Stewardship Account for Dense-flowered Lupine

Lupinus densiflorus

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March, 2002

Funding provided by the Habitat Stewardship Program of the Government of Canada and the Nature Conservancy of Canada

STEWARDSHIP ACCOUNT

1. Species information

Common Name and Scientific Name
Family: Fabaceae or Pea Family
Lupinus densiflorus Benth. var. *densiflorus*

Dense-flowered Lupine or Whitewhorl Lupine

Synonymy
(From Douglas *et al*. 1999; U.S.D.A. Natural Resources Conservation Service Plants database).
Lupinus densiflorus Benth. var. *scopulorum* C.P. Smith
Lupinus microcarpus Sims var. *scopulorum* C.P. Smith
Lupinus densiflorus Benth. var. *latilabris* C.P. Smith
Lupinus densiflorus Benth var. *stenopetalus* C.P. Smith
Lupinus densiflorus Benth var. *tracyi* C.P. Smith
Lupinus microcarpus Sims ssp. *scopulorum* (C.P. Sm.) C.P. Smith
Lupinus microcarpus Sims var. *densiflorus* (Benth.) Jepson

Classification
Hitchcock *et al*. (1961), speaking of lupines in the Pacific Northwest, observed that "taxonomically, the genus is probably in a more chaotic state than any other to be found in our area ". They observed that the species are extremely plastic and that many species interbreed freely. Barneby (1989) mentions the morphological uniformity of flowers and pods, which complicates classification.

Lupinus densiflorus, a member of the informal group *Microcarpi*, has a complicated history. Bentham described the combination but many taxonomists have included it within *L. microcarpus*, an earlier combination described from material grown in England from seed likely collected in Chile. Dunn and Gillett (1966) concluded that the two species are distinct based on a number of morphological attributes. Riggins (1988) disagreed on the basis of a multivariate analysis of morphological characters and placed all members of the *Microcarpi* within one *L. microcarpus*.

Smith (1917, 1918a,b, 1919) described five species and 35 new or newly combined varieties within the *Microcarpi* but subsequent authors have been reluctant to recognize all of Smith's taxa. Recent authors have referred to the element occurring in the Victoria area as *L. densiflorus* var. *densiflorus*, L. *densiflorus* var. *scopulorum*, *L. microcarpus* var. *densiflorus*, *L. microcarpus* var. *scopulorum* and *L. microcarpus* var. *microcarpus*.

Douglas *et al.* 1999 decided to recognize B.C. material as *L. densiflorus* var. *densiflorus* and his nomenclature has been adopted in this report.

Similar species

There are no similar species in Canada. The taxonomy of the genus *Lupinus* has proven challenging to taxonomists and it cannot be reasonably elucidated in this report.

2. Range and Known Distribution

Global range

Lupinus densiflorus Benth. ranges from Vancouver Island and coastal Puget Sound, south on the east side of the Cascades to Baja California (Hitchcock and Cronquist 1973). The variety *densiflorus* (*sensu* Douglas *et al*. 1999) is restricted to the area of Victoria, British Columbia and adjacent islands of Washington State (Hitchcock *et al*. 1961, Douglas *et al*. 1999).

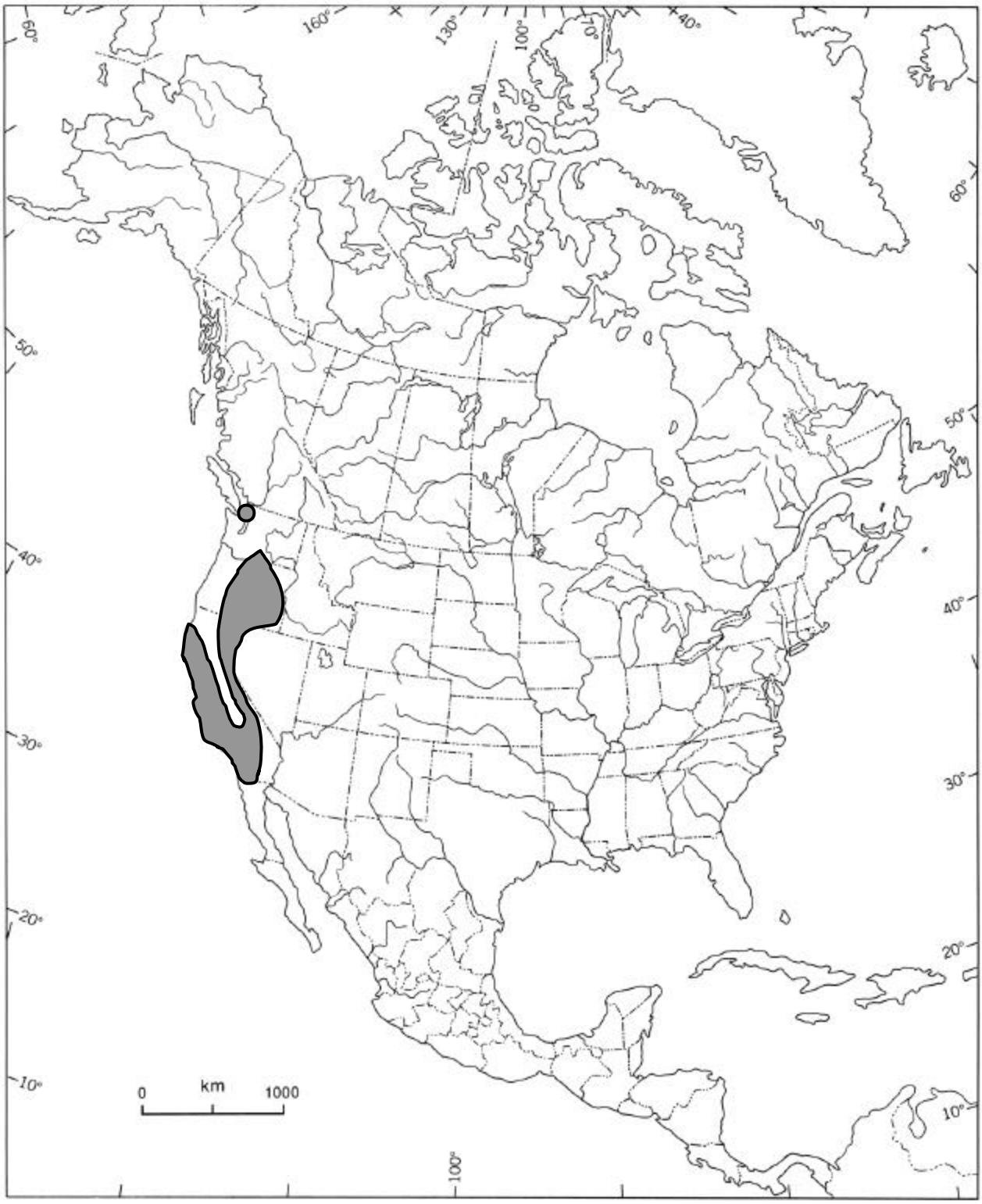
Riggins (pers. comm.) has hypothesized that South American elements of the *Microcarpi* are deliberate or accidental introductions from California, made by early Spanish explorers. It is unlikely this was the case with populations in the Victoria area – Spanish explorers did not settle the area and the historical and extant populations do not correlate well with likely landing spots or ballast piles.

Dunn and Gillett (1966) speculated that the British Columbia populations of *L. densiflorus* "could represent an introduction of a seed from a single source". They based this hypothesis on three rather weak lines of evidence: (1) the uniformity of Canadian material; (2) obligate self-pollination of the plants; and (3) the disjunction between British Columbia plants and "the main population in the southern half of California". Subsequent authors (Taylor 1974, Clark 1976 but not Hitchcock *et al*. 1961 or Douglas *et al*. 1999) appear to have adopted the speculation that B.C. populations are introductions as fact. The balance of evidence does not support Dunn and Gillett's hypothesis: (1) morphological and even genetic uniformity among annuals is not unusual; (2) there is no evidence anywhere that *Lupinus densiflorus* is an obligate self-pollinator – Dunn and Gillett do not provide any evidence that it is self-pollinated and may have simply intended to suggest this as a means by which it could maintain its uniformity; (3) the disjunct distribution is paralleled by several other 'semi-desert' species[1] of the Pacific Northwest (Hitchcock *et al*. 1961) and indeed other species with similar disjunct species and it is unreasonable to assume they are all introductions. The sub-Mediterranean climate of Victoria and the Georgia basin is anomalous along the Pacific Northwest coast and likely accounts for the pattern of disjunct distributions observed by Hitchcock *et al*. (1961). Three other lines of evidence support recognition of var. *densiflorus* as a native endemic to the area: (1) it is locally abundant and well distributed in the San Juan Islands of the Georgia basin despite the poor dispersal abilities of its seeds, (2) the variety is not known from elsewhere in the species range; and (3) it was collected in Victoria in 1887,

1 For example, *Allium amplectens, Crassula erecta (= C. connata), Clarkia viminea, Dryopteris arguta, Isoetes nuttallii, Juncus kelloggii, Minuartia pusilla, Microseris bigelovii, Montia howellii, Myrica californica, Ranunculus californicus, Trifolium depauperatum, Triphysaria versicolor, Vulpia pacifica,* and *Woodwardia fimbriata*, as well as the salmander, *Aneides ferreus*

early in the European settlement of Vancouver Island and at the very beginning of botanical studies in the area. In conclusion there is little evidence to suggest it is an introduced taxon.

Figure 2. North American Distribution of *Lupinus densiflorus*
(distribution in Baja California not shown)



Canadian range

In Canada, *L. densiflorus* is restricted an area in and around Victoria, British Columbia (Douglas *et al*. 1999, B.C. Conservation Data Centre database 2002) (Figure 3). There are three populations; one at Macaulay Point, Esquimalt, one at Beacon Hill Park, Victoria and the last on Trial Island just offshore of Victoria. Sub-populations within the Macaulay Point and Beacon Hill populations may have limited genetic interchange because of limitations in seed and pollen dispersal.

L. densiflorus was formerly known from Clover Point, Victoria, where it was last collected on beach slopes and 'grasslands' (RBCM accession numbers 101329 and 100762) in 1954. A 2001 survey of Clover Point failed to find any extant populations. The extent of range changes of this species, other than those of extirpated populations, is impossible to assess due to the severe year-to-year fluctuations expected of annual species.

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

The range of this species is both restricted and fragmented as is documented by the population data in Table 1. Clearly there is a restricted distribution as indicated by the small population size and the number of sub-populations or colonies within those populations. The sub-populations or colonies are assumed to be genetically isolated.

Table 1: *Lupinus densiflorus* Population Data for 2001

Population	Population Extent (summary of colonies or sub-populations)	Number of Sub-populations or Colonies	Number of Individuals
Trial Island	20 x 40 m^2	1	600 - 800*
Beacon Hill	20 x 12 m^2	3	227**
Macaulay Point	20 x 10 m^2	4	1045**

*Jenifer Penny, Matt Fairbarns, and Shane Ford, 2000; Fairbarns 2001

** Shane Ford and Matt Fairbarns, 2001

1. Habitat Description

In Canada, *Lupinus densiflorus* is restricted the lowland Coastal Douglas-fir biogeoclimatic zone. It occurs in dry to moist grassy openings, clay cliffs and eroding grassy banks and benches above the seashore, usually with a south or west facing exposure. Shrubs on these upper eroding slopes include Nootka rose (*Rosa nutkana*) and snowberry (*Symphoricarpos albus*). Associated native herbaceous perennials include nodding onion (*Allium cernuum*), sea thrift (*Armeria maritima*), harvest brodiaea (*Brodiaea coronaria*), common camas (*Camassia quamash*), California oatgrass (*Danthonia californica*), red fescue (*Festuca rubra*), gumweed (*Grindelia integrifolia*), beach pea (*Lathyrus japonicus*), naked broomrape (*Orobanche uniflora*), bracken fern (*Pteridium aquilinum*), Pacific sanicle (*Sanicula crassicaulis*) and barestem desert-parsley (*Lomatium nudicaule*). Many sites have a high cover of introduced grasses including orchard grass (*Dactylis glomerata*), perennial ryegrass (*Lolium perenne*), soft brome (*Bromus hordeaceus*), and barren brome (*Bromus sterilis*). *Lupinus densiflorus* occurs in an elevational band up to 10 metres above the shoreline. A portion of the Trial Island population grows in an atypical habitat – a level meadow with shallow soils that is dominated by introduced grasses and forbs. The other component of the Trial Island population grows on moderate to steep, unstable slopes similar to the habitats favoured at Macaulay Point and Beacon Hill Park.

Lupinus densiflorus seedlings may be found in a variety of microhabitats. Adult plants seem to be more restricted, likely due to either edaphic requirements or competitive exclusion.

Trends

Less than 1% of the Coastal Douglas-fir biogeoclimatic zone remains in a relatively undisturbed state (Pacific Marine Heritage Legacy 1996). Habitats suitable for *Lupinus densiflorus* have probably declined proportionally. Surveys of historical sites referenced in the Conservation Data Centre CDC database indicated that some habitat loss has occurred as a result of urban development (pers. obs.).

Lupinus densiflorus is restricted to benches and banks above the ocean splash zone. Both the benches and banks have suffered from a gradual increase in trampling damage over the past century. Fire suppression has likely favoured the development of dense shrub patches within the populations at Macaulay Point and Beacon Hill Park. Several introduced species of grasses and forbs have formed thick swards at all three locations. The dense shrub patches and thick swards have substantially reduced habitat quality for *L. densiflorus* over the past century.

4. Status of Species

Population Info

Lupinus densiflorus is likely a relictual population with the extent of occurrence being approximately 2 km^2. In Canada, there is a continued decline in the area and quality of habitat and few suitable sites for new populations. There are only three known locations in Canada, and less than 2,500 mature individuals in total with the potentially drastic fluctuations in numbers of individuals associated with annual species.

Species Rank

Lupinus densiflorus var. *densiflorus* is not covered under the Convention on International Trade in Endangered Species (CITES), the Endangered Species Act (USA) or the IUCN Red Data Book. Natureserve has designated a G5 T4 rank for the species. The G5 indicates that the species is classified as "common to very common; demonstrably secure and essentially ineradicable under present conditions". The T4 ranking reveals that the variety is "apparently secure, with many occurrences". This variety rank should be considered with care given the perplexing status of infraspecific elements. In fact, if the plants of Victoria and adjacent islands of Washington State are treated a separate element as many authors propose, the true T-rank might be raised to T2.

The British Columbia Conservation Data Centre (2000) provincial ranking is S1, "critically imperiled", because of extreme rarity or because of some factor(s) making it especially vulnerable to extinction. *Lupinus densiflorus* is currently on the B.C. Conservation Data Centre RED LIST, which includes any indigenous species or subspecies (taxa), considered to be Extirpated, Endangered, or Threatened in British Columbia.

Significance and Protection

Populations of *L. densiflorus* in British Columbia are at the northern extent of their range and may represent a genetically distinct element important for the long-term survival and evolution of the species. The populations are restricted to areas that are federally-, provincially- and municipally-controlled. No populations are known to occur on private lands. None of the three levels of government have made provision for the conservation of *Lupinus densiflorus* in management plans. The species is not afforded protection under any general legislation or regulations in British Columbia.

5. Life History

General

Lupinus densiflorus var. *densiflorus* is an annual, usually branched and growing 20-30 cm tall from a taproot. The leaves are palmately compound and occur basally and alternate along the stem but tend to cluster near the top and are glabrous above and spreading-pilose below. The white to pale yellowish-white flowers are 12-14 mm long. The fruit is egg-shaped and 1.5-2 cm long with a persistent style. The seeds, generally two but occasionally one per pod, are brownish tan to olive-coloured seeds and 4-6 mm long.

Lupinus densiflorus flowers from May until October with partial fall seed germination while others remain dormant on the soil surface at least until spring. Those that germinate in the fall and survive do so in the cotyledon stage or with some emergent primary leaves. Herbarium specimens of seedlings collected from the Victoria area (accession numbers 40414 and 142029) bearing cotyledons and primary leaves were collected in April and March respectively. However, seedlings germinate as early as November in the Victoria area (pers. obs.).

The greatest fluctuation in population numbers seems to occur at the seedling stage as seed herbivory, flower herbivory, and leaf herbivory was low in most populations (2001-2002). Despite seedling mortality there seems to be enough seedlings remaining to maintain the populations.

Plant and Pollinator Interactions

No details have been gathered about pollination and reproduction in *Lupinus densiflorus* var. *densiflorus* and it may be both insect-pollinated, likely by bees, and self-pollinated. Seed set (2001-2002) was prolific and began in June and July.

General information has been gathered about pollination in the group Micranthi of lupines to which this species belong. Bees do pollinate some species of some annual lupines in the group Micranthi, as they are able to manipulate the piston mechanism of the flower (Dunn 1956). Cleistogamy occurs in smaller-flowered lupines (those with flowers <8 mm long) while larger-flowered species (>12 mm long), require insect pollination (Dunn 1956). *Lupinus densiflorus* var. *densiflorus* flowers are 1-1.5 cm in length (Douglas *et al*. 1999) which would predispose them to insect pollination though Dunn and Gillett (1966) mention that they believe at least some Victoria area populations are maintained by obligate self-pollination. Pollination mechanisms in the section Micranthi of lupines are effected by details of structure, differences in the extent of flower opening, the period of receptivity of the stigma, duration of pollen viability and flower size (Dunn 1956).

Germination

Dunn (1956) found that, with the species of lupine he investigated, germination was best in moist, loose soil when the temperature was relatively low, near freezing at night. However, Neilson (1964) found germination in controlled conditions and adequate

moisture was best at temperatures between 55° F and 85° F for *Lupinus densiflorus*. A small germination study was conducted using seeds from a healthy population (i.e. high seed set) in the Victoria area. Seeds were subjected to an 18-hour light regime with temperature ranging from 13-22° Celsius and regular watering on a sterile soil substrate. These are not normal germination conditions given the *in situ* winter conditions that this species normally experiences but within the optima indicated by Neilson (1964). Results to date indicate 15% germination (n=72) without seed scarification.

There does not seem to be any strong inhibitors to germination based on *in situ* observations and the germination study conducted in a growth chamber although seeds may remain dormant for long periods because the hard seed coat requires either decomposition or abrasion before germination can take place (Dunn 1956). Neilson (1964) found that seeds remain viable for up to four years but *L. densiflorus* var. *densiflorus* seeds with hardened seed coats did not germinate while those that were scarified had 100% germination (n=10). Similar seed characteristics and germination pretreatment requirements have been observed with similar germination success in perennial lupines (Ratliff 1974).

Seedling Ecology

Lupinus densiflorus var. *densiflorus* emergent seedlings overwinter with enlarged cotyledons and a few primary leaves. Neilson (1964) has acknowledged that outgrowths of the cotyledons of *Lupinus densiflorus* form an effective enclosure over the leaf primordia and offers one of the best seedling protection mechanisms in the genus. The high clay content soil and the winter rains may combine to produce optimal conditions for germination based on field observations though seedlings were observed on a variety of other substrates including gravel, rotting wood, and in the crevasses of beach wood. Their long-term survival in these sites is questionable since no adults were found occupying these types of habitats during the summer. Depending on spring conditions, it appears that seedlings mature and may begin to produce flowers in May.

Seedlings establishment was tracked over the winter of 2001/2002 using reference sites at Macaulay Point, Esquimalt and Beacon Hill, Victoria. The results thus far (current to February 2002) indicate that while most plots showed declines in the number of seedlings, there remain enough seedlings to maintain the populations. Individuals were not tracked so it is unknown whether those originally sampled were the same ones counted during the second survey. At most plots un-germinated seeds were obvious on the surface.

Survival

The potential for year-to-year fluctuation in numbers of *Lupinus densiflorus* var. *densiflorus*, individuals and in population extent is high. Having said that, this species has persisted at Beacon Hill, Victoria since it was first collected there by John Macoun in 1887 (Clark 1976) and most of the historical populations documented in the CDC database still persist. What needs to be considered is whether or not the persistent populations have slowly migrated downslope over the last 115 years and have now run out of suitable downslope habitat. It should be noted that some individuals observed at

Macaulay Point, Esquimalt were established in areas above the main population in areas where landscaping by the municipality had occurred. However, in the long-term, there may be increased negative pressure from introduced species and habitat degradation due to human trampling and landscaping.

Field observations during the summer of 2001 did not reveal any significant causes of individual adult mortality. Seed herbivory, flower herbivory, and leaf herbivory was noted in most populations but was low and is not considered to be a significant factor in population survival (pers. obs.). Bennett (pers. comm.) observed high seed predation in other British Columbian lupines presumably caused by bruchid seed weevils.

Salt-water exposure due to high winter tides is the single largest risk to individual seedling survival.

Physiology

The clay-based soil and high winter precipitation may combine favorably for this species on the steep slopes and marine benches that it occupies though the habitat on Trial Island seems quite different with no apparent detriment to *Lupinus densiflorus* populations. Clearly, the ecological amplitude and tolerances of this annual are not known and no transplant to ecological stress experiments have been undertaken.

Movements/dispersal

Pollen dispersal in *Lupinus densiflorus* var. *densiflorus* is probably quite limited due to the foraging behaviour of bees, which are a presumed pollinator of this species. It is possible that there is little of no transfer of genetic material (pollen) among the sub-populations at Trial Island, Macaulay Point, and Beacon Hill, which effectively isolates them.

Seed are likely gravity dispersed but birds (e.g. possibly rock doves) and small mammals may also consume the seeds and effect secondary dispersal. It is also possible that strong onshore winter winds commonly affecting this species' habitat may act as a dispersal agent. Explosive germination has been reported in some lupines (e.g. Dunn 1956, Neilson 1964) but was not observed in the field and the potential to increase population size, establish new populations, and re-colonize extirpated populations through natural dispersal is low.

Behaviour/adaptability

Though it is clear that introduced species and human activities pose serious potential threats in addition to hostile downslope habitat, no multi-year assessments of *Lupinus densiflorus* populations have been conducted that can address this species adaptability under these conditions. Its reaction to disturbance and its ecological tolerances has not been determined.

6. How the species is at risk

Habitat loss presents a serious and urgent threat to *Lupinus densiflorus* in Canada. The unique coastline habitats in Victoria and surrounding areas have been extensively developed for residential and commercial purposes and recreation facilities. Facility development almost certainly caused the loss of the Clover Point population.

Habitat degradation compounds this threat. All three populations are threatened by the encroachment of exotic grasses and shrubs, most notably Scotch *broom (Cytisus scoparius*), English ivy (*Hedera helix*), gorse (*Ulex europaeus*), orchard grass (*Dactylis glomerata*), sweet vernal grass (*Anthoxanthum odoratum*), perennial ryegrass (*Lolium perenne*), barren brome (*Bromus sterilis*) and soft brome (*B. hordeaceus*).

The warm dry sites that support *Lupinus densiflorus* were probably burned frequently by First Nations groups seeking to improve Camas (*Camassia* spp.) production on the adjacent uplands. Fire has been almost completely suppressed on coastal sites for several decades, which has favoured ingrowth by introduced shrubs as well as native species including Nootka rose (Rosa nutkana), common snowberry (Symphoricarpos albus), trembling aspen (*Populus tremuloides*) and bracken (*Pteridium aquilinum*). *L. densiflorus* was not found within dense patches of native or exotic shrubs or thick swards of introduced grasses.

Land management practices have also reduced site capability *for Lupinus densiflorus*. Landscaping, lawn fertilizing, de-thatching and mowing are all common practices at one or more population sites. Lawn mowing at Trial Island (to reduce the threat of fire) has been deferred until after seed set has begun in order to favour the perpetuation of *Lupinus densiflorus*. This informal agreement has undoubtedly had a positive effect, but the majority of plants are still mowed before seed set is complete.

Landform processes also influence lupine populations. The unstable slopes where lupines occur are susceptible to mass wasting and micro-slumping. The persistence of populations on these sites demonstrates that the plants can successfully survive a degree of slope instability. In fact, micro-slumping exposes numerous small fissures, which expose mineral soil where seedling establishment is most successful. Currently, mass wasting at Macaulay Point and Beacon Hill greatly exceeds historic levels. Slope damage has increased with visitor traffic over the past century to a point where several sub-populations lie within a matrix of deeply worn and compacted footpaths and associated sheet erosion.

Summing up, it appears possible that less than 5% of the sites capable of supporting *Lupinus densiflorus* at the turn of the century currently provide suitable conditions.

Seed dispersal and rescue effects present a complex problem. At the broad scale, seed dispersal over distances greater than 10 m is probably extremely rare. The widely separated populations (including those on islands in nearby Washington State) have no

potential for re-colonizing former sites. The potential for a rescue affect among sub-populations is also slight, as most are separated by well over 10 m of unsuitable habitat.

Within sub-populations, replenishment of up-slope elements is problematic. Seeds are gravity-dispersed. Stochastic events and increased human trampling might be expected to deplete up-slope elements. The former has not eliminated the Beacon Hill population first observed by Macoun in 1887 although individual sub-populations may have disappeared. Human trampling has increased sharply over the years and many of the up-slope populations appear to be heavily impacted (particularly in the vicinity of trails and park benches). The loss of up-slope elements of sub-populations cannot be balanced by recruitment into new down-slope habitats because the slopes all tail into the ocean splash zone. Severe winter winds may enable some 'rescue effect' within sub-populations by blowing seeds upslope, but this is unlikely to counterbalance up-slope human impacts in many sub-populations.

7. Management Recommendations

Any successful management for this species will require that federal, provincial, and municipal governments actively contribute to the management of this species. Access control of humans into the populations will have the most significant effect on the success of this species in most populations. However, the single most important activity that can be undertaken to manage this species is a regular census of the sub-populations for changes in population extent and changes is life stage survival. An established short- and long-term management plan would assist in structuring management and monitoring activities.

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