Stewardship Account for Winged Water Starwort

Callitriche marginata

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by

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Literature Review and Stewardship Account
for
Callitriche marginata

1. Species Information

a) **Scientific name:** *Callitriche marginata* Torr.
Synonyms: *Callitriche longipedunculata* Morong
Callitriche sepulta S. Wats.
Common name: winged water starwort

b) **Classification:** The current accepted scientific name for this taxon is *Callitriche marginata*. However, it is referred to in some of the earlier (pre-1980) ecological literature as *Callitriche longipedunculata* (e.g., McLaughlin 1974), potentially leading to confusion in some cases.

c) **Similar species:** Aside from *Callitriche marginata*, a total of five *Callitriche* species occur in southern B.C. (Douglas et al. 1998): *Callitriche anceps* Fern. (two-edged water starwort), *Callitriche hermaphroditica* L. (northern water starwort), *Callitriche heterophylla* Pursh ssp. *bolanderi* (Hegelm.) Calder & Taylor (diverse-leaved water starwort), *Callitriche stagnalis* Scop. (pond water starwort), and *Callitriche verna* L. (spring water starwort). Although morphological differences between species in this genus are subtle, making it difficult to distinguish them in the field, only *Callitriche marginata* produces female flowers with pedicels that are longer than the fruit (Douglas et al. 1998). In addition, *Callitriche marginata* is the only *Callitriche* species in B.C. restricted in distribution to vernal pools on or adjacent to SE Vancouver Island.

2. Range and Known Distribution

a) **Global range:**

Current. Western California and Mexico, with disjunct populations in Oregon (Josephine County and Wasco County) and southern Vancouver Island, British Columbia (Hitchcock and Cronquist 1973, Douglas et al. 1998, Kartesz 1994, NatureServe 2001, ONHP 2001). Absent from Washington.

Historic. Prior to the 1970s, known only from western and southern California (McLaughlin 1974). **Unknown** in B.C. prior to 1977 (Ceska and Ceska 1980). It is unclear whether the B.C. records for this species are the result of recent colonisation, or have been overlooked by previous collectors.

b). **Canadian range:** see British Columbia Range.

c) **British Columbia range:**

Current. SE Vancouver Island and adjacent Gulf Islands.

Historic. **Unknown** prior to 1977.

Distribution. Restricted to vernal pools; distribution is disjunct and fragmented.

General localities. *Callitriche marginata* has been collected from a total of five sites in Canada, all of them on SE Vancouver Island and nearby islands:

Site Locality	Number of Occurrences
Victoria (Cattle Point, Uplands Park)	undocumented
Victoria (Rocky Point)	undocumented
Victoria (Discovery Island)	three clumps (150 plants total)
Victoria (Chatham Island)	undocumented
Mitlenatch Island	undocumented

Range changes in B.C. during last 10 years. **Unknown**. The last recorded collections at each site were: Rocky Point—1977; Mitlenatch Island—1977; Chatham Island—1981; Uplands Park—1991; and Discovery Island—1997.

Continued existence of the Uplands Park population and other populations near Victoria has neither recently been confirmed nor disconfirmed. However, a recent attempt (1996) to relocate the Mitlenatch Island population was unsuccessful (A. Ceska, pers. communication), leading to fears that this population may no longer be extant.

3. Habitat Description

a) **General habitat requirements:**

General habitat type:

Community type. Across its range, *C. marginata* is reported from a variety of arid community types. In California, these include Blue Oak Woodland, Chaparral, Valley Grassland, Yellow Pine Forest, Foothill Woodland, and riparian areas (California; Lum 1975, Hrusa 1998, CalFlora 2001, Muth et al. 2001). Within British Columbia, *C. marginata* occurs predominantly on low-lying, coastal rocky knolls and outcrops within the Garry oak ecosystem (Ceska 1986).

Structure and successional stage. **Unknown.** However, both forest encroachment due to secondary forest succession and invasion of exotic weeds pose potential serious threats to the hydrologic and light regimes of vernal pools, many of which are thought to be fire-maintained and thus characteristic of early-mid seral stages (Witham et al. 1998).

Elevation. Sea level to 900m in California (McGlaughlin 1974); near sea level in British Columbia.

Climate. Mediterranean (winter-wet and summer-dry).

Specific habitat type:

Microsite characteristics. *C. marginata* is found in well-lighted vernal pools and other temporary wetlands (e.g., rocky depressions) formed by winter rains and drying by late spring or early summer (McGlaughlin 1974, Ceska 1986, Douglas 1991); also in draining wetlands, seeps and springs (McGlaughlin 1974, Muth et al. 2001). *C. marginata* exists only as seed in summer and autumn (McGlaughlin 1974). Classified by federal agencies in the US as an obligate wetland species and a wetland indicator (USFWS 1988, USDA-NRCS 2001), it occurs either on dried mud at the edge of pools or, less commonly, as mats in the water (Fassett 1951).

Vernal pool habitats of western North America typically experience a pronounced summer drought that is relieved in late fall or early winter by sufficient rainfall to permit germination and early survival (Bliss and Zedler 1998).

Site quality. **Unknown.** In general, vernal pools are thought to be among the most pristine of vegetation types (Holland and Jain 1977). Because of the demanding nature of the vernal pool habitat—requiring species to be begin growth while submerged in water—most introduced grassland species have thus far been unable to successfully colonize vernal pools (BLM 1997). The current condition of most *C. marginata* sites in British Columbia is, however, unclear (H. Roemer, pers. Communication).

Soil type. Clay, mud, or shallow soil. Vernal pools tend to occur as small depressions, usually underlain by hardpan, that fill with water during the winter (Holland and Jain 1977, Warner 1997).

Moisture level. *Callitriche* species can be classified as either 'terrestrial,' 'amphibious,' or 'obligately submersed' *Callitriche marginata* is considered 'amphibious'(Cooper et al 2000), meaning that it requires flooded conditions at some point but cannot persist unless the habitat dries (Zedler 1987). Furthermore, there is evidence that seed germination in *C. marginata* is highly sensitive to the timing of the onset of fall rains (Bliss and Zedler1998). Bliss and Zedler (1998) studied the effects of variation in environmental conditions on seedbank germination in vernal pool species using three factors: monthly timing of first moistening, length of moist period before inundation, and length of inundation. They found that monthly timing of first moistening was the most important factor in determining the number of *C. marginata* plants that germinated, while prolonged inundation of seeds also resulted in low germination (Bliss and Zedler 1998).

pH. **Unknown.**

Light requirements. Shade intolerant (McGlaughlin 1974).

Dependence on dynamic factors (abiotic and biotic). **Unknown**. However, the life cycle of *C. marginata* is thought to be closely tied to annual precipitation patterns (see above). There is also evidence that germination and flowering in *C. marginata* occurs only over a relatively narrow temperature range (see below), suggesting that it has evolved mechanisms that keep it from emerging under unfavourable conditions. The sensitivity of this and other vernal pool species to out-of-season germination suggests that they could undergo a negative response to changes in climate, such as those anticipated from the effects of increasing CO_2 concentrations (Bliss and Zedler 1998).

Fire. The historical role fire may have played in creating and/or maintaining *C. marginata* habitat on Vancouver Island is presently unknown, but cannot be disregarded as a potentially important moderating factor affecting its range and distribution.

Dispersal. This species has no innate mechanism for dispersing its seeds, and thus dispersal likely depends on the presence of appropriate animal vectors (most likely waterfowl and/or small mammals; Zedler and Black 1992). Seeds are known to float for several hours before sinking following dehiscence, which may aid in their dispersal (McGlaughlin 1974). Seedlings, which are easily uprooted by disturbance, are also capable of floating independently on the surface for some time, and may thus also play a role in dispersal (McGlaughlin 1974).

Associated species. In British Columbia, *C. marginata* appears to be closely associated with another rare vernal pool endemic, *Isoetes nutallii* (A. Ceska, pers. communication). It has also been observed growing with *Sagina* (Calder 1961); *Bryum* and *Ranunculus* spp. (Ceska 1997); *Poa bulbosa* (Douglas 1991); and in the same vicinity as *Orthocarpus pusillus*, *Plagiobothyrs scouleri*, and *Poa confinis* (Ceska and Ceska 1980).

Co-occurring species at risk. In addition to *Isoetes nutallii*, several other provincially Red and Blue listed species have been documented in the same vicinity as *C. marginata*, including the southern elements *Tillaea erecta, Arenaria pusilla*, *Lotus formosissimus, and Microseris bigelovii* (Ceska and Ceska 1980); and *Orthocarpus faucibarbatus*, *Myosurus minimus*, *Trifolium depauperatum*, and *Limnanthes macounii* (Douglas 1991).

b) **Habitat availability/habitat trends:**

Sufficient habitat protected for long-term survival. **Unknown**. Populations of annual plants in an unpredictable and variable habitat (such as vernal pools) are subject to strong variations in density and abundance over time (Bonis et al. 1995, Venable and Lawlor 1980). Beyond this generalisation, little can be said at present about the factors affecting long term survival of *C. marginata*, either here in British Columbia or elsewhere. For example, for plants like *C. marginata* that are specialised for island-like habitats, long term site occupancy could be explained either by low rates of dispersal and low rates of local extinction, or by high rates of extinction and high rates of dispersal (Zedler and Black 1992). In the absence of long term data on life history, demography and dispersal patterns, however, it will be difficult to assess the importance of such key factors as habitat connectivity and reserve size to the long term survival prospects of *C. marginata* here at the northern periphery of its range.

Of the five known *Callitriche marginata* sites known in B.C., two are in marine provincial parks, one is in a managed municipal park, one is on land protected by the Department of National Defence, and one is on an isolated First Nations reserve (see below). This either suggests (a) that *C. marginata* was once more widespread on southern Vancouver Island than it is at present, and therefore that present colonies are actually relicts of a once more widespread population, preserved until now only by virtue of their location in protected habitat; or (b) that this species is a relatively new arrival to B.C. and is in fact in the process of expanding its range northward. In either case, the fact that it is presently found only on sites where there is already some level of habitat protection in place suggests that *C. marginata* is highly sensitive to changes to its environment.

Net gains or loss to critical habitat. **Unknown.** I was unable to locate any information with respect to historical losses or gains of vernal pool habitat on southern Vancouver Island, nor is such information likely to exist (H. Roemer, pers. communication).

Threats to habitat. The management and conservation of vernal pools has received considerable recent attention in California (see, e.g., Whitham et al. 1998 and papers therein) due to the species richness and high degree of endemism of their flora, and the fact that a number of these species have now been listed as threatened or endangered by the US Fish and Wildlife Service (USFWS 1988). At present, the primary threats to *C. marginata* habitat in California are urbanisation and agriculture; competition from exotics weeds; changes in

hydrology from water runoff; pollutants (herbicides, fertiliser); cattle grazing (Barry 1995); and increased foot traffic(BLM 1997, Clark et al. 1998). Some or all of these concerns may also apply to *C. marginata* habitat within British Columbia, but no studies in this regard have yet been undertaken.

Habitat trends across the border. **Unknown.** Although *C. marginata* is tracked in Oregon by the Oregon Natural Heritage Program, the status of its critical habitat in that state has not been assessed (T. Kaye, pers. communication).

c) **Habitat ownership/protection**:

Ownership and management.

Site	**Management/Ownership**
Uplands Park	Municipal park (City of Oak Bay)
Rocky Point	DND (Dept. of National Defence)
Discovery Island	Provincial park (Discovery Island Marine Provincial Park)
Chatham Island	1st Nations (Songhees) Indian Reserve
Mitlenatch Island	Provincial park (Mitlenatch Island Nature Provincial Park)

Legal protection and future land use. Each of the five known *C. marginata* sites are legally protected to some extent, but to varying degrees. The Rocky Point area, west of Victoria, lies within a National Defence establishment and is restricted to the public. This area is thus ideal for the protection of many plants that have disappeared from more populated areas around Victoria (Ceska and Ceska 1980). Furthermore, because this site occurs on federal land, it is one of the few 'habitats' on southern Vancouver Island (the 1st Nations Reserve on Chatham Island being another) that would qualify for full legal protection under the proposed Species At Risk Act currently being tabled before the House of Commons. For their part, the Discovery Island and Mitlenatch sites are protected from future development by virtue of their status as provincial parks, but since both islands are marine tourist destinations, impacts relating to human visitation may be a concern. Lastly, Uplands Park, due to its lower-level status of municipal park, its close proximity to some of the most populated areas of Victoria, and the heavy human use it already receives, is probably the least secure of all the *C. marginata* sites. Long term prospects for the survival of *C. marginata* at Cattle Point will be tied closely to any future land use decisions that are made for this popular area.

4. Status of Species

Endemic/relict/indicator or keystone species. Callitriche marginata is endemic to Western North America (California, Oregon, and SW British Columbia). Within B.C., populations may represent relictual occurrences of a once more widespread distribution, but there is at present no evidence to support or reject this hypothesis. Due to its obligate dependence on seasonal wetlands, federal agencies in the US (US Fish and Wildlife, USDA) have classified *C. marginata* as a regional wetland indicator species (USFWS 1988).

Globally at risk. *C. marginata* is not currently considered to be globally at risk. It is not tracked in California, where it has been reported from several counties (CalFlora 2000), or at the national level.

Heritage status (from information in NatureServe 2001).

Global Heritage Status Rank: G4

National Heritage Status Rank:

United States: N?

Canada: N2N3

State/Provincial Heritage Status Rank:

California: SR

Oregon: S2

British Columbia: S2S3

Status of related forms. Currently, one other native *Callitriche* species in British Columbia is on the provincial Blue list and considered at risk: *C. anceps* Fern. Within B.C., *C. anceps* is restricted to shallow ponds and shorelines in the lowland and montane zones along the coast (Douglas et al. 1998), but is more widespread—both within Canada and globally—than *C. marginata* (Hitchcock 1973).

Special scientific interest. The Callitrichaceae (water starworts) are an aquatic family of dicots comprised solely of the genus *Callitriche*. The family contains 40-50 terrestrial, amphibious, and obligately submersed species, and is only the second (with Ceratophyllaceae) family of dicots in which hypohydrophily (underwater pollination) occurs. Even more significantly, it is the only known group in the plant kingdom in which both aerial pollination and hypohydrophily (underwater pollination) have been documented in the same genus (Cooper et al 2000). The Callitrichaceae have thus come to serve as a model system for understanding the nature of the changes that occur during the evolution of hydrophily from aerial pollination systems (Philbrick and Anderson 1992, Philbrick 1993, Osborn and Philbrick 1994, Philbrick and Osborn 1994, Cooper et al 2000, Philbrick and Les 2000). Several species of *Callitriche* (but not *C. marginata*) have also been noted for their reliance on a unique form of self-fertilisation known as internal geitonogamy, wherein pollen grains germinate inside indehisced anthers and the pollen tubes grow through vegetative tissues to nearby pistillate flowers, where pollination occurs (Philbrick 1984, Philbrick and Bernardello 1992, Cooper et al. 2000).

In general, 'the population features of species associated with vernal pools, such as the presence of disjunct subdivisions of species range, low effective population sizes, low dispersability, competition at the zonal boundaries with other species, low species diversity and the diversity of breeding systems among congeneric species in several genera, offer exciting research opportunities for an evolutionary ecologist' (Griggs and Jain 1983). From an ecological perspective, the highly ephemeral nature and island-like structure of *C. marginata* habitat, itself sometimes further nested within real, geographic islands, implies the existence of specific demographic mechanisms (e.g., prolonged seed dormancy, complex metapopulation dynamics) that enable it to establish in these areas and persist for long periods. Consequently, *C. marginata* and other *Callitriche* species could prove to be exemplary subjects for the study of questions relating to island biogeography, metapopulation systems, and population dynamics in a variable environment. Finally, *C. marginata* has been shown to be highly sensitive to

fluctuations in annual precipitation and temperature patterns (McGlaughlin 1974, Bliss and Zedler 1998), and may thus serve here in Canada as a useful subject for the study of the potential effects of global climate change on species at or near their northern range limits.

Potential to be confused with another common species. According to Douglas et al. (1998), the following *Callitriche* species frequently occur in southern B.C. in similar habitat to *C. marginata,* and could thus be accidentally taken for it:

i) *C. hermaphroditica*
ii) *C. heterophylla ssp. bolanderi*
iii) *C. stanalis (introduced)*
iv) *C. verna*

Callitriche species are notoriously hard to distinguish from one another in the field (due in part to their highly reduced floral structures). However, one diagnostic field characteristic of *C. marginata* distinguishes it from all other *Callitriche* species in north America: *the presence of distinct pedicels on female flowers that are longer than the fruit* (thus accounting for the synonym *C. longipedunculata* that is sometimes applied to this taxon) (Hitchcock 1973).

Genetic importance. **Unknown.** However, measurement and observations of pollen or seed movement in other vernal pool plants imply relatively restricted gene flow, and several vernal pool plant taxa exhibit intrapopulation differentiation over distances of 2 to 5 metres, from pool centre to periphery (Elam 1998). This trend, combined with the small population sizes and marked geographic and genetic isolation (at several scales) of *C. marginata* colonies in B.C., suggest that knowledge of levels of genetic variation as well as genetic structure within populations may be an important factor in the design of conservation efforts for this species.

Other uses. **Unknown.**

Plant and pollinator interactions. **Unknown.**

Amount of range in protected areas. **Unknown** at the global level; within British Columbia, most of the current known range is in protected areas of some sort (see above). On the other hand, only a small percentage of its *potential* range (i.e., Garry oak meadows and coastal rock bluffs) is presently protected on southern Vancouver Island.

5. Life History

a) **General:** *C. marginata* is a small, limp-stemmed, annual amphibious herb that is restricted to ephemeral wetlands. Plants of *C. marginata* grow either terrestrially, with submersed stems that reach to the water surface and produce floating rosettes of leaves, or as completely submerged stems that lack floating leaves (Cooper et al. 2000). Unlike some amphibious C*allitriche* species that can produce flowers on both aerial and submersed stems, *C. marginata* produces only aerial flowers (Cooper et al. 2000). Plants are monoecious, with separate male and female flowers occurring side by side in the same leaf axil (Philbrick and Anderson 1992). *C. marginata* usually occurs in well-lighted vernal pools formed by winter rains and dry by late spring or early summer. However, for most of the year the species exists only as dormant seeds in the sediment (McLaughlin 1974). The number of years seeds can potentially remain dormant before germinating is unknown, but may be a critical factor in determining how long populations are able to maintain themselves during episodes of reproductive failure (e.g., due to prolonged drought).

b) **Phenology:** In its California range, *C. marginata* begins flowering in February and sets seed by March. Seeds remaining dormant through the summer and germinate in December and January (McLaughlin 1974). The precise phenology of *C. marginata* in British Columbia has not been documented, but germination and flowering probably commence several weeks earlier than in California (A. Ceska, pers. communication).

c) **Pollination biology:** *Callitriche* is the only genus of angiosperms in which anemophily (aerial pollination), epihydrophyly (water surface pollination), and hypohydrophily (water-mediated pollination below the water surface) are all reported. Because of this unusual diversity and the interest it holds for evolutionary biologists, pollination systems in the Callitrichaceae have been relatively well studied (e.g., Philbrick and Anderson 1992,Cooper et al. 2000). In *C. marginata*, pollination is effected through the air, and is primarily geitonogamous (among flowers on one plant). Fertilisation takes place either by the style from a female flower coming in contact with the dehisced anther of a male flower or by pollen falling from the anther onto the stigma (Philbrick and Anderson 1992). Pollinator-mediated fertilisation may be rare; when *C. marginata* was grown under pollinator-free conditions in the greenhouse, seed set was always near 100% (Philbrick and Anderson 1992). In cases where cross-pollination does occur, the lack of perianth or obvious pollinator rewards suggests that abiotic (e.g., wind) rather than biotic vectors are involved.

d) **Reproductive ecology:** *C. marginata* is an annual plant and, like most other *Callitriche* species, is monoecious (separate male and female flowers on the same plant), with reduced flowers that lack petals and sepals. The pistillate flower consists of two compressed carpels bearing two filiform styles. The fruit is a non-fleshy schizocarp comprising 4 one-seeded nutlets, which are individually dispersed (McGlaughlin 1974, Hitchcock and Cronquist 1973). Asexual reproduction in *C. marginata* has not been studied but is probably common, since in *Callitriche* any node together with a minute part of the adjacent internode is capable of becoming a new plant (Sculthorpe 1967).

Callitriche seed exhibits *primary dormancy*, i.e., dormancy exists at the time of seed dispersal. Seeds must be dried in order for afterripening (the post-maturation loss of dormancy) to take place but, once ripened, show high germinability (McGlaughlin 1974). Germination appears to be both light- and temperature-sensitive; in greenhouse trials, *C. marginata* failed to germinate aty room temperature, but showed almost 100% germination at cooler (10°C and 18°C) temperatures. Germination of previously frozen seed was variable, but freezing alone did not render seed ungerminable (McGlaughlin 1974). Thus, *C. marginata* may be protected against out-of-season germination by partial keying to cool, moist weather conditions. In an unrelated experiment, germination rates in *C. marginata* also responded to the timing of the onset of fall flooding, as well as the length of inundation (Bliss and Zedler 1998). In this study, conditions simulating a delayed rainy season (i.e., March) resulted in lower seed germination than conditions simulating earlier rains (i.e., January), while seeds that were kept constantly inundated germinated poorly compared to those kept in moderately moist conditions (Bliss and Zedler 1998).

e) **Survival/demography: Unknown.** Over-shading (McGlaughlin 1974, Pollak and Kan 1998), over-fertilisation (Best et al. 1995), competition from exotic weeds (Pollak and Kan

1998), and over-grazing by waterfowl (Sondergaard et al. 1996) are among the factors that have been identified as posing potential threats to the persistence of vernal pool species, including *Callitriche* species. However, specific factors affecting population survival, as well population age structure; recruitment rate; seedling survival rates; causes of mortality; and intrinsic growth rate in *C. marginata* are poorly understood (R. Landsdown, pers. communication).

f) **Physiology:** See *Reproductive ecology*, above, for information on seed germination requirements and dormancy in *C. marginata.* There is some evidence that *Callitriche* species, which are C_3 plants, are in general limited by inorganic free-CO_2 concentrations under natural conditions (Vadstrup and Madsen 1995).

g) **Dispersal: Unknown.** This species has no innate mechanism for dispersing its seeds, and thus dispersal likely depends on the presence of appropriate animal vectors (most likely waterfowl and/or small mammals; Zedler and Black 1992). Seeds are known to float for several hours before sinking following dehiscence, which may aid in their dispersal (McGlaughlin 1974). Seedlings, which are easily uprooted by disturbance, are also capable of floating independently on the surface for some time, and may thus also play a role in dispersal (McGlaughlin 1974). Nevertheless, actual dispersal mechanisms in this family remain largely unknown.

h) **Nutrition and interspecific interactions: Unknown.**

i) **Behaviour/adaptability: Unknown.** As a species restricted to open, seasonally ephemeral wetlands, *C. marginata* is highly specialised ecologically and likely ill-adapted to respond to major structural or hydrologic alterations to its habitat. Furthermore, there is evidence to suggest that germination in *C. marginata* is sensitive to changes in temperature during the rainy season, to the timing of initial rains, and to the occurrence of aseasonal rains (Bliss and Zedler 1998), implying that this species could be negatively affected by changes in climate associated with global warming. On the other hand, patterns of establishment, growth, and reproduction tend to fluctuate strongly from one year to the next for all annual plants living in unpredictable and variable habitats (Bonis et al. 1995), and it is therefore likely that *C. marginata* has evolved specific mechanisms (such as a dormant seed bank) that allow it persist through 'bad' as well as favourable years. Nevertheless, actual responses to, and tolerance of, specific disturbance regimes such as fire have not been documented. Because little or no horticultural research has been devoted to this species, the response of *C. marginata* to potential management interventions such as *ex-situ* propagation and transplantation are also unknown at present (C. Philbrick, pers. communication).

6. How the species is at risk.

Because all five extant *C. marginata* populations in British Columbia were 'discovered' only relatively recently, there is little information available on either long term or recent changes to population numbers and range of this species in Canada, or on the biological and environmental factors currently limiting its distribution and abundance. Nevertheless, the

potential threats to *C. marginata* in B.C. likely fall into one of two general categories. The first of these includes all those factors that in general are thought to threaten numerous species native to the Garry oak ecosystems of SW British Columbia by virtue of their membership in this highly imperilled plant community. These threats have been well documented elsewhere (Fuchs 2001) and include habitat loss due to land conversion for agricultural and urban uses; altered fire regimes; and invasions by exotic species such as Scotch broom (*Cytisus scoparius*) and orchard grass (*Dactylis glomerata*).

The second category, nested within the first, comprises factors that apply specifically to the vernal pool micro-ecosystems where *C. marginata* is found. These threats are less well-understood, but based on research that has been conducted in California (see, e.g., Jain 1976, Whitham et al. 1998), potentially comprise such factors as: changes to drainage patterns as a result either of land management modifications, secondary succession, or livestock grazing; competition for light and water from introduced annual grasses; over-grazing by waterfowl; eutrophication; agricultural run-off; exposure to herbicides; exposure to foot traffic and cycling; climate change; and habitat fragmentation. Given that populations of annual plants living in unpredictable and variable habitats are naturally subject to strong variations in density over time and space (Venable and Lawlor 1980), high population turnover may be a fundamental characteristic of *C. marginata* ecology, particularly at the northern limits of its range. If so, this species might be put further at risk in B.C. should a lack of sufficient habitat, or of habitat connectivity, prevent dispersal and/or local recolonisation events from occurring in the future.

7. Management recommendations

There are presently no management policies in place that address *C. marginata* conservation in B.C. Due to the fragmentary nature of its distribution, however, any future management practices will have to be tailored to fit the needs of the particular site.

Hydrology. All preserves should receive an evaluation of historic, existing and potential impacts to on-site hydrology. A hydrologic plan should be designed that includes provisions for eliminating unseasonal runoff, while providing the historic hydrology of the vernal pools. Buffers and perimeter drainage systems may be appropriate in certain cases.

Pollutants. Sites should be evaluated for the potential impacts from herbicide, fertiliser and road runoff (particularly at Cattle Point). Local agencies managing road runoff should be contacted to develop a plan that addresses the vegetation management needs of affected areas.

Access. Habitats containing *C. marginata* should be protected from foot traffic and off-road vehicles. Fencing could be used to 'guide' visitors around vernal pools. If fire is to be used as a management tool, fencing should be fireproof.

Exotic plant invasion. Sites should be protected from invasive pest plant species, particularly annual grasses. Management tools may include selective weeding, controlled herbicide use, grazing, and fire. Monitoring should occur to detect pest plant encroachment as early as possible. Maintaining the area's historic hydrology regime will also help maintain its endemic flora.

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