



**Garry Oak
Ecosystems
Recovery Team**

**Stewardship Account for
Muhlenberg's Centaury**
Centaureum muehlenbergii

Prepared by
Wynne Miles
for

the BC Conservation Data Centre and
the Garry Oak Ecosystems Recovery Team
March 2002

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

Canada



**NATURE
CONSERVANCY**
C A N A D A

STEWARDSHIP ACCOUNT - *Centaurium muehlenbergii*

1. Species Information

a) Name:

Scientific: *Centaurium muehlenbergii* (Griseb.) Wight ex Piper

Synonyms: *C. curvistamineum* (Witttr.) Abrams and *C. floribundum* (Benth.) B.L. Rob. (Missouri Botanical Gardens - W3TROPICOS November 2001; ITIS November 2001) Kartesz (1994) does not list *C. floribundum* as a synonym.

English name: Muhlenberg's centaury; The name *Centaurium* is from the greek word kentauros, referring to the centaur Chiron who supposedly discovered the medicinal properties of the genus (Hitchcock et al 1969).

Family: *Gentianaceae* - Gentian Family

b) Classification:

Centaurium is generally considered to be a taxonomically difficult genus (Cronquist et al. 1984; Hickman 1993; Holmes & Wivagg 1996; Mansion, pers. com., 2001; Pringle, pers. com., 2001, Turner 1993) and further work is needed to clarify the taxonomic status of the species within this genus. Dr. Pringle suggests that the name *C. muehlenbergii* has been misapplied to *C. exaltatum*, *C. tenuiflorum*, *C. davyi*, *C. erythraea*, *C. pulchellum*, and possibly three or four other species. Similarly he feels the synonym *C. floribundum* has often been applied to North American specimens of the naturalized *C. tenuiflorum* (Pringle, pers. com., 2001). Guilhem Mansion is currently studying the molecular systematics of the genus *Centaurium* on a worldwide basis. His preliminary results suggest it would be useful to recognize a '*Centaurium muehlenbergii* complex' which includes *C. curvistamineum*, *C. floribundum*, and *C. tenuiflorum*. He also suggests a hybrid origin of *C. muehlenbergii*, involving *C. erythraea* and *C. tenuiflorum*. Dr J Pringle feels that G. Mansion has misapplied the name *C. muehlenbergii* to a naturalized weedy taxon (which is closely related to *C. tenuiflorum* and *C. erythraea*), and that his molecular studies do not relate to the 'true' rare *C. muehlenbergii* (ie. none of the specimens used for the molecular work were from the 'true' rare taxon).

Due to the confusion regarding the taxonomy of *C. muehlenbergii* it is difficult to ascertain which literature references to *C. muehlenbergii* actually pertain to the 'true' rare plant, and which references have been misapplied.

An alternate spelling for the specific epithet is *muhlenbergii* (Gillett 1963)

c) Similar Species [in B.C.]:

Two other species of *Centaurium* are recognized in B.C. *C. erythraea* has a well developed basal rosette and the flowers are unstalked [or nearly so]. *C. exaltatum* lacks a well developed basal rosette, the flower stalk is much longer than the calyx, the calyx is as long or longer than the corolla tube and the anthers measure 0.5 - 1.0 mm. *C. muehlenbergii* lacks a well developed basal rosette, the flower stalk is shorter than the calyx, the calyces are shorter than the corolla tubes and the anthers measure 1.5 - 2.0 mm long (Douglas et al. 1999). Also, see 1 b. Dr. J. Pringle feels that the naturalized *C. tenuiflorum* is 'due' to show up in B.C. (Pringle, pers. com., 2001).

2. Range and Known Distribution:

a) Global range:

From south west British Columbia south to Nevada and California [ie B.C., Washington, Oregon, California, Idaho and Nevada (Douglas et al. in press; NatureServe 2001)].

The USDA Plants Database indicates that *C. muehlenbergii* also occurs in Texas, Mississippi and Louisiana

(USDA 2001).

Dr. James Pringle feels that the specimens reported from Nevada are misidentified *C. exaltaum*, and those from Texas, Mississippi and Louisiana are *C. tenuiflorum* (Pringle, pers. com., 2001).

b) Canadian range:

Known only from SW Vancouver Island [Uplands Park, Oak Bay], Chatham Island and Stanley Park in the Lower Mainland (Douglas et al. in press; Donovan, pers. com., 2001).

c) British Columbia range:

- As listed in 2b.
- *C. muehlenbergii* has not been collected in the Lower Mainland [Stanley Park] since 1911.
- It was collected at a minimum of two locations on Chatham Island in 1976.

3. Habitat Description

a) General habitat requirements of the species:

- general habitat type: In B.C. - Moist meadows in the lowland zone [CDFmm, CWHdm] (Douglas et al. in press), also salt marsh (Donovan, pers. com., 2001);
- Over entire range - coastal bluffs, wet openings in woods, moist places in sagebrush scrub (Pringle, pers. com., 2001), damp places below 1500', redwood forest, oak woodland and mixed evergreen forest (Munz 1959) [Dr. Pringle feels that some of the characters used by Munz (1959) are questionable.], stabilized sand dunes (Rittenhouse ____), wet prairies (Guard 1995), facultative wetland [FACW ie. usually occurs in wetlands, but occasionally found in non-wetlands] (Reed 1988), sagebrush scrub, redwood forest, mixed evergreen forest, northern oak woodland, foothill woodland, valley grassland, northern juniper woodland (Calflora 2001), serpentine and annual grassland (Callizo et al. 1997); low damp ground, moist places, south slope and dry prairie (Kinter, pers. com., 2001); common to moist open forest in Northern California (Keeler-Wolf et al. 1998).
- specific habitat type: BC - moist meadows, salt marsh, vernal pools (Donovan, pers. com., 2001).
- specific characteristics: BC - chernozem-like soil, dark brown with abundant humus incorporated into the upper horizons; seasonally flooded meadow which dries out during the summer (upland park); margin of drier *Distichalis spicatus* marsh [Chatham island] (Donovan, pers. com., 2001), Mediterranean-like climate with dry, warm summers and mild, wet winters (Fuchs 2001).
Over entire range - serpentine formations (Callizo et al. 1997), poorly drained lowland soils or well drained soils with shallow bedrock impeding drainage allowing standing water to accumulate during the summer (Wilson 1998a).
- dependence on abiotic and biotic dynamic factors: most abundant in small patches where old wheel ruts are present, or in shallow depressions where *Agrostis* sp. does not form a dense cover.
- dynamic factors- no information found.
- associated native and non-native species: *Agrostis* sp., *Cynosurus cristatum*, *Danthonia californica*, *Distichalis spicatus*, *Lolium perenne*, *Trifolium dubium*
- other species at risk occurring in same habitat: 60 other plant taxa are listed as being at risk in Garry oak [*Quercus garryana*] and associated ecosystems, including 11 designated by the COSEWIC as being at risk at the national scale. Twelve are at risk on a global scale (Fuchs 2001).

b) Habitat availability and net trends in habitat change:

British Columbia:

- Less than five percent of Garry oak ecosystems remain in near natural condition in B.C. Since the arrival of European settlers approximately 150 years ago, much of the Garry Oak habitat has been lost due to agricultural, urban or industrial use. The remaining areas have been impacted by encroachment of woody

species due to fire suppression and invasions of exotic species. It is estimated that less than 1000 hectares remains in near-natural condition and this is fragmented.

- Victoria, one of the fastest growing urban areas in North America, is located in the centre of the Garry oak habitat in BC. It has been estimated that the population could increase by thirty percent in the next 30 years, resulting in further encroachment of the natural areas.
- Fuchs (2001) indicates that additional global warming could increase the range of Garry oak and associated ecosystems.

United States:

- Similar trends exist in Garry oak habitats in Washington, Oregon and California. The relationship between fire history and Garry oak [and associated ecosystems] has been studied in all three states (Fuchs 2001). One area that has been well documented is the Willamette Valley in Oregon. Before European settlement, the Willamette Valley is thought to have been covered by oak savannah and prairie that was maintained by controlled burning. Fire suppression after European settlement in the 1800's allowed the growth of dense stands of uniform aged oak trees (Pike 1971; Merifield 2000). *C. muehlenbergii* is a common native forb of the remaining wetland prairies of the Willamette Valley (Wilson 2001). These wetland prairies are highly fragmented and considered among the rarest of Oregon's ecosystems. The decline is due to invasion of both woody plant species and pest organisms, agricultural or urban encroachment and changes in hydrology (Wilson 1998a &b).
- Habitats other than Garry oak ecosystems have also been reported for *C. muehlenbergii* [see3a].

c) Habitat ownership/protection:

- There is no existing legislation that compels any level of government to protect Garry oak or associated ecosystems. Most of the Garry Oak habitat in B.C. is held by private landholders, and therefore land use planning falls under jurisdiction of local governments (GOERT 2001). Other areas are managed by BC Parks, Capital Regional District Parks, Municipal Parks, Songhees First Nation, The Nature Conservancy of Canada, The Land Conservancy of Canada and The Department of National Defence,
- Management of existing *C. muehlenbergii* sites in B.C. : Chatham Island is part of the Songhees First Nation (phone 250-386-1043). Upland Park is a municipal park managed by the District of Oak Bay (www.district.oak-bay.bc.ca). Stanley Park is managed by the Vancouver Board of Parks and Recreation, City of Vancouver (www.parks.vancouver.bc.ca).
- Amount legally protected: no information found.

4. Status of Species

- endemic to Western North America (Calflora 2001).
- global rank: G5? (Douglas et al. in press) - A global rank of 5 indicates that the taxa is demonstrably secure across its entire range and usually widespread and abundant. *C. muehlenbergii* is rare in B.C. but more common in the southern parts of its range (Hickman 1993; Wilson 2001; Keeler-wolf et al. 1998). *C. muehlenbergii* is not included in the Special or Rare Plants Lists maintained by the Natural Heritage Programs in the states of Oregon, California, Nevada or Idaho (Oregon Natural Heritage Program 2001; California National Diversity Database 2001; Nevada Natural Heritage Program 2001; Idaho Conservation Data Center 2001). As it is not a sensitive species in these states, occurrence records are not available through the Bureau of Land Management (California State Office, BLM 1998; Camp, pers. com., 2001; Loerentzen, pers. com., 2001).

However *C. muehlenbergii* is now rated as SH [possibly extirpated] by the Washington Natural Heritage Program (Washington Department of Natural Resources 2001). It does not appear on the current list of Rare Plants with Ranks (Washington Natural Heritage Program 2001) as the list has not been updated. (Caplow, pers. com., 2001). All but one of the Washington collections of *C. muehlenbergii* were reassigned to the taxa *C. pulchullem* by Curtis Bjork and C. Rose Broome. This taxa will probably be placed in Review Group 2 - taxa with taxonomic questions which must be resolved (Caplow, pers. com.). Dr. Pringle agrees that the species may be extirpated from Washington (Pringle, pers. com., 2001).

- provincial rank: S1, status: red - A provincial rank of S1 indicates that the plant is critically imperiled because of extreme rarity [less than 5 extant sites] [in this case, one historic site and two extant sites].
- threatened related forms: *Centaurium exaltatum* is also on the red list in B.C., with a rank of G5 S1. *Centaurium namophilum* [spring-loving centaury] is listed as a federally threatened (FT) by the US Fish and Wildlife Service (USFW Service 2001b) and the Bureau of Land Management in California (BLM in California 2001). These flowers are endemic to the Ash Meadow wetland in a narrow desert valley about 72 km long situated between Beatty, Nevada and Tecopa, California (University of Nevada 2001). An Endangered Species Recovery Plan is available online (USFW Service 2001b) (Roy, pers. com., 2001). *Centaurium sebaeoides* is also listed as FT by the USFW Service. It is only found in Hawaii. (USFW Service 2001b). *C. rigualii* is noted as endangered by Gonzalez et al. (1997)
- special scientific interest: Centaurium species have been used in a variety of research topics. The systematics of the group has been investigated through cytotaxonomic studies (Zeltner 1978,1985,1990 &1991; Broome 1978; Ward 84) molecular systematics (Yuan & Kupfer 95; Mansion, pers. com., 2001), chemotaxonomical studies (Van der Sluis 1985) and plant anatomy (Rao & Chinnappa 1983a&b). The phytochemistry of Centaurium species has been studied by a number of authors (Khafagy & Mnajed 1970; Beerhues & Berger 1994; Jankovic et al. 1998; Barillas & Beerhues 1997; Mandal et al. 1992).
- possibility to be confused with other common species: See section 1b. Other authors mention the possibility of confusing *C. muehlenbergii* with *C. erythraea* (Hickman1993), or *C. exaltatum* and *C. pulchellum* (Cronquist et al. 1984).
- genetic importance: Specimens of *C. muehlenbergii* found in B.C. may be of special interest genetically, as populations on the periphery of a range may be genetically distinct from the main population and more vulnerable to disturbances such as climate change (Ward et al. 1998).
- Other Uses: Most members of the Gentianaceae are found to contain a variety of phytochemicals, most commonly xanthenes and secoiridoids. Xanthenes are yellow dyes that are pharmacologically active. Secoiridoids are responsible for the bitter taste of many gentians and are used for their digestive properties (Mansion, pers.com., 2001). *C. erythraea* which contains both xanthenes and secoiridoids has a long history of use as a herbal remedy. A translation of a mediaeval Latin poem of the tenth century mentions Centaury as being powerful against 'wykked sperytis'. Similarly, *C. erythraea* is mentioned in a translation of a slavic medical text from the fifteenth century (Grieve 1992; Jankovic et al. 1998 & 2000; Ruxic & Simonic 1993). More recently it has been studied by a number of authors. *C. erythraea* has been shown to have anti-inflammatory, antipyretic, antioxidant, antimutagenic and diuretic effects (Berkan et al. 1991;Valentao et al. 2001;Haloui et al. 2000; Schimmer & Mauthener 1996) and has been used as part of a herbal preparation to treat hyperglycemia (Petlevski et al. 2001). Other Centaurium species such as *C. linarifolium* are also known to have medicinal properties (Mandal et al. 1992). Centaurium spp. are used in the Pacific Northwest by herbalists to prepare a bitter tonic used to treat poor appetite and digestive problems (Moore 1995). *C. muehlenbergii* is used by the Mahuna tribe in California as a laxative. *C. venusta* is used by the Luisenos tribe to treat fevers.(MPNADB 2001).
- How much of range is protected: no information found

5. Life History

- a) General - *C. muehlenbergii* is a small [3 -30(40) cm] annual which blooms from June to early fall and produces numerous small [<0.5mm] brown reticulate seeds (Pringle, pers. com., 2001; Cronquist et al. 1984;St. John 1962; Kinter, pers. com., 2001).
- b) Phenology - see 5a.. Baresova (1984) studied the hormonal control of morphogenesis in *C. erythraea*. Schaeppi (1969) studied shoot development in Centaurium species. Seed germination in *C. umbellatum* has been studied by Formanowiczowa & Kozlowski (1973). Schat et al. (1984) found that *C. littorale* had an absolute requirement for cold vernalization. After vernalization, flowering occurred as soon as the day length exceeded a critical value [12-16 hours].
- c) Pollination biology - *C. muehlenbergii* has a salverform corolla when the lobes are extended [corolla 12-19 mm including the narrow elliptic lobes [2-7mm]] (Pringle, pers.com., 2001). Kugler (1977) reports that *Centaurium erythraea* with its nectarless salverform blossom, produces very little pollen and is essentially

autogamous. Broome's thesis (1974) contains a section on breeding systems of the Mexican and Central American Centaurium species. Dr Pringle suggests that it would not be advisable to extrapolate from generalities about the species, because some species are largely autogamous and some are largely outcrossing. In some the floral morphology may vary according to growing conditions (Pringle, pers. com., 2001). In the genus Centaurium, nectary glands are located at the base of the corolla tubes, alternate with the stamens (Douglas et al, 1999).

- d) Reproductive ecology - Most authors refer to *C. muehlenbergii* as an annual. The PLANTS Database (USDA 2001) lists it as either an annual or biannual. Hickman (1993) suggest that it may persist as abiannual if damaged. Natural hybridization has been observed between *C. erythraea* and *C. littorale* in England (Ubsdell 1979; Vohra 1970). In his ongoing study of the 'Phylogenetic relationships within the subtribe Chironiinae [Gentianaceae] with a particular focus on...the genus Centaurium' Guilhem Mansion proposes that allopolyploidy has occurred in several clades of Centaurium and that the *C. muehlenbergii* complex shows evidence of diverse introgressive hybridization (Mansion, pers.com., 2001).
- e) Survival - See 5h. McGee (1985) found that *C. erythraea* was dependent upon mycorrhizal infection for growth and survival under conditions of low nutrients.
- f) Physiology - With regard to the genus as a whole, Mansion notes that Centaurium species may be found in various habitats. Most species are calcic olous, some are acidiphilous [*C. scilloides*] and a few are restricted to gypseous soils. However, for Centaurium germination and growth, edaphic conditions appear to be of little importance compared to the amount of available moisture and sunlight (Mansion, pers. com., 2001). Schat (1983) noted that *C. littorale* would not germinate without light and that even moderate salinity levels strongly reduced growth and prolonged the vegetative stage (Schat 1986). Freijsen (1971) and Freijsen & Van Dijk 1975) studied the differences in growth rate and salt tolerances between different varieties of *C. littorale*. Catling & Mckay (1980) studied the ecology of the halophytic species *C. pulchellum* in southern Ontario.
- g) Dispersal - no information found.
- h) Nutrition and interspecific interactions - Schat et al. (1984) studied the response of *C. littorale*, a biennial, to nutrient stress and found that growth was limited by phosphorous levels. In another study, Schat et al. (1989) found that *C. pulchellum* produced longer [as apposed to more] capsules and therefore more seeds in eutrophicated sites compared to less fertile sites. As noted in 5e, seedlings of *C. erythraea* were found to be dependent on mycorrhizal infection for growth and survival, with the plants showing a marked growth response to infection. Gay et al.(1982) found that seedlings of *C. erythraea* became mycorrhizal within two weeks of germination. Both studies found the mycorrhizal species to be a peculiar form of vesicular-arbuscular type.
- i) Behaviour/ Adaptability - Mansion suggests that most Centaurium species do not compete well with other species and therefore are found in disturbed and open places (Mansion, pers. com., 2001). Gay et al. [1982] describe *C. erythraea* as 'turf compatible' i.e., able to regenerate in closed turf. Some Centaurium species such as *C. erythraea* do appear to be very successful weeds. Davies & Waite (1998) found that seeds from *C. erythraea* dominated the seed bank in a calcareous grassland area. Bekker et al. (1999) considered *C. littorale* a early successional pioneer species. However the seeds persisted in the soil for a significant time.

6. How the Species is at Risk

As discussed in 3b, less than five percent of Garry oak ecosystems remain in near natural conditions in B.C. Within that available habitat, *C. Muehlenbergii* is apparently restricted to moist open areas. The remaining Garry oak habitat is also fragmented and the native species have to compete with aggressive exotics such as Scotch broom, English ivy, Himalayan blackberry and orchard grass. The remaining habitat has also been impacted by growth of native shrubs due to fire suppression. Both these native and exotic shrubs pose a problem for *C. muehlenbergii* if it does in fact need full sunlight for germination. Turf forming exotic grasses may also be difficult to compete with.

7. Management Recommendations

A recovery strategy for the Garry oak and associated ecosystems has been developed (GOERT 2001). Phase one focuses on the development of an information base, to protect and manage known sites to minimize immediate loss, and to motivate protection and stewardship through public education

General management prescriptions:

- Fire exclusion has been identified as the most serious ecological problem facing remnant Garry oak stands in the United States and prescribed fire has been tried as a restoration tool in Washington, Oregon and California (GOERT 2001; Wilson 1999). A variety of management tools have been tried to control exotic species, including manual, mechanical, chemical and biological controls, as well as fire. However success has been limited (GOERT 2001). Management strategies for the wetland and upland prairies of the Willamette Valley are currently being studied at Oregon Sate University. Prescribed burning has been effective in controlling woody plants but must be supplemented with additional control of weedy herbs [manual weed removal, and seeding of native species] (Wilson et al. 1995; Wilson 1999; Clark & Wilson 2001). The use of mowing as a control tool produced mixed results (Bartels & Wilson, in press; Wilson & Clark 1997; Wilson & Ingersoll 1993; Clark & Wilson 2000a,b). Further research is needed on the timing and frequency of burns and to determine the long term effects of different techniques (Maret & Wilson 2000; Clark & Wilson 1998b).
- A study by Zwaenepoel & Hermy (1987) in Belgium suggests that mowing, and the maintenance of a high water table as well as oligotrophic conditions are important for the survival of *C. erythraea* and *C. pulchullem*. Studies on grassland seedbanks by Dutoit and Alard (1995) found that the naturally occurring seedbanks in previously species-rich areas [which had been intensely grazed or abandoned] were not sufficient to restore the area [i.e. recolonization from another source was necessary]. Therefore management of a species rich grassland had to be designed to preserve the plant community, as well as improving dispersion from other source areas.
- Research is required to determine the feasibility of reintroducing *C. muehlenbergii* to restored areas. *C. erythraea*, a biennial, is cultivated commercially on a small scale in North Africa and central Europe (Stuart 1979; Mackova 1988). This species has also been cultured in vitro in laboratory settings, and propagated from different types of aseptic seedling explants (Amorim & Fernandes 1998). Laboratory work has also allowed for the micropropagation and in vitro storage of the endangered species, *C. rigualii* (Iriondo & Perez 1996). Further work on the same species has allowed for the cryopreservation of nodal explants using the encapsulation-dehydration method (Gonzalez et al. 1997). In the future, similar work on *C. muehlenbergii* could provide plants for restoration work.
- Research is required to determine if *C. muehlenbergii* is dependent on a mycorrhizal relationship to maximize its nutritional uptake [as appears to be the case for other *Centaurium* spp.]. This information could then be applied to any reintroduction programs
- It would appear that a mixed approach will be necessary to restore the remnant Garry oak areas remaining in B.C. As any management plan will be labour intensive, it would be prudent to be proactive to prevent new exotics from becoming established.

Specific management prescriptions;

- Removal of exotics from existing moist meadow habitats.
- Removal of native and exotic shrubs from other potential wet meadow areas.
- Reintroduction of *C. muehlenbergii*.

- The meadows in Uplands Park are used heavily as dog exercise areas. It may be necessary to restrict access to the meadows during the flowering/seed set period.
- Removing flower/seeds from exotics [such as Scotch thistle] before the seeds mature could be an effective weed control measure.

8. References/Literature Cited

- Amorim, L.R. and F.M. Fernandes. 1998. Micropropagation of *Centaurium erythraea* from different type of aseptic seedling explants. In *Vitro Cellular & Developmental Biology*. Animal 34 (3 Part 2). 62A. (citation only)
- Baresova, H., T. Herben, M. Kaminek and J. Krekule. 1985. Hormonal control of morphogenesis in leaf segments of *Centaurium erythraea*. International Symposium on Plant Growth Regulators, Liblice, Czechoslovakia, June 18-22, 1984. *Biologia Plantarum* (Prague) 27(4-5): 286-291. (citation only)
- Barillas, W. and L. Beerhues. 1997. 3-Hydroxybenzoate: coenzyme A ligase and 4-coumarate: coenzyme A ligase from cultured cells of *Centaurium erythraea*. *Planta Heidelberg* 202(1): 112-116. (abstract only)
- Bartels, M.R. and M.V. Wilson. In press. Fire and mowing as management tools for conserving a threatened perennial and its habitat in the Willamette Valley, Oregon. in *Proceedings of the 17th North American Prairie Conference*.
- Beerhues, L. and U. Berger. 1994. Xanthones in cell suspension cultures of two *Centaurium* species. *Phytochemistry* (Oxford) 35(5): 1227-1231. (citation only)
- Bekker, R.M., E.J. Lammerts, A. Schutter and A.P. Grootjans. 1999. Vegetation development in dune slacks: the role of persistent seed banks. *Journal of Vegetation Science* 10(5): 745-754. (abstract only)
- Berkan, T., L. Ustunes, F. Lermioglu and A. Ozer. 1991. Antiinflammatory, analgesic, and antipyretic effects of an aqueous extract of *Erythraea centaurium*. *Planta Medica* 57(1):34-37.
- Broome, C.R. 1974. Systematics of *Centaurium* (Gentianaceae) of Mexico and Central America. Ph.D. dissertation; Duke University. 429 pp.
- _____. 1978. Chromosome numbers and meiosis in North and Central American species of *Centaurium* (Gentianaceae). *Systematic Botany* 3(3): 299-312.
- Bureau of Land Management in California, U.S. Department of the Interior. California BLM Special Status Plants. Website: http://pub4.ca.blm.gov/caso/ssplist_c.html [accessed November 2001]
- CalFlora: Information on California plants for education, research and conservation. 2001. Berkeley, California. Website: <http://www.calflora.org> [accessed November 2001].
- California Natural Diversity Database (CNDDDB). 2001. California Department of Fish and Game, Wildlife and Habitat Data Analysis Branch. Website: <http://www.dfg.ca.gov/whdab/html/cnddb.html> [accessed November 2001].
- California State Office, Bureau of Land Management. 1998. California BLM special status plants - SSP list. Website: http://pub4.ca.blm.gov/caso/ssplist_c.html [accessed November 2001].

- Callizo, J., J. Ruygt and G. Muth. 1997. The Flora of Napa County, California. Website: http://www.puc.edu/Faculty/Gilbert_Muth/napa.htm [accessed November 2001].
- Catling, P.M. and S.M. McKay. 1980. Halophytic plants in southern Ontario, Canada. *Canadian Field Naturalist* 94(3): 248-258. (abstract only)
- Clark, D.L. and M.V. Wilson. 1998. Fire effects in wetland prairie plant species - final report. Prepared for U.S. Fish and Wildlife Service, Western Oregon Refuges, Corvallis, Oregon. Project no. 14-48-0001-96749. Available online: http://www.onid.orst.edu/~wilsomar/Persp_Fire.htm
- _____ and _____. 2000a. Controlling woody vegetation in wetland prairies (1994-1999). Report to the Coast Range Resource Area, Bureau of Land Management, Eugene, Oregon. Website: http://www.onid.orst.edu/~wilsomar/Persp_Wetland.htm
- _____ and _____. 2000b. Promoting regeneration of native species in Willamette Valley upland prairies. Report to the US Fish and Wildlife Service. Available online: http://www.onid.orst.edu/~wilsomar/Persp_Fire.htm
- _____ and _____. 2001. Increasing the abundance of rare native wetland prairie species. Report to the US Bureau of Land Management. Available online: http://www.onid.orst.edu/~wilsomar/Persp_Fire.htm
- Cronquist, A., A.H. Holmgren, N.A. Holmgren, J.K. Reveal and P.K. Hol. 1984. Intermountain Flora: Vascular Plants of the Intermountain West, U.S.A. Hafner Pub. Co., New York. Volume 4.
- Davies, A. and S. Waite. 1998. The persistence of calcareous grassland species in the soil seed bank under developing and established scrub. *Plant Ecology* 136(1): 27-39. (abstract only)
- Douglas, G.W., D. Meidinger and J. Pojar. 1999. Illustrated Flora of British Columbia, Volume 3 Dicotyledons (Diapensiaceae through Onagraceae). Province of British Columbia.
- Douglas, G.W., G.B. Straley and D. Meidinger. In press. Rare Native Vascular Plants of British Columbia. Province of British Columbia.
- Dunbar, F.F. 1929. The Gentianaceae of the Pacific Coast. M.A. thesis; Stanford University.
- Dunn, R.A. 1967. A revision of the Genus *Centaurium* of continental United States. Ph.D. dissertation; The Catholic University of America. 598 pp.
- Dutoit, T. and D. Alard. 1995. Permanent seed banks in chalk grassland under various management regimes: their role in the restoration of species-rich plant communities. *Biodiversity and Conservation* 4(9): 939-950. (abstract only)
- Formanowiczowa, H. and J. Kozłowski. 1973. Biology of germination of seeds of medicinal plants part 11 the seeds of *Centaurium umbellatum*. *Herba Polonica* 19(2): 160-166. (citation only)
- Freijssen, A.H. 1971. Growth physiology salt tolerance and mineral nutrition of *Centaurium littorale* adaptations to its oligotrophic and brackish habitat. *Acta Botanica Neerlandica* 20(6): 577-588. (citation only)
- Freijssen, A.H.J. and A. Van Dijk. 1975. Differences in growth rate and salt tolerance between varieties of the halophyte *Centaurium littorale* and their ecological significance. *Acta Botanica Neerlandica* 24(1): 7-22. (citation only)
- Fuchs, M.A. 2001. Towards a recovery strategy for Garry Oak and associated ecosystems in Canada: ecological

- assessment and literature review. Technical report GBEI/EC-00-030. Environment Canada, Canadian Wildlife Service, Pacific and Yukon Region.
- Gay, P.E., P.J. Grubb and H.J. Hudson. 1982. Seasonal changes in the concentrations of nitrogen phosphorus and potassium and in the density of mycorrhiza in biennial and matrix forming perennial species of closed chalkland turf. *Journal of Ecology* 70(2): 571-594. (abstract only)
- Gillett, J.M. 1963. The gentians of Canada, Alaska and Greenland. Research Branch, Canada Department of Agriculture, Ottawa. Publication 1180. 99 pp.
- Goert. 2001. Recovery strategy for Garry Oak and associated ecosystems and their associated species at risk in Canada: 2001-2006. Prepared by the Garry Oak Ecosystems Recovery Team. Available online: <http://www.bc.natureconservancy.ca/cgo/index.htm>
- Gonzalez-Benito, M.E. 1997. Cryopreservation of nodal explants of an endangered plant species (*Centaurium rigualii* Esteve) using the encapsulation-dehydration method. *Biodiversity and Conservation* 6(4): 583-590. (citation only)
- Grieve, M. 1992. *A Modern Herbal: The Medicinal, Culinary, Cosmetic and Economic Properties, Cultivation and Folklore of Herbs, Grasses, Fungi, Shrubs and Trees With All Their Modern Scientific Uses*. Tiger Books International, London.
- Guard, B.J. 1995. *Wetland Plants of Oregon & Washington*. Lone Pine Publishing, Vancouver, British Columbia. 239 pp.
- Haloui M., L. Louedec, M.J. Baptiste and B. Lyoussi. 2000. Experimental diuretic effects of *Rosmarinus officinalis* and *Centaurium erythraea*. *Journal of Ethnopharmacology* 71(3): 465-472. (abstract only)
- Hickman, J.C. [ed.]. 1993. *The Jepson Manual - Higher Plants of California*. University of California Press. Berkeley and Los Angeles, California.
- Hitchcock, C.L., A. Cronquist, M. Ownbey and J.W. Thompson. 1969. *Vascular Plants of the Pacific Northwest*. University of Washington Press, Seattle and London. (Volume 4).
- Holmes, W.C., D.E. Wivagg. 1996. Identification and distribution of *Centaurium muhlenbergii* (Griseb.) Piper and *C. pulchellum* (Sw.) Druce (Gentianaceae) in Louisiana, Mississippi and Texas. *Phytologia* 80(1):23-29.
- Idaho Conservation Data Center. 2001. Idaho Fish and Game. Website: <http://www2.state.id.us/fishgame/info/cdc/cdc.htm> [accessed November 2001].
- Integrated Taxonomic Information System (ITIS). Website: <http://www.ITIS.USDA.gov/index.html> [accessed November 2001].
- Iriondo, J.M. and C. Perez. 1996. Micropropagation and in vitro storage of *Centaurium rigualii* esteve (Gentianaceae). *Israel Journal of Plant Sciences* 44(2-3): 115-123. (abstract only)
- Jankovic, T., D. Krstic, F.K. Savikin, N. Menkovic and D. Grubisic. 1998. Comparative investigation of secoiridoid compounds of *Centaurium erythraea* grown in nature and cultured in vitro. *Pharmaceutical & Pharmacological Letters* 8(1): 30-32. (abstract only)
- Jankovic, T., D. Krstic, F.K. Savikin, N. Menkovic and D. Grubisic. 2000. Xanthone compounds of *Centaurium erythraea* grown in nature and cultured in vitro. *Pharmaceutical & Pharmacological Letters* 10(1): 23-25.

- Kartesz, J.T. 1994. A Synonymized Checklist of the Vascular Flora of the United States, Canada, and Greenland, Second Edition. Timber Press, Portland, Oregon. 2 volumes.
- Keeler-Wolf, T., D.R. Glam, K. Lewis and S.A. Flint. May 1998. Californai vernal pool assessment - preliminary report. State of California Department of Fish and Game. Website: http://maphost.dfg.ca.gov/wetlands/vp_asses_rept/index.htm [accessed December 2001].
- Khafagy, S.M. and H.K. Mnajed. 1970. Phytochemical investigation of *Centaurium pulchellum*. *Acta Pharmaceutica Suecica* 7(6): 667-672. (citation only)
- Kugler, H. 1977. On the pollination of Mediterranean springtime flowers. [German]. *Flora* 166(1): 43-64. (English abstract only)
- Mackova, A. 1988. Small-plot cultivation of common centaury (*Centaurium erythraea* Raf. Gentianaceae) in East Slovakia (Czechoslovakia). *Herba Hungarica* 27(2-3): 67-74. (abstract only)
- Mandal, S., P.C. Das and P.C. Joshi. 1992. Naturally occurring xanthones from terrestrial flora. *Journal of the Indian Chemical Society* 69(10): 611-636. (abstract only)
- Maret, M.P. and M.V. Wilson. 2000. Fire and seedling population dynamics in western Oregon prairies. *Journal of Vegetation Science* 11; 307-314.
- McGee, P.A. 1985. Lack of spread of endomycorrhizas of *Centaurium* (Gentianaceae). *The New Phytologist* 101: 451-458.
- Medical Plants of North America home page (MPNADP). Available through website: <http://ars-genome.cornell.edu/botany.htm> [accessed November 2001].
- Merrifield, K. 2000. Bryophytes on isolated *Quercus garryana* trunks in urban and agricultural settings in the Willamette Valley, Oregon. *The Bryologist* 103(4): 720-724.
- Missouri Botanical Garden W3TROPICOS Nomenclatural Data Base. Web site: <http://www.mobot.org> [accessed November 2001].
- Moore, M. 1995. *Medicinal Plants of the Pacific West*. Red Crane Books, Santa Fe, New Mexico.
- Munz, P.A. and D.D. Keck. 1959. *A California Flora*. University of California Press, Berkely, California. 1681 pp.
- NatureServe: An online encyclopedia of life [web application]. 2001. Version 1.5. Arlington, Virginia, USA: Association for Biodiversity Information. Website: <http://www.natureserve.org> [accessed November 2001].
- Nevada Natural Heritage Program. 2001. Department of Conservation and Natural Resources, State of Nevada. Website: <http://www.state.nv.us/nvnhp> [accessed November 2001].
- Oregon Natural Heritage Program. 2001. Website: <http://www.abi.org/nhp/us/or/index.htm> [accessed November 2001].
- Petlevski, R., M Hadzija, M. Slijepcevic and D. Juretic. 2001. Effect of 'antidiabetis' herbal preparation on serum glucose and fructosamine in NOD mice. *Journal of Ethnopharmacology* 75(2-3): 181-184. (abstract only)

- Pike, L.H. 1971. The role of epiphytic lichens and mosses in production and nutrient cycling of an oak forest. Ph.D. dissertation; University of Oregon. xiii + 72 pp.
- Rao, K.S. and C.C. Chinnappa. 1983(a). Pericolporate pollen in Gentianaceae. *Canadian Journal of Botany* 61(1): 174-178.
- Rao, K.S. and C.C. Chinnappa. 1983(b). Studies in Gentianaceae micro sporangium and pollen. *Canadian Journal of Botany* 61(1): 324-336.
- Reed, P.B.(Jr.) 1988. National list of plant species that occur in wetlands: 1988 national summary. U.S. Fish and Wildlife Service. Biological Report 88(24).
- Rittenhouse, B. _____. Botanizing the southern Oregon coast (Coos Bay to Port Orford). Website: http://www.or.blm.gov/coosbay/newriver/oregon_plants.htm [accessed November 2001].
- Ruzic, V. and A. Simonic. 1993. Identification of medical plant from glagolitic medical recipe. *Acta Facultatis Medicae Fluminensis* 18(1): 5-9. (abstract only)
- Schaeppi, H. 1969. On the formation of the shoots in some indigenous Gentianaceae. *Vierteljahresschr Naturforsch Ges Zurich* 114 (1): 1-27. (citation only)
- Schat, H. 1983. Germination ecology of some dune slack pioneers. *Acta Botanica Neerlandica* 32(3): 203-212. (abstract only)
- Schat, H. and M. Scholten. 1986. Effects of salinity on growth, survival and life history of four short-lived pioneers from brackish dune slacks. *Acta Oecologica Oecologia Plantarum* 7(3): 221-232. (abstract only)
- Schat, H., A.H. Bos, M. Scholten. 1984. The mineral nutrition of some therophytes from oligotrophic dune slack soils. *Acta Ecologica* 5(19): 119-131.
- Schat, H., J. Ouborg and R. De-Wit. 1989. Life history and plant architecture: size-dependent reproductive allocation in annual and biennial *Centaurium* species. *Acta Botanica Neerlandica* 38(2): 183-202.
- Schimmer, O. and H. Mauthener. 1996. Polymethoxylated xanthenes from the herb of *Centarium erythraea* with strong antimutagenic properties in *Salmonella typhimurium*. *Planta Medica* 62(6): 561-564. (abstract only)
- St. John, H. 1962. *Flora of Southeastern Washington and of Adjacent Idaho*. Students Book Corporation, Pullman, Washington.
- Stuart, M. 1979. *Encyclopedia of Herbs and Herbalism*. Classic Bookshops, Rexdale, Ontario.
- Turner, B.L. 1993. The Texas species of *Centaurium* (Gentianaceae). *Phytologia* 75 (3): 259-275.
- Ubsdell, R.A.E. 1979. Variation and evolution in *Centaurium erythraea* and *Centaurium littorale* in the British Isles 3. Breeding systems floral biology and general discussion. *Watsonia* 12(3): 225-232. (abstract only)
- University of Nevada, Reno, Biological Resources Research Center. Website: <http://www.brrc.unr.edu/data/plants/centnamo.html> [accessed November 2001].
- USDA, NRCS. 2001. The PLANTS database, version 3.1. National Plant Data Center, Baton Rouge, LA 70874-

4490 USA. Website: <http://plants.usda.gov> [accessed November 2001].

U.S. Fish and Wildlife Service (a), Endangered Species Recovery Plans. Website: http://www.calflora.org/calflora/reference.html#cnps_elect [accessed November 2001]

U.S. Fish and Wildlife Service (b), Species Profile. Website: http://ecos.fws.gov/species_profile.html [accessed November 2001].

Valentao, P., E. Fernandes, F. Carvalho, P.B. Andrade, R.M. Seabra and M.L. Bastos. 2001. Antioxidant activity of *Centaurium erythraea* infusion evidenced by its superoxide radical scavenging and xanthine oxidase inhibitory activity. *Journal of Agricultural & Food Chemistry* 49(7): 3476-3479. (citation only)

Van Der Sluis, W.G. 1985. Chemotaxonomical investigations of the genera *Blackstonia* and *Centaurium* Gentianaceae. *Plant Systematics & Evolution* 149(3-4): 253-286. (abstract only)

Vohra, J.N. 1970. Natural hybridization in *Centaurium erythraea* and *Centaurium littorale* at Freshfield and Ainsdale south Lancashire. *Bulletin of the Botanical Survey of India* 12(1-4): 144-150. (citation only)

Ward, D.E. 1984. Chromosome counts from New Mexico and Mexico. *Phytologia* 56(1): 55-59.

Ward, P., G. Radcliffe, J. Kirby, J. Illingworth and C. Cadrin. 1998. Sensitive ecosystem inventory. east Vancouver Island and Gulf Islands, 1993-1997. Vol. 1 Methodology, ecological descriptions and results. Technical Reports Series No. 320, CWS, Pacific and Yukon Regions, B.C.

Washington Department of Natural Resources. 2001. State of Washington Natural Heritage Plan: 192 pp. Olympia. Website: <http://www.wa.gov/dnr/htdocs/fr/nhp/refdesk/plan/index.htm>

Washington Natural Heritage Program. 2001. Washington State Department of Natural Resources, Asset Management & Protection Division. Reference desk on website: <http://www.wa.gov/dnr/htdocs/fr/nhp/wanhp.html> [accessed November 2001].

Wilson, M.V. 1998a. Wetland Prairie - contributed chapter: part 1 the U.S. Fish and Wildlife Service Willamette basin recovery plan. U.S. Fish and Wildlife Service, Oregon State Office. Order no. 13420-6-0287 (2). Available online: <http://search.orst.edu>

_____. 1998b. Fire effects on wetland prairie plant species. U.S. Fish and Wildlife Service, Western Oregon Refuges, Corvallis, Oregon. Project no. 14-48-0001-96749. Available online: http://www.onid.orst.edu/~wilsomar/Persp_Fire.htm

_____. 1999. Evaluating prescribed burning to improve prairie quality in the Willamette floodplain research natural area, W.L. Finly National Wildlife Refuge, Oregon. Submitted to U.S. Fish and Wildlife Service, Western Oregon Refuge Complex. Agreement 14-48-0001-96749. Available online: <http://search.orst.edu>

_____. 2001. Willamette Valley Prairies - research from Oregon State University. Website: <http://www.onid.orst.edu/~wilsomar/WetNatForbs.htm> [accessed November 2001].

Wilson, M.V. and D.L. Clark. 1997. Final report 1994-1997. Effects of fire, mowing, and mowing with herbicide on native prairie of Baskett Butte, Baskett Slough NWR. U.S. Fish and Wildlife Services, Western Oregon Refuges. http://www.onid.orst.edu/~wilsomar/Persp_Fire.htm

Wilson, M.V. and C.A. Ingersoll. 1993. Management guidelines and recommendations for Fern Ridge reservoir.

A component of the project to develop management guidelines for native wetland communities. Oregon State University, Department of Botany and Plant Pathology. http://www.onid.orst.edu/~wilsomar/Persp_Fire.htm

Wilson, M.V., E.R. Alverson, D.L. Clark, R.H. Hayes, C.A. Ingersoll and M.B. Naughton. 1995. The Willamette valley natural areas network: a partnership for the Oregon prairie. *Pacific Northwest Reports - Restoration & Management Notes* 13:1 Summer: 26-28. Available online: http://www.onid.orst.edu/~wilsomar/Persp_Fire.htm

Yuan, Y.M. and P. Kupfer. Molecular phylogenetics of the subtribe *Gentianinae* (*Gentianaceae*) inferred from the sequences of internal transcribed spacers (its) of nuclear ribosomal DNA. *Plant Systematics and Evolution* 196(3-4): 207-226. (abstract only)

Zeltner, L. 1978. Cytotaxonomic notes on the genera *Blackstonia* and *Centaurium* in Crete Greece. [French]. *Bulletin de la Societe Neuchateloise des Sciences Naturelles* 101: 107-118. (English abstract only)

_____. 1985. Cytotaxonomical and cyto geographic study of *Centaurium pulchellum* sensu lato. [French]. *Botanica Helvetica* 95(1): 47-58. (English abstract only)

_____. 1990. On some *Centaurium* Hill species (*Gentianaceae*) from Egypt, the Arabian peninsula, and India. *Bulletin de la Societe Neuchateloise des Sciences Naturelles* 113(0): 255-270. (abstract only)

_____. 1991. Contribution of the cyto geographical study of the genera *Blackstonia* Huds. and *Centaurium* Hill (*Gentianaceae*) in Turkey, Rhodes, and Cyprus. *Bulletin de la Societe Neuchateloise des Sciences Naturelles* 114(0): 77-103. (abstract only)

Zwaenepoel, A. and M. Hermy. 1987. *Cicendia filiformis* and other *Nanocyperion* species in Vloethemveld (Belgium): A plea for habitat conservation and management. *Bulletin de la Societe Royale de Botanique de Belgique* 120(2): 153-161. (abstract only)

9. Authorities Consulted

Broome, C.R. December 2001. E-mail: rbroome@starband.net

Camp, P. December 2001. Spokane, Washington District Office, Bureau of Land Management, U.S. Department of the Interior, E-mail: spokane_mail@or.blm.gov

Caplow, F. November 2001. Rare Plant Botanist, Washington Natural Heritage Program, Department of Natural Resources, P.O. Box 47014, Olympia, Washington 98504-7014, Tel: (360) 902-1793, E-mail: florence.caplow@wadnr.gov

Donovan, M. November 2001. Biological Information Coordinator, BC Conservation Data Centre, Ministry of Sustainable Resources Management, Tel: (250) 356-0928, Fax: (250) 387-2733, E-mail: cdcdata@victoria1.gov.bc.ca

Kinter, C.L. December 2001. Curatorial Assistant, Marion Ownbey Herbarium [WS], School of Biological Sciences, Washington State University, Pullman, WA, 99164-4236, Tel: (509) 335-3250, Fax: (509) 335-3184, E-mail: wsherb@mail.wsu.edu

Lorentzen, E. November 2001. California State Office, Bureau of Land Management, 2800 Cottage Way, Room W-1834, Sacramento, California, 95825-1886, Tel: (916) 978-4646, Fax: (916) 978-4657, E-mail:

Edward_Lorentzen@ca.blm.gov

Mansion, G. December 2001. Laboratoire de Botanique Evolutive, Institut de Botanique, Emile Argand 11, 2007 Neuchatel, Switzerland, E-mail: guilhem.mansion@unine.ch

Pringle, Dr. J.S. November 2001. Botanist, Royal Botanical Gardens, P.O. Box 399, Hamilton, Ontario, L8N 3H8, Tel: (905) 527-1158, extension 236, E-mail: jpringle@rbg.ca.

Roy, A.P. November 201. U.S. Fish and Wildlife Service, National Conservation Training Center, Conservation Library, Rt. 1, Box 166, Shepherdstown, WV, 25443, Tel: (304) 876-7399, Fax: (304) 876-7213, E-mail: Anne_Roy@fws.gov