaptability to disturbance should lend it some protection from anthropogenic disturbances such as clearing brush, mowing or using a weed-eater. Indeed, many mowed plants were observed in one site and, although tiny, these flowered and set seed. However, they would still be vulnerable to eradication through radical alteration of the site.

This species flowers from May to September, and produces seed continuously from June onwards. We noted maturing seedpods on these plants in June. The species' ability to withstand disturbance, and its obvious adaptation to riverbanks, indicate that it is probably quite capable of survival in the face of natural catastrophic disturbances such as flooding during snowmelt. Flooding would perhaps eradicate some plants, but it might also allow some seeds from the seed bank to emerge and reestablish afterwards. The perennial nature of this species, and the very deep taproot, indicate that it is likely also quite drought tolerant.

This is also a species that is being cultivated in the US. Ads for purchase of plants or seeds are common on the internet. The biggest danger in this is that the stock for these seeds/plants may contain genes from *L. arboreus* and thus pose a threat of

hybridization and contamination of the gene pool. However, they may also contain pure species, and provide a method of continuance for the *L. rivularis*. This requires investigation.

POPULATION SIZES AND TRENDS

This species has not been studied in Canada before, and little data exists on the numbers of populations or numbers of individuals within a population (Table 1). Therefore, declines or increases in numbers, or trends in health or vigour cannot be assessed at this point. However, given that some collections from the extant sites span at least a ten year period, we at least know there is continuity of these stations.

Table 1. *Lupinus rivularis*: Extant Natural Populations in 2001.

	Location	Subpopulation	Mature Plants	Seedlings ¹
1	Sooke	--	1	0
2	Delta River Road	--	45	100+
3	Delta / Surrey Border ²	--	50	100+
4	Surrey (Fraser Surrey Docks)	a) railway bed #1	1	0
		b) railway bed #2	11	30+
		c) roadside	20	0
5	Port Coquitlam (Pitt River Dyke)	--	20	100+
6	Port Coquitlam (Coquitlam River)	--	100	200+

¹Because this is a perennial species that flowers from May to September, producing pods and dispersing seeds from June onwards, numbers of seedlings at each site vary from visit to visit as the summer progresses. The numbers given here represent seedlings observed on May 22, 2001.

²A second sub-population of 11 plants was found in this vicinity in 1990 by Lomer, but was not rediscovered in 2001.

Extant locations

1. Sooke

A single plant was discovered at this site in full flower. It appeared to be about three or four years old. While this is not necessarily the site of the collection record by Anderson in 1926, it is likely that collection came from the immediate vicinity. The plant is vulnerable to annual flooding and scouring; however, this would appear to be a natural process for this species, and scouring may actually allow seeds from the seed bank to be uncovered and to germinate. This site possibly lies within a provincial park. The single plant was growing alone, with no associated species, in river rocks behind a low gravel ridge along a river (collection, 2001, Klinkenberg, UBC).

2. Delta River Road

2001 status:

Plants at this site occur both along the Canadian National and Burlington Northern Railway tracks, and on a low floodplain immediately adjacent to the tracks, in the municipal road allowance, along a creek bank leading directly to the Fraser River. Forty-five mature plants were counted, and more than 100 seedlings. The plants on the low floodplain may well represent the founding population for this site, and over time some plants have migrated up onto the railway bed where competition is low and the substrate quite suitable for the species. This site was severely impacted by summer (2001) spraying, and all the mature plants died off. However, a quick check in September 2001 revealed that the seedlings were doing well and were abundant. Plants at this site are growing in a bare gravel substrate (railway bed) and low silted floodplain site adjacent to the tracks. This site was first reported by Lomer in 1986, who recalls that plants were abundant (Lomer 2001 pers. comm.) (collection, 2001, Klinkenberg, UBC).

2002 Update:

Since we last checked this site in late summer 2001, major railway bed grading has taken place. All of the seedlings we counted then that survived the herbicide spraying have been wiped out. Fresh gravel has been piled alongside the tracks, directly on top of these seedlings, and much of the pre-existing gravel has been pushed outward during the grading process.

What is left of the population at this site is one dozen flowering plants of mixed ages on the small floodplain below the railway bed, and approximately two dozen newly germinated seedlings in the loose gravel at the edge of the railway bed grading area. These seedlings are at risk if further railway maintenance occurs.

Before and after photographs of the site are available and have been deposited with COSEWIC as archival material. The photographs are also available at this web site: <http://www.geog.ubc.ca/~brian/lupinusrivularis.htm>

3. Delta/Surrey Border

This population grows beside a municipal road on a low floodplain in an industrial development. Forty-five mature plants were counted, and at least 100 or more seedlings. This population occurs in a vulnerable situation where roadside spraying or mowing will impact on the population. Plants are presently strung out along the roadside, both in the open and under an open canopy of small trees, and around telephone poles. It appears that the site might be brushed periodically. Lomer reported a small subpopulation near here, although there is no previous collection (Lomer 2001 pers. comm.). The road allowance is leased by the municipality from the Fraser River Port Authority. Actual ownership of the road allowance is not clear (Fraser River Port Authority 2002 pers. comm.) (collection, 2001, Klinkenberg, UBC).

4. Surrey (Fraser Surrey Docks)

This site is a continuation of the low floodplain site described in #3 above, though separated by nearly two kilometres. Three subpopulations are reported here (Table 1), and it is possible that other subpopulations exist scattered along the railway yards. A total of 31 mature plants were recorded, with 30 or more seedlings. This site, like the one above, likely represents a residual population that has been reduced by industrial development and railway yarding along the floodplain. Two of the subpopulations at this site were previously reported by Lomer (subpopulations 'a' [1 plant] and 'c' [more plants than in 2001]), and a specimen was collected at one of them in 1990 (Lomer 2001 pers. comm.). Because of the close proximity of the three subpopulations, a collection was made at only one of them in 2001. However, photo records are available. There are several railway lines immediately adjacent to the populations, owned by different railway companies and / or the Fraser River Port Authority (Fraser River Port Authority 2002 pers. comm.). Ownership of the tracks in this area is shared by Canadian National Railway, Burlington Northern Railway, and the Fraser River Port/Railway. Precise ownership of the land on which these subpopulations occur will require detailed investigation and examination of land titles, easements, and management agreements (collection, 2001, Klinkenberg, UBC).

5. Port Coquitlam (Pitt River Dyke)

The plants at this site occur both on the municipality-owned dyke along the fence line, and on the other side of the fence on private property. The properties behind the dyke are located in an industrial subdivision that was built on a low floodplain area. It is likely that this is a residual population that has opportunistically moved on to the dyke. Twenty mature plants were counted and more than 50 seedlings. Lomer recalls observing two patches in a similar location in 1993, but with fewer plants overall (Lomer 2001 pers. comm.) (collection, 2001, Klinkenberg, UBC).

6. Port Coquitlam (Coquitlam River)

The plants at this site occur both on the Canadian Pacific Railway bed as it approaches the river, and on the adjacent roadside verge, and likely represent a residual population that has opportunistically shifted onto the railway bed where competition is low. Railway maintenance operations (brushing and possibly spraying) have maintained a site with open gravelly substrate and no competition. This is the largest population of the species in Canada, with 100 plus mature plants, and more than 200 seedlings counted. Where the plants grow on the roadside verge, they are routinely mowed, and seem to still survive and set seed. Plants growing along the railway verge, just to the side of the tracks, were in excellent condition. The site is both railway-owned, and municipality-owned along the roadside verge, and the tracks traverse a municipality-owned park. The site was reported to have abundant plants by Lomer in 1998 (collection, 2001, Klinkenberg, UBC).

LIMITING FACTORS AND THREATS

Limiting factors

There are several critical limiting factors for the occurrence of this species in Canada. These include severe habitat loss and biogeographic range limits.

This is a species that occurs at the extreme northern limits of its range and is, therefore, probably limited in the extent to which it will occur in our region.

In the past, we believe this species was somewhat more extensive in coastal areas in the lower Fraser Valley, but that the extensive dyking introduced for flood control has significantly reduced its available habitat. It may be a species that is tied to flooding and the associated scouring and siltation. These factors are now severely limited in our range by dyking and flood control. Most of the few isolated populations that remain may be relicts from pre-dyking populations that might once have been more frequent along the river and creek banks of our area. These populations may simply be subsisting in conditions that might otherwise have allowed further seed/population dispersal and establishment of colonies. The presence of seedlings at our populations may indicate vigour, or they may actually be occurring in much lower numbers that they would have in more natural settings. Further investigation of this is needed. Other areas of suitable habitat—secondary shoreline floodplain sites in the lower Fraser Valley—have been drastically altered and now support, for the most part, industrial subdivisions. No plants have yet been found on the gravel bars of the Fraser in the Mission area, although this requires further investigation.

Threats

Several major imminent threats exist for this species, including 1) genetic swamping and hybridization, 2) site maintenance and herbicide spraying, 3) introduced invertebrates, and 4) wildflower picking. In addition, given the very small areal extent of the populations and the complete lack of protection for them, we feel that they are in a precarious position. All sites have the potential for catastrophic (human or natural) occurrences that could have a major impact on the species in Canada. The entire species could be eliminated within its Canadian range with very little effort. Serious damage from ground maintenance has already occurred in 2001.

1. *Lupine rivularis* is a species that is threatened throughout its entire range by genetic swamping by the highly aggressive *Lupinus arboreus*, and the threat is imminent. In our region, *L. arboreus* has been introduced, and is now being planted extensively on Vancouver Island by the Ministry of Highways (Fraser 2001 pers. comm). We have observed its occurrence now in the lower Fraser Valley, where hybrids between the two species have been observed. In addition to 'natural' invasion, highways crews are actively planting *L. arboreus* on Vancouver Island, and seeds are presently being sold in garden shops

throughout our region. Further, wildflower seeds from packages are being planted/scattered in our area and on the island as part of a beautification effort. The lupine seeds in these packages, which contain other plants such as California poppy, may have originated from California stock where *L. rivularis/arboreus* hybrids are common. Even without the hybridization threat, these seeds are introducing a completely different gene pool in our region.

This threat by *Lupinus arboreus* is substantial, and probably is the single greatest threat facing the continued existence of *Lupinus rivularis* throughout its global range. Teresa Sholars (2001 pers. comm.) has indicated that pure populations of the species in the US might be extremely rare: most populations south of us show introgression with *L. arboreus*, and this may make our populations the most "pure" that still exist along the coast. This genetic purity needs to be investigated, and Sholars has indicated that status reassessment may result from her present work on *Lupinus* for Flora North America. Introgression with *L. littoralis* is probably less of a concern, and would likely be a natural occurrence.

2. Further threat comes from direct site maintenance/roadside maintenance activities such as herbicide spraying. Die-off was observed this year at one site as a result of spraying. Mowing, and in particular repeated mowing, may also kill off individuals, though this requires investigation. Mowing is occurring at one site.
3. In cultivation this species is very prone to predation by slugs, particularly the European Furrowed Slug (*Arion ater*). It is almost impossible to grow this species on southern Vancouver Island and on Saltspring Island without diligent slug control. Since this slug, and several other non-native slugs and snails are rapidly spreading within the range of *Lupinus rivularis*, this threat may be preventing or limiting seedling establishment at some locations (Fraser 2002 pers. comm.).
4. Wildflower picking of this species because of its lovely flowers has been observed, and will significantly reduce seed set. Because this species often occurs on road and railway edges where there is human access, wildflower picking is likely.
5. "The water district for Greater Victoria and DFO are raising the water level in the Victoria watershed an additional meter in order to redirect water flows down the Sooke River, in order to create additional salmon spawning habitat. This will change the hydrological regimes of the river, and may or may not impact the gravel bars where *L. rivularis* grow. Environmental Impact Assessment of this project appears to be limited to the impacts of the expanded water reservoir only, not the changes in the river." (Fraser 2002 pers. Comm.).

Significant habitat loss has, we believe, already occurred for this species, and the remaining populations may well be relicts of populations that survived, for the most part, opportunistically. We believe that substantial potential habitat would have existed in the lower Fraser Valley prior to the building of the dyking system. This, combined with extensive industrial use of low floodplain sites that are ideal habitat for the species, has resulted in a major decline of the species in Canada. Further habitat loss is not likely; however, any expansion of the species in Canada is unlikely without direct intervention.

SPECIAL SIGNIFICANCE OF THE SPECIES

Our populations of *Lupinus rivularis* may well be the most genetically pure populations that remain within the entire range of the species in North America (Sholars 2001 pers. comm.), although this will require verification. Sholars has indicated (2001 pers. comm.) that US populations of this species have been highly impacted as a result of genetic swamping by *Lupinus arboreus*, and most plants show traits of *L. arboreus*. Pure populations may now be very rare. Our examination of specimens from the US would support this observation, as most plants in the collections appeared not to be *rivularis*, with fewer than 25% of specimens falling within our definition of *Lupinus rivularis*.

In contrast, our six natural populations appear mostly pure, with one or two plants exhibiting what may be traits of another native lupine (*Lupinus littoralis*) and only one plant exhibiting what may or may not be a *Lupinus arboreus* trait (one sweet smelling plant of *L. rivularis* was found at one site, and this may or may not indicate the presence of *L. arboreus* genes). These characters, however, may well fall within the normal range of the species once further taxonomic study is carried out by Sholars and others.

It is not known if this relatively pure situation will persist. In the lower Fraser Valley, planted populations of apparently hybrid plants have been recorded during this study in three locations, and one instance of what appears to be an *L. arboreus* x *L. rivularis* hybrid occurring naturally was found. On Vancouver Island, *Lupinus arboreus* is being actively planted along highways (Fraser 2001, pers. comm.), and we observed a thick invasion of it along the coast in the Sooke area, not far from the single Vancouver Island station of *L. rivularis*. In addition, seed packets for *Lupinus arboreus* are being actively sold in the lower mainland in outlets that include the UBC Botanical gardens.

In addition to this genetic importance, *Lupinus rivularis* occurs in Canada at the extreme northern limit of its range, making our populations even more distinct and important genetically and ecologically.

Little other information specific to this species has as yet been found. However, a great deal of information is available on the significant uses of other lupine species and lupines in general.

Legumes have global importance as a food source, for fodder, for fuelwood and as a nitrogen source for natural and agro-ecosystems (O'Dell and Trappe 1992). Lupines are presently being grown as crops (Aniszewski 1988, 1993), have been tested for use as insecticides (Sas-Piotrowska et al. 1997, Wyrostkiewicz et al. 1997), are grown extensively in gardens, and are used in herbal/alternative medicines. Davila-Ortiz et al. (1998) indicate that lupines are being considered as a substitute for cow's milk and they have investigated the production of a yogurt-like product from them. In this regard, the gene pool offered by each species may become important agriculturally.

Considerable literature search was conducted for information on Aboriginal traditional uses of *Lupinus rivularis*. Two references were found that referred to this species as being used by the Thompson First Nations in BC (Moerman 1998, Teit and Steedman 1930). However, examination of the references, and the range and habitat described, indicate that the plant referred to was not *Lupinus rivularis*.

Several First Nations individuals were also contacted regarding traditional use of this species, including two who were met in person (see below). They were not able to provide to us any information. It is likely, however, that this species was uncommon to rare in BC prior to habitat loss, and may not have played a major role in Aboriginal use. There is no evidence supporting its widespread use that may be indicated by either the locations or the abundance of the populations. There is information, however, on the use of *Lupinus littoralis* (seashore lupine or Chinook Lupine) as a food source.

SUMMARY OF STATUS REPORT

No formal protection presently exists for this species in Canada. The single flowering individual found in Sooke occurs on the boundary of a provincial park and may or may not be protected under the Parks Act. All other sites are unprotected. At present it is red-listed in BC. Its heritage status as listed by NatureServe (2002) is listed below:

Global Heritage Status Rank: G4G5 (01Sep1998)

Nation: United States

National Heritage Status Rank: N? (01Aug1993)

Nation: Canada

National Heritage Status Rank: N1

U.S & Canada State/Province Heritage Status Ranks

United States: California (S?), Oregon (SR), Washington (SR)

Canada: British Columbia (S1)

(SR: Species reported by not ranked; S?: Species unranked)

This species is not formally listed in the US as threatened or endangered, although it has been given a G4G5 rank. However, based on our examination of specimens and

subsequent re-determination of 75% of these, and based on discussion with Teresa Sholars (2001 pers. comm.) who will be reassessing this species over the next year, this situation may change. In addition, the recent recognition of the major threat to *L. rivularis* from *L. arboreus*, and the ongoing efforts at removal of the latter in California and elsewhere, indicate that reassessment of the status of *L. rivularis* may be overdue.

Lupinus rivularis is found in Canada at only six known stations, and in comparatively low numbers. Only one of these stations might be within the boundaries of a provincial park, and active protection is not presently in place at that site. The other populations occur in unprotected sites which are either privately owned, or owned by railway companies, municipalities, or the Fraser River Port Authority. Site maintenance activities at these sites pose imminent threat to the populations, and indeed one population was severely affected by herbicide spraying this year, wherein most plants that were several years old were killed off, and only seedlings remain.

We believe at present this species is holding on only by virtue of its ability to withstand disturbance, but that its continued existence in Canada is in peril. While the populations appear viable in that they are setting seed, they are unlikely to expand in any way, and dispersal seems limited to the immediate vicinity. Further understanding of this species' biology is necessary before true viability of the populations can be assessed and, thus, the adequacy of the existing habitat pockets.

It is clear that it would take very little coincident action at all of the known sites to extirpate this species from the Canadian flora.

Adding to this critical picture of *Lupinus rivularis* in Canada is the possibility that our populations may represent some of the most pure populations that are left in its entire range. Severe genetic swamping by the highly invasive and genetically aggressive *L. arboreus* has occurred elsewhere throughout its range, where major attempts are being made now to eradicate *L. arboreus*. The danger of hybridization is strong in our area, and may occur very quickly. Indeed a few plants were found that appear to be unplanted hybrids showing very strong arboreus traits. The biggest hybridization threat in the lower Fraser Valley, however, appears to be wildflower plantings that contain hybrid lupine plants, while on Vancouver Island, the greatest threat comes from the introduction and recent spread of *L. arboreus* along the coast. Widespread planting is occurring.

This is a species, too, that we believe has suffered extensively from severe habitat loss, and while probably not common prior to this, it may well have been a little more frequent in occurrence prior to dyking of the Fraser River.

In addition, like all lupines, it runs the risk of being picked for the beauty of its flowers. Picking of lupines at one of the six stations was observed in 2001.

TECHNICAL SUMMARY

***Lupinus rivularis* Dougl. Ex. Lindl.**

riverbank lupine

lupin des ruisseaux

Occurrence in Canada: Southwestern BC

Extent and Area information	
• extent of occurrence (EO)(km ²)	70
• specify trend (decline, stable, increasing, unknown)	Unknown (Stable)
• are there extreme fluctuations in EO (> 1 order of magnitude)?	Unknown
• area of occupancy (AO) (km ²)	0.5
• specify trend (decline, stable, increasing, unknown)	Unknown (Stable)
• are there extreme fluctuations in AO (> 1 order magnitude)?	Unknown
• number of extant locations	6
• specify trend in # locations (decline, stable, increasing, unknown)	Unknown
• are there extreme fluctuations in # locations (>1 order of magnitude)?	Unknown
• habitat trend: specify declining, stable, increasing or unknown trend in area, extent or quality of habitat	Declining
Population information	
• generation time (average age of parents in the population) (indicate years, months, days, etc.)	2 Years (?)
• number of mature individuals (capable of reproduction) in the Canadian population (or, specify a range of plausible values)	248
• total population trend: specify declining, stable, increasing or unknown trend in number of mature individuals	Unknown (Stable?)
• are there extreme fluctuations in number of mature individuals (> 1 order of magnitude)?	Unknown
• is the total population severely fragmented (most individuals found within small and relatively isolated (geographically or otherwise) populations between which there is little exchange, i.e., ≤ 1 successful migrant / year)?	Yes
• list each population and the number of mature individuals in each	
• specify trend in number of populations (decline, stable, increasing, unknown)	Unknown (Stable?)
• are there extreme fluctuations in number of populations (>1 order of magnitude)?	Unknown
Threats (actual or imminent threats to populations or habitats)	
- All populations: Genetic swamping by <i>Lupinus arboreus</i> genes.	
- All populations: Predation by invasive invertebrates (European Furrowed slugs).	
- Populations 2, 3, 4, 5 & 6: Site management, including spraying of herbicides (observed at population 2 in 2001), mowing and other landscaping activities.	
- Population 3 & 4a & b: Storage of industrial supplies from adjacent properties.	
- Population 4c: Construction activities related to adjacent property development.	
- Populations 5 & 6: Wildflower picking.	

Rescue Effect (immigration from an outside source)	Low
• <i>does species exist elsewhere (in Canada or outside)?</i>	Yes
• <i>status of the outside population(s)?</i>	Not listed
• <i>is immigration known or possible?</i>	Possible
• <i>would immigrants be adapted to survive here?</i>	Yes
• <i>is there sufficient habitat for immigrants here?</i>	Yes
Quantitative Analysis	Not applicable (No information available)

Location Subpopulation Mature Individuals (in 2001)
1 Sooke
-- 1
2 Delta River Road
-- 45
3 Delta / Surrey Border
-- 50
4 Surrey (Fraser Surrey Docks)
a) railway bed #1
1
b) railway bed #2
11
c) roadside
20
5 Port Coquitlam (Pitt River Dyke)
-- 20
6 Port Coquitlam (Coquitlam River)
-- 100

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We would like to thank Frank Lomer for providing extensive information on the *Lupinus rivularis* sites and populations in the lower Fraser Valley, and for accompanying us in the field, both to examine the known populations and to search for additional populations. We would also like to thank Mike Oldham for accompanying us in the field in early May, and Laurence Brown and Jeanine Lucas for field searches for additional lupine sites over the course of the summer.

Thanks also to Fred Ganders, who provided critical discussion on speciation, hybridization, and key characters in taxonomic work, while Teresa Sholars provided critical discussion on lupines, and on *Lupinus rivularis* in particular, based on her past and present work on the lupines of North America.

George Douglas and Marta Donovan of the British Columbia Conservation Data Centre provided available BCCDC records for *Lupinus rivularis* and *L. littoralis* in British Columbia. Adolph Ceska provided critical information on the Sooke station, and collected additional lupine specimens for examination. Dave Fraser (BC Ministry of Environment and Parks) provided critical information on *Lupinus arboreus* plantings on Vancouver Island.

Thanks also to Nick Page for kindly keeping an eye out for lupines during his fieldwork throughout the summer, and providing collections of *Lupinus littoralis*; to Hugh Griffith for providing additional information on *Lupinus littoralis* in Richmond; to Ross Waddell of the British Columbia Native Plant Society for providing information on the cultivation of this species in BC.

We would also like to thank Fred Ganders and Helen Kennedy for providing continuing access to the UBC Herbarium, and for arranging loans of lupine specimens. Wilf Schofield provided critical discussions on delimitation of species. And, of course, thanks to Olivia Lee for continuous help and support.

Loans of lupine specimens were kindly provided by the following university herbaria: OSC, RBCM (V), WWB, WTU, WS, UBC, UC/JEPS

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BIOGRAPHICAL SUMMARY OF CONTRACTORS

Brian Klinkenberg is an associate professor of Geography at the University of British Columbia, and an Associate with the Centre for Applied Conservation Biology (Faculty of Forestry). He holds a PhD in Geography and MSc in Biogeography from the University of Western Ontario. He specializes in GIS, conservation biology, biogeography and rare species. He is the author or co-author of several COSEWIC status reports on rare plant species, including *Cephalanthera austiniiae*, *Bidens amplissima*, *Opuntia humifusa*, *Celtis tenuifolia*, *Collinsia verna* and *Desmodium illinoense*. In addition, he has carried out spatial analyses of the coincidence of rare plants in the Carolinian Zone of Ontario, and on the island biogeography of the flora of the Erie Islands. He sits on more than thirty graduate committees of students in conservation biology and geography. Presently he is co-compiler of the biodiversity database for Richmond and the Fraser Delta, British Columbia, and sits on the Conservation and Planning Recovery Action Group of the Garry Oak Ecosystems Recovery Team (GOERT).

Rose Klinkenberg is a former ecologist/botanist with the Ontario Ministry of Natural Resources, and holds a BSc in Field Biology from the University of Toronto. She has carried out life science inventories in provincial parks and nature reserves, ANSI/nature reserve selection in southwestern Ontario, habitat and species evaluations for threatened and endangered species and habitats, also in southeastern Ontario, and was project coordinator for the Kent/Elgin Natural Areas Survey. She has also authored or co-authored several COSEWIC status reports on rare plants, including *Cephalanthera austiniiae*, *Bidens amplissima*, *Isotria verticillata* and *Opuntia humifusa*, and has co-authored several vegetation management plans for provincial parks and reserves. Presently she is co-compiling a database on the bogs of the lower mainland of British Columbia, and co-compiling the biodiversity database for Richmond and the Fraser Delta, British Columbia. She is presently a director of the Richmond Nature Park Society, and sits on the Ecology Committee. She is a co-author of the Checklist of Vascular Plants of Richmond.

AUTHORITIES CONSULTED

The following experts on rare species in British Columbia, on *Lupinus rivularis* specifically, on the possible occurrence of the species in other locations in BC, and on traditional use of *L. rivularis* were contacted for information on this species and provided information (individuals contacted, as per the list provided by COSEWIC, but who did not respond or indicated that they could not provide any information, are not listed below):

1. Beverly Bird. Personal communication. email: bbird@istar.ca As an Aboriginal GIS/environment expert, Beverly provided four email address for other individuals who may have further knowledge of this species. Only one responded (Keith Williams), and he directed us to the Teit and

Steedman (1930) publication. Beverly has followed up with each person, but no further response to date.

2. Cheryl Bryce, Researcher and Public Relations, Songhees First Nations, Victoria, BC. Email: songhees@pacificcoast.net Contacted July 23, 2001. No response. Met in person in May on a field trip, when she indicated she had no personal knowledge of the species, but would look into it.
3. Adolph Ceska, Ecologist/botanist, British Columbia Conservation Data Centre, Wildlife Inventory Section, Resources Inventory Branch. Ministry of Lands and Parks, Government of BC, P. O. Box 9344, Stn. Prov. Govt., Victoria, BC. Contacted several times. Provided location for Sooke collection, and additional lupine specimens.
4. Rob Alvo, Conservation Biologist, Ecological Integrity Branch, Parks Canada, 25, rue Eddy, Hull (Quebec), K1A 0M5 email: robert_alvo@pch.gc.ca Contacted July 23, responded July 23, and on August 7 with a note from Don Rivard. He contacted three others who may have had more info (Brian Reader, Heather Holmes, Norm Sloan), but no response was received from these individuals.
5. George Douglas, Botanist, British Columbia Conservation Data Centre, Wildlife Inventory Section, Resources Inventory Branch, Government of BC, P. O. Box 9344, Stn Prov. Govt., Victoria, BC. Contacted several times. Provided data files for this species, and has been in contact throughout the project.
6. Dave Fraser, Endangered Species Specialist, Wildlife Branch, Ministry of Environment, Lands and Parks, Government of British Columbia, P.O. Box 9374 Stn Prov. Govt., Victoria, BC V8W 9M4, e-mail: Dave.Fraser@gems8.gov.bc.ca. Contacted July 23, 2001, Dave responded twice with additional critical information on *Lupinus arboreus* on Vancouver Island. Dave also provided valuable comments on the draft report (incorporated as Fraser 2002 pers. comm.).
7. Fred Ganders, Professor, Department of Botany, University of British Columbia, Vancouver, BC. Personal communication. Provided substantial comments on taxonomic characters and species separation/hybridization.
8. Frank Lomer. Botanical consultant, expert on the Flora of the Fraser Valley, and on *L. rivularis*. New Westminster, BC. In continuous contact about this species. Provided information on all Fraser Valley stations and assisted in site examinations and searches for additional stations. He is the only other botanist in BC who has seen all of the Fraser Valley locations.

9. Nick Page. Graduate Student, Department of Botany, University of British Columbia, Vancouver, BC. Studying sand dune species, and provided information on populations of *L. littoralis* on Vancouver Island.
10. Hans Roemer, Plant Ecologist, Ministry of Lands and Parks, Government of British Columbia. Contacted May 2001. Responded that he had no familiarity with this species.
11. Teresa Sholars, Ecologist and taxonomist, Professor of Biological Sciences, Science Coordinator, Mendocino Coast Campus, College of the Redwoods, 1211 Del Mar Drive, Fort Bragg, 95437. Teresa is the co-author of the lupine treatment in the Jepson Manual of California Plants, and present author of the lupine treatment for Flora North America. Provided critical information on the species, taxonomy, ecology and hybridization/introgression. We have been in ongoing contact about this species.

COLLECTIONS EXAMINED

OSC	Oregon State University Herbarium
RBCM (V)	Herbarium, Royal British Columbia Museum
WWB	Herbarium, Western Washington University
WTU	Herbarium of the University of Washington
WS	Marion Ownbey Herbarium, Washington State University
UBC	University of British Columbia Herbarium
UC/JEPS	University Herbarium and Jepson Herbarium, University of California

In addition to the above herbarium specimens, additional specimens for consultation were provided by:

Ceska	recent collections
Page	recent collections