Cypripedium montanum (mountain lady's slipper): Species Assessment for the Tongass National Forest, Alaska Region

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Cover Photo: Etolin Island population of *Cypripedium montanum.* Photo by Shauna Hee.

EXECUTIVE SUMMARY

Cypripedium montanum Douglas ex Lindley (mountain lady's slipper) is widely distributed in seven western states and provinces. In the Alaska Region of the USDA Forest Service, it is known from a single population on the Tongass National Forest. There are 13 occurrences of the orchid in Alaska and are concentrated in southeast Alaska. The closest population to the Tongass population is located over 200 km away. The NatureServe Global rank for *Cypripedium montanum* is G4 (apparently secure). The Alaska Natural Heritage Program State rank for this species is S2 (Imperiled). It has been designated as a Sensitive Species in Forest Service Regions 2 (Rocky Mountain), 5 (Pacific Southwest) and 10 (Alaska Region). It is not listed as Threatened or Endangered by the U.S. Fish and Wildlife Service.

The primary potential threats to *Cypripedium montanum* are large disturbances that can destroy all or a portion of breeding populations. These may be natural or human-related disturbances such as vegetation succession, logging, minerals activities, road construction, road maintenance or recreational activities. Human collection may be a threat to *Cypripedium montanum* when flowering, due to its beauty and its proximity to roads. Grazing by wildlife may also be a threat. In the Alaska Region its distribution is limited to a single known population near the edge of its range, which increases its vulnerability to threats.

The degree to which *Cypripedium montanum*, a long-lived perennial orchid, may be adversely affected depends largely on the nature of the disturbance and how it affects elements of the species' life cycle. Evidence indicates that *C. montanum* is particularly vulnerable to the consequences of environmental or human-related habitat alterations when populations are small and have low reproductive success. Lack of a standard monitoring program hampers managing the population in the Alaska Region. Documenting population changes through inventorying and monitoring the population and habitat is an essential first step in evaluating whether current populations are stable, increasing, or decreasing.

There is no documentation of how the abundance of *Cypripedium montanum* and its range have changed over the last century. Stabilizing populations on the periphery of the species' range has implications for the conservation of the genetic diversity not only of the species, but also the genus *Cypripedium*, which is among the most threatened of all orchid genera.

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INTRODUCTION

This assessment of *Cypripedium montanum* (Orchidaceae) is one of several being produced to support current and future forest planning efforts on the Tongass National Forest. *Cypripedium montanum* is considered both a rare species in Alaska and is designated as a Sensitive Species in The Alaska Region. Sensitive Species are plants and animals whose population viability is identified as a concern by a Regional Forester because of significant current or predicted downward trends in abundance or significant current or predicted downward trends in habitat capability that would reduce a species distribution (Forest Service Manual 2670.5(19)). Sensitive Species require a detailed effects analysis be conducted during project planning which identifies any special management that may be needed for a particular population. Knowledge of their biology and ecology is critical for a science-based, informed analysis that is consistent amongst resource managers. Rare Species serve as a barometer for species viability at the State level.

Goal

Species assessments are designed to provide forest managers, research biologists, and the public a thorough discussion of the biology, ecology, and conservation status of certain species based on the most current body of scientific knowledge for the species. The assessment goals limit the scope of the work to critical summaries of scientific knowledge, discussion of broad implications of that knowledge, and outlines of information needs. The assessment does not develop specific management recommendations but provides the ecological background upon which effective management should be based. It focuses on the consequences of changes in the environment that result from management (i.e., management implications). Furthermore, it cites management recommendations proposed elsewhere and, when management recommendations have been implemented, the assessment examines the success of the implementation.

Scope of the Assessment

The *Cypripedium montanum* assessment examines the biology, ecology, and management of this species with specific reference to the geographic and ecological characteristics of the Tongass National Forest and the Alaska Region. Although some (or a majority) of the literature on the species may originate from investigations outside the region, this document places that literature in the ecological and social context of southeastern and to a lesser extent, south-central Alaska. Similarly, this assessment is concerned with reproductive behavior, population dynamics, and other characteristics of *Cypripedium montanum* in the context of the current environment rather than under historical conditions.

In producing the assessment, we reviewed refereed literature, non-refereed publications, research reports, and data accumulated by resource management agencies. Not all publications on *Cypripedium montanum* are referenced in the assessment, nor was all published material considered equally reliable. The assessment emphasizes refereed literature because this is the accepted standard in science. Non-refereed publications or reports were regarded with less certainty. We chose to use some non-refereed literature in the assessments, however, when information was unavailable elsewhere. Unpublished data (e.g., Natural Heritage Program and USFS records) were important in estimating the geographic distribution. These data required special attention because of the diversity of persons and methods used to collect the data.

The motivation to produce species assessments rapidly in order to make information available for Forest Plan amendment leads to tight timelines. The goal to produce assessments rapidly limited the analysis of existing, unpublished data, or attempts to conduct meta-analysis to synthesize information from published literature. Occurrence data were compiled from the Alaska Natural Heritage Program (2014), University of Alaska, Fairbanks Herbarium, and the Glacier Bay Herbarium.

Treatment of Uncertainty

Science represents a rigorous and systematic approach to obtaining knowledge, in which ideas regarding how the world works are measured against observations. Because our descriptions of the world are incomplete and our observations limited, some level of uncertainty is implicit in the scientific approach. Science includes approaches for dealing with this uncertainty. A commonly accepted approach in science resulting in reductions of uncertainty and development of stronger inference is based on a progression of critical experiments (Platt 1964). However, conducting meaningful and critical experiments in the ecological sciences is often difficult, time consuming, and expensive. Often, a systems approach is applied to an ecological question, in which existing data and observations from multiple sources (including those derived from inventories, categories, and counting [Allen and Hoekstra 1992]) are used to construct a predictive framework in which ideas can be tested. Reduced uncertainty follows when there is high consistency among the diverse sources of information in support of the inference.

Publication of the Assessment on the World Wide Web

To facilitate use of species assessments in this Project, this document is published in PDF format on the Tongass N.F., the Alaska Region, and the Alaska Natural Heritage Program web site. This makes them available to agency biologists and the public and facilitates revision, which will be done based on guidelines established by the Alaska Region.

Peer Review of the Assessment

Assessments developed for the Species Assessment Project have been peer reviewed prior to release on the Web. This assessment was reviewed by biologists of the Alaska Region.

MANAGEMENT STATUS AND NATURAL HISTORY

Management Status

Within the Alaska Region, *Cypripedium montanum* occurs only on the Tongass National Forest as a single population. Nine additional populations have been recorded outside of Tongass National Forest lands in southeastern Alaska. The species is not listed as threatened or endangered under the federal Endangered Species Act, nor is it on the National Park Service or Alaska BLM Sensitive Species list. It is listed as Vulnerable by the IUCN (Rankou 2014). The NatureServe global rank for *C. montanum* is apparently secure (G4) (NatureServe 2015). The Alaska Natural Heritage Program state rank for *C. montanum* is Imperiled in Alaska (S2).

Cypripedium montanum occurs on non-National Forest Lands and National Forest System lands in other USFS regions, and is designated as a Sensitive Species in the Rocky Mountain and the Pacific Southwest Regions. State conservation ranks in states outside of Alaska include apparently secure (S4) in California, Vulnerable to Apparently Secure (S3S4) in Montana and Oregon, Critically Imperiled (S1) in Wyoming, and Not Ranked (SNR) in Idaho, Montana, and

Washington. It is Critically Imperiled (S1) in Saskatchewan, Vulnerable to Extirpation (S2) in Alberta, and Vulnerable to Apparently Secure (S3S4) in British Columbia. See the Alaska Natural Heritage Program website (http://aknhp.uaa.alaska.edu/botany/rare-plant-species-information/) for more information on the Natural Heritage Program Network and their conservation ranking system.

Existing Regulatory Mechanisms, Management Plans, and Conservation Strategies

Sensitive Species management follows Forest Service Manual direction (FSM 2670) as well as standards and guidelines outlined in the Tongass National Forest Plan Revision for Plants, which recommends providing protection around plant populations that meet the habitat needs of the species. Forest Service Manual direction requires the agency to "maintain viable populations of all native and desired nonnative wildlife, fish, and plant species in habitats distributed throughout their geographic range on National Forest System lands" (FSM 2670.22). No other laws or regulations confer protection to this species on private, state, or other federal lands.

USFS management objectives for sensitive species are designed to ensure continued viability throughout their range on National Forest System lands and to ensure that they do not become threatened or endangered as a result of USFS actions (FSM 2670.22). Existing Forest Service policy calls for avoiding or minimizing impacts to species whose viability has been identified as a concern, or if impacts cannot be avoided, analyzing the significance of potentially adverse effects on populations or habitat within the area of concern and on the species as a whole (FSM 2670.32).

The National Forest System Land Management Planning Rule was revised in 2012 and under the new regulations discontinues the concept of "sensitive species" and adopts a revised approach to "At risk species" by evaluating potential "Species of Conservation Concern (SCC)". Similar to the sensitive species process of listing, formal SCC lists are designated by the Regional Forester in consultation with Forest managers who prepare recommendations based on a species ability to persist over the long term in the plan area (36 CFR 219.9). The Forest Service through direction from the National Forest Management Act requires that plans provide for diversity of plant and animal communities (16 USC 1604 (g)(3)(B)). The new planning rule requires that all plans identify and assess At -risk Species (36 CFR 219.6(b)). In addition, new direction requires plans to assess the status of the ecosystems for ecosystem integrity for the purpose of determining whether ecosystems are functioning normally and are uncompromised. The plan shall identify and assess available information relevant to the plan area for threatened, endangered, proposed and candidate species and potential species of conservation concern present in the plan area by assessing the ecological conditions for these species in the assessment.

Adopting the revised National Forest System regulations provided in the 2012 Planning Rule and new directive system (FSM 1909.12.52) which defines "At risk species" is currently in transition. The departure of the "Sensitive Species" designation and subsequent adoption of "Species of Conservation Concern" will likely take the Tongass N.F. several years. In the meanwhile, it is important to note that to date, this species (and others on the Tongass) remain under the "Sensitive Species" policy (FSM 2670.22 and 2670.32). Whether designated as "Sensitive" or as "SCC", the core concept of "At risk species" remains consistent in both definitions.

Cypripedium montanum was recently under review to be designated as a species of conservation concern (SCC) by the Alaska Region and was recommended as such due to the limited number of populations on the Tongass plan area, the past impacts to habitat at the only known site on NFS lands, the ongoing vulnerability of that site, and the limitations of the species success with the required mycorrhizal interaction. However, it currently remains on the Regional Forester's Sensitive Species List.

Biology and Ecology

Classification and Description

Systematics, Synonymy, and History

Cypripedium montanum Douglas ex Lindley is a member of the subfamily Cypripedioideae in the Orchidaceae. The Orchidaceae is in the class Liliopsida (monocot), subclass Liliidae, and order Orchidales (Cribb 1997, Sheviak 2002). The slipper orchids are composed of five genera and share the characteristics of having two fertile anthers, a shield shaped sterile anther or staminode, a deeply sacchate labellum or lip (Argue 2012). All slipper orchids were once included in the genus *Cypripedium*, originally named by Linnaeus, but the diversity of species was gradually recognized. Rolfe (1896) listed 28 *Cypripedium* species, of which 11 were restricted to the western hemisphere, 14 to eastern Asia, while three were widespread (Cribb 1997). The genus now is thought to contain about 45 species mostly occurring in temperate and tropical regions Eurasia and North America (Sheviak 2002). There are more than 30 species distributed in the northern hemisphere and 12 species in the United States (Sheviak 2002). The Flora of North America Editorial Committee lists *Cypripedium montanum* as the accepted binomial for this taxon (Sheviak 2002).

The early nineteenth century explorers Lewis and Clark observed an orchid where Clark described as a "lady's slipper or moccasin flower" near Traveler's Rest in Montana. Clark collected a specimen on the Weippe Prairie in Clearwater County, Idaho on June 14, 1806. In 1828, David Douglas collected an orchid specimen in the Blue Mountains of Washington and named it *Cypripedium montanum* (Douglas 1914). John Lindley (1840) published a description of this specimen. Watson published the name *C. occidentale* in 1876 based on several collections from western North America. Subsequent examination of the material confirmed that *C. occidentale* was conspecific with *C. montanum* (Cribb 1997).

Figure 1. Herbarium specimen of *Cypripedium montanum* from EO2 Haines, ALA specimen: #85578.

Species description

Cypripedium montanum stems are between 2 and 7 dm (8 and 28 inches) tall, glandular-pubescent, and leafy throughout, with one or more stems growing from a short, stout rhizome. The mature plants have five to seven leaves that are broadly elliptic to ovate-elliptic, alternating up the erect stem (Figure 1). The glandular pubescent stem is covered at the base with sheaths. The leaves are 5 to 15 cm (2 to 6 inches) long, up to 7 cm (2.3 inches) broad, somewhat glandular-pubescent, sessile and usually sheathing. The inflorescence may have one to three flowers that are each subtended and usually exceeded by an erect leaf-like bract. Sepals and petals range from a light to rather deep brownish-purple. The dorsal sepal is 3 to 6 cm (1 to 2.4 inches) long and ovate-lanceolate (Coleman 1995, Cribb 1997); the synsepal is elliptic, lanceolate and bidentate, and fused except for the slender terminal tooth-like lobes. The petals are 4.5 to 7 cm (1.8 to 2.4 inches) long, slightly longer than the sepals, narrowly to broadly lanceolate, and usually more or less twisted and wavy. The labellum is obovoid and strongly pouched, 2 to 3 cm (0.8 to 1 inch) long, dull white to purplish-tinged, usually purplish-veined and inrolled around the orifice. The column is about 1 cm (0.4 inch) long. The staminode is up to 12 mm (0.5 inch) long, glabrous and yellow with red spotting, and only rarely auriculately lobed at the base (Hitchcock et al. 1969). The orchid is diandrous with each of the two fertile stamens on either side of the column. The pedicel and ovary are 2 to 3.6 cm (0.8 to 1.4 inches) long, densely glandular, and pubescent (Cribb 1997).

A rare color form *Cypripedium montanum* was described by Sheviak and named *Cypripedium montanum* Dougl. Ex Lindl. forma *praetertinctum* Sheviak (Sheviak 1990). The form is not distinct to warrant a subspecies or variety level of classification. This rare color form distinctly looks like a typical *C. montanum*, except it lacks the red coloration and is a bright green color of the sepals, petals, yellow staminode without spots, and a pure white lip. This form was found in Alberta and British Columbia. This color form has been observed in one population in Alaska, EO 14 Donoho Basin (Figure 2).

Detailed technical descriptions with line drawings appear in Abrams (1940), Correll (1950), Munz (1959), Peck (1961), Hitchcock et al. (1969), Hultén (1968), Luer (1969), Hickman (1993), and Douglas et al. (2001). Descriptions and photographs are found in Coleman (1995), and a description with color photographs and line drawings is located in Cribb (1997). Cribb (1997), Doherty (1997) and Sheviak (2002, 2010) present summaries of the genus *Cypripedium*. Their reviews cover morphology, life history, cytology, phylogenetic relationships, biogeography, ecology including mycorrhizal associations, uses, culture and propagation, artificial hybridization, and taxonomy.

Cypripedium montanum and *C. parviflorum* can hybridize to form *C.* × *columbianum* Sheviak when the two species grow in mixed or adjacent populations (Sheviak 2002). Other *Cypripedium* that occur in southeastern Alaska are *Cypripedium parviflorum* var. *pubescens* and *Cypripedium passerinum* Rich. These three *Cypripedium* known from southeastern Alaska are compared in the table below (Table 1).

Figure 2. *Cypripedium montanum* population at Donoho Basin (EO14), the most northern population in Alaska. The rare color form of *C. montanum* occurs in this population but not pictured. Photo by Peter Frank.

Table 1. Morphological differences between Cypripedium species in southeastern Alaska.

Species	Lip	Petals
Cypripedium montanum	White; 19–33 mm long	Spiral or twisted; intense red-brown, usually not spotted. 33–60 mm long
Cypripedium parviflorum* var. *pubescens	Yellow; up to 54 mm long	Spiral or twisted; Generally larger, green-tan with red-brown spots; 24–97 mm long.
Cypripedium passerinum	Yellow to white; 11–20 mm long	Flat, not twisted; White or green

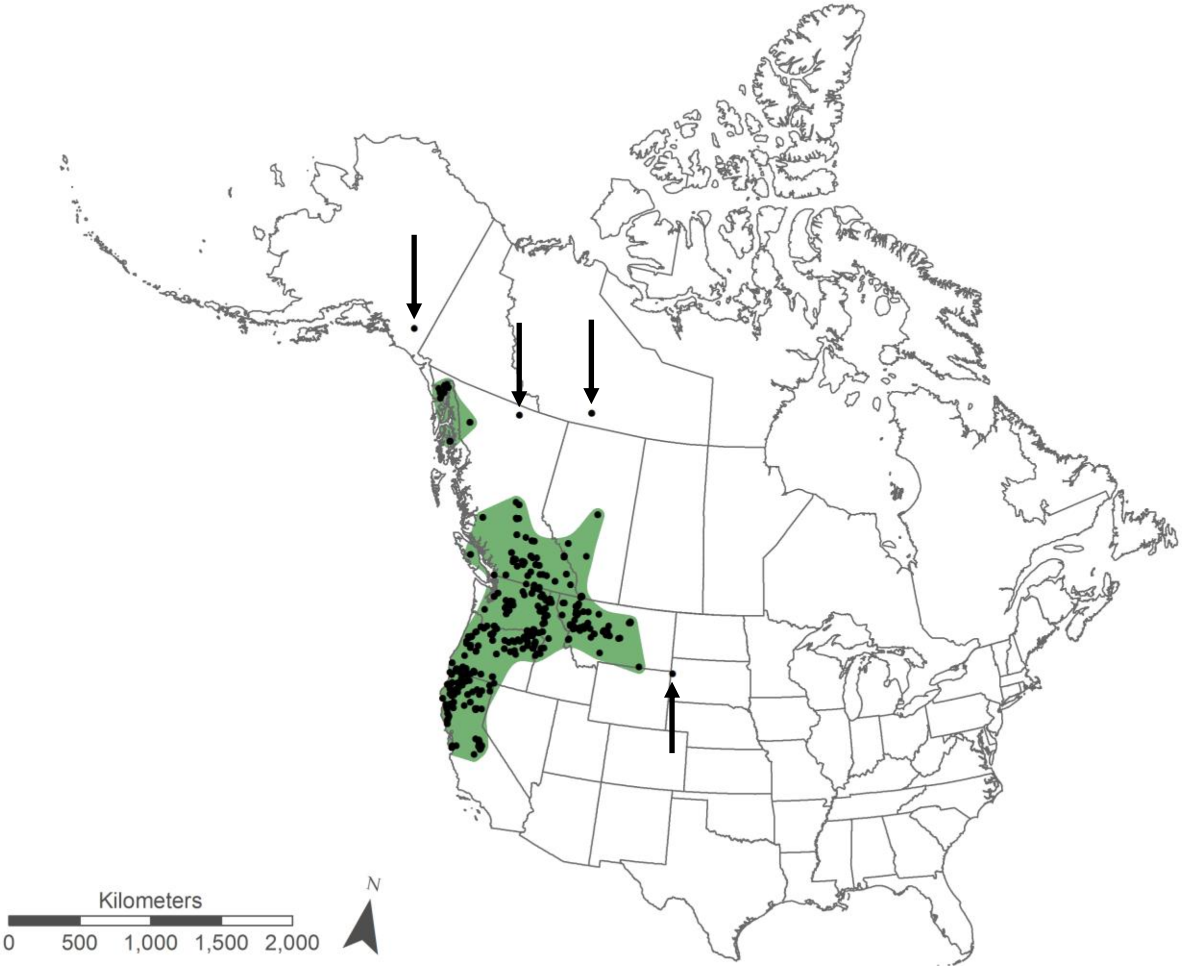

Figure 3. Range distribution of *Cypripedium montanum* based on herbarium records. Arrows indicate disjunct populations.

Distribution

The global range of *Cypripedium montanum* spans seven western states and three Canadian provinces (Figure 3). The species is known in California, Oregon, Washington, Idaho, Montana, Wyoming, South Dakota, Alaska, British Columbia, Alberta and Saskatchewan. Occurrences in Alaska represent the northwestern edge of the species' range. The Wyoming and South Dakota populations are at the easternmost edge of the species range and are considered disjunct (Keinath et al. 2003, Gabel and Tackett 2008). In British Columbia, occurrences are more frequent south of Point George and concentrated inland).

In Alaska, *C. montanum* is documented from thirteen populations (Figure 4; Figure 5; Table 2). The Alaska populations represent the northwestern edge of the species range and are considered disjunct from the primary range of the taxon. *Cypripedium montanum* was included in Hultén's (1941) treatment of the Alaskan flora based on observations by W. S. Cooper in 1929 (Cooper 1930). Cooper documented *C. montanum* on the Stikine River just east of the Alaska-Yukon Border (near Stikine Glacier, this may be the same as Great Glacier). Cooper also observed it at Tlingit Point in Glacier Bay, where it was observed again in 1990 (Figure 5). The Stikine River population was mistakenly thought to be in the Tongass National Forest; a search was conducted in 2014 near the Alaska/Canada border but the population was not located.

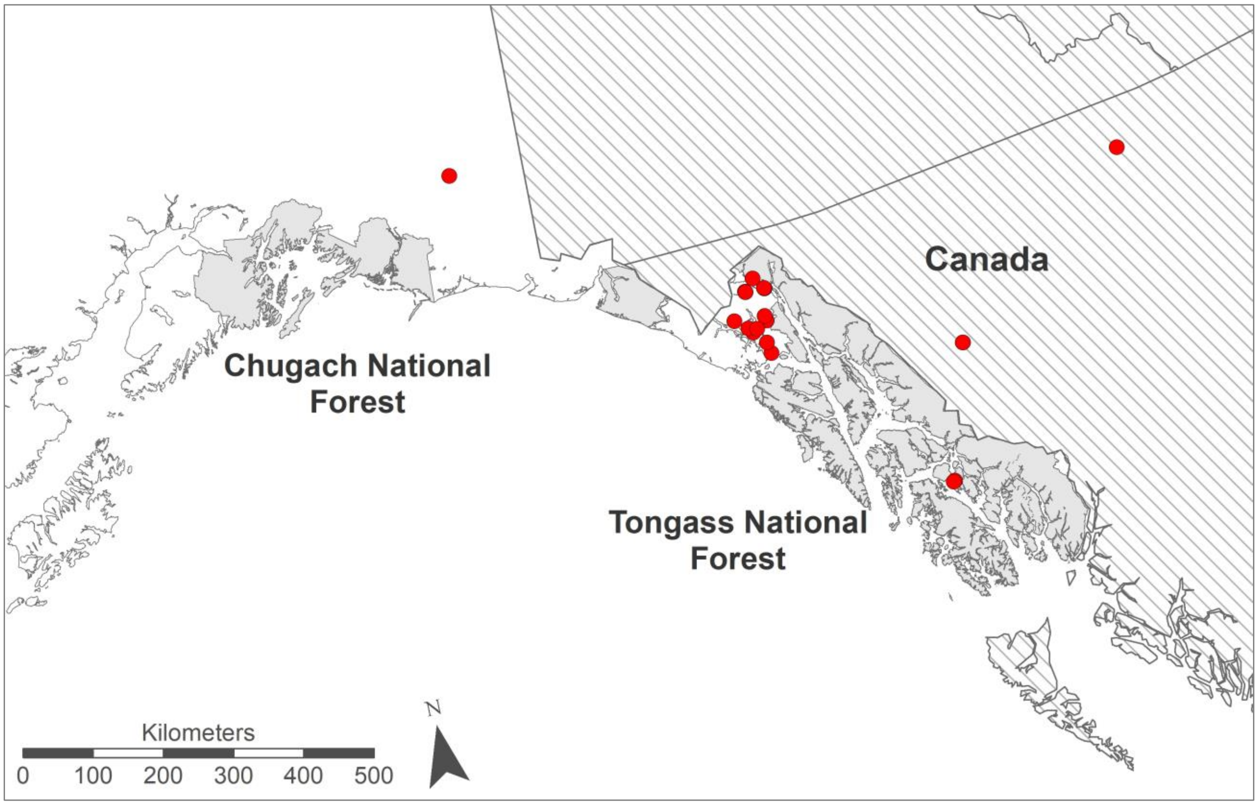

Figure 4. Known occurrences of *Cypripedium montanum* in Alaska and adjacent Canada.

Three populations have been revisited since their first discovery, EO 1 Tlingit Point, EO 7 Etolin Island, and EO 14 Donoho Basin. The Etolin Island Population (EO 7) occurs on the Tongass National Forest on near Kindergarten Bay and has been revisited three times and therefore has the most population and habitat data for any of the populations in Alaska (Table 2). A complete summary of population occurrences with dates and habitat data are summarized in Table 2.

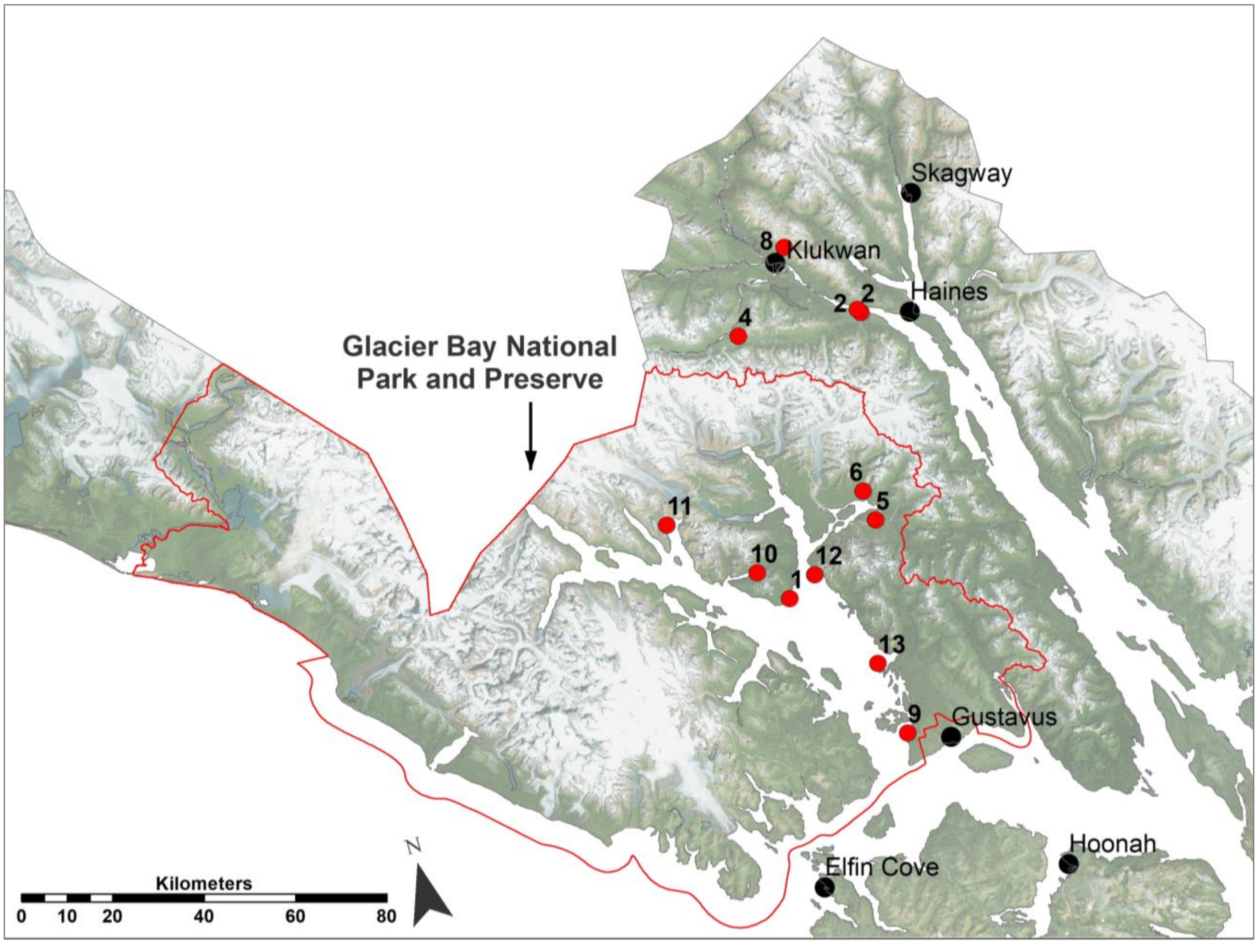

Figure 5. Occurrences of *Cypripedium montanum* in Glacier Bay NP region.

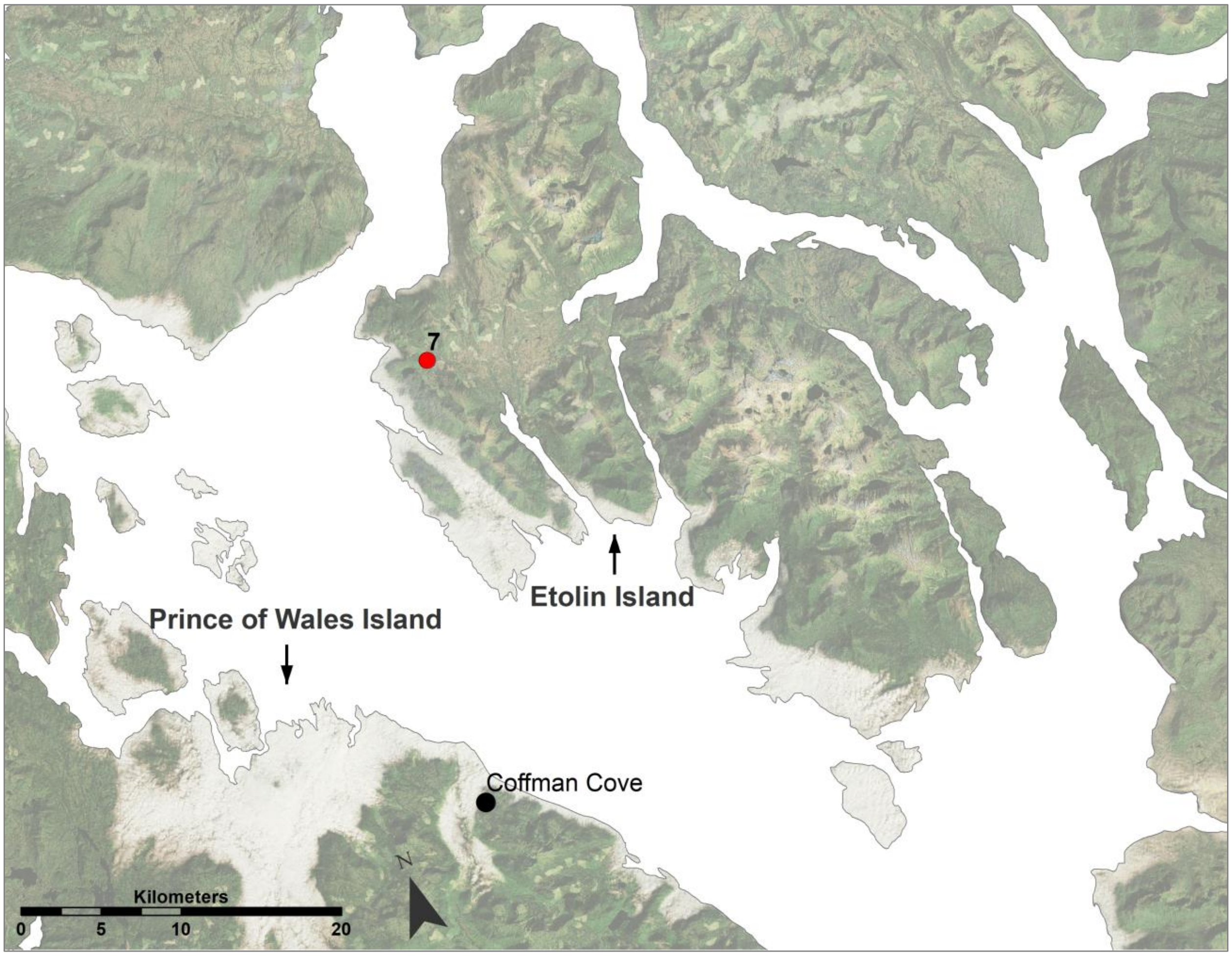

Figure 6. Occurrence of *Cypripedium montanum* on the Tongass National Forest.

Vrilakas (2002a) reported approximately 200 *Cypripedium montanum* occurrences in eastern Oregon. Based on the Interagency Species Management System (ISMS) electronic database (USDA Forest Service 2003b), Vance et al. (2004) reported 132 documented occurrences in California and 311 in western Oregon. Sixty percent of documented occurrences that contained abundance estimates reported fewer than 11 individuals. Ten percent of the occurrences reported more than 50 individuals (USDA Forest Service 2003b). The occurrences in western Oregon were reported as small and scattered (Seevers and Lang 1998, Vance et al. 2004). The species' extremely slow growth rate, complex symbiotic relationships with other organisms, and exposure to possibly frequent wildfires, suggest that recolonization of *C. montanum* throughout its range is unlikely (USDA Forest Service and USDI Bureau of Land Management 1994a). The current distribution pattern of scattered small populations may be the natural product of successional processes, reproductive traits, and environmental disturbances over geologic time. However, recent (last 100 years) anthropogenic influenced the distribution pattern directly or indirectly.

Table 2. Occurrences of *Cypripedium montanum* in Alaska.

Occurrence	Observers	First Observed	Revisited	Data Source	Land Status	Habitat	Elev. (m)
EO1 Tlingit Point	W.S. Cooper	1 Jul 1929	7 Jul 1990 (K. Bosworth)	Cooper 1930. GLBA Herbarium		Closed thicket, glacial succession (Cooper). wet spotted cottenwood (sic) meadow under *Salix barclayi*	30
EO 2 Haines MP 8	M. Williams, G. Smith	11 Jun 1979	N/A	ALA Herbarium	Private & State	Woods	n/a
EO4 Takhin Ridge	C. Parker, A. Batten, B. Bennett	18 Jul 2000	N/A	ALA Herbarium	State	Limestone outcrops and subalpine mesic meadow	~1200
EO5 Adams Inlet	K. Bosworth, J. Grunblatt	19 Jul 2001	N/A	Carlson et al. 2004	Glacier Bay N.P.	Alpine, east aspect, slope 30°.	~900
EO6 Adams Inlet	K. Boggs, L. Stratford	19 Jul 2001	N/A	Carlson et al. 2004	Glacier Bay N.P.	45° sideslope, in organics over sand, silt and rock	636
EO7 Etolin Island	J. Johnson	24 Aug 2006	1 Jun 2011, 30 Aug 2011, 24 Jul 2012	NRIS database	Tongass N.F.	Sphagnum wetland with limestone-influenced water	60
EO 8 Iron Mountain-Haines	M. Williams	11 Jun 1979	Aug 2017 (M. Saupe-confirmed)	ALA Herbarium & Observation		Above ridgeline	n/a
EO 9 Cooper's Notch	S. Studabaker	21 Jun 2014	N/A	GLBA Herbarium	Glacier Bay N.P	bog edge. Found next to *C. passerinum*	n/a
EO 10 Tidal Inlet	Bruce B. Paige	9 Jun 1971	N/A	GLBA Herbarium	Glacier Bay N.P	Alder slope	n/a
EO 11 Queen Inlet	M. Stensvold	27 Jun 1999	N/A	Observation	Glacier Bay N.P	Sphagnum peatland	n/a
EO 12 Garforth Island	M. Stensvold	27 Jun 1999	N/A	Observation	Glacier Bay N.P	Beach meadow	n/a
EO 13 Northern Beardslee Islands	T. Lewis, N. Drumheller	2004	N/A	Lewis and Drumheller 2004	Glacier Bay N.P	Presumably a beach meadow based on photograph	n/a
EO 14 Donoho Basin	Peter Frank	13 Jun 2014	Jun 2016	Observation	Wrangell St. Elias N.P.	Scree slope, rocky with a sandy gravel substrate.	975

Population Trend

The main evaluation of population trend for *C. montanum* in Alaska is from the Etolin Island population (EO 7); it has been revisited three times since it was first found in 2006. The initial population size on Etolin Island had between 75–100 individuals (NRIS database). Subsequent visits estimate the population from 188 to 412 individuals (Table 3, NRIS database; Turner 2012). Although the population has appeared to increase over time, no trend can be determined from the limited data. The fluctuations can be due to several factors: the lack of a standard monitoring protocol, the timing of the site visits because flowering individuals are more easily seen than vegetative individuals, late seasonal visits that may miss individuals because they have senesced, or plants that did not emerge but were dormant due to climatic and natural history factors. A full census and delineation of the population has not been done, only estimates. Establishment of a long-term demographic monitoring program (e.g., Gray et al. 2012) would be effective in determining population size and trend. A population in Haines has been revisited yearly by a local Alaska Native Plant Society Member, M. Saupe. The population trend has remained steady at about 12 plants for the past decade except for in 2017 when the population was accidentally destroyed (M. Saupe *pers. comm.*).

Table 3. Population size estimates of *Cypripedium montanum* on Etolin Island (EO7) based on NRIS database.

Date of Visit	Population Size Estimate
8/24/2006	75 to 100
6/1/2011	188
8/30/2011	300
7/24/2012	412

While there appears to be a downward trend in overall occurrences across the species' range, the trend in individual numbers within occurrences is variable. *Cypripedium montanum* populations change spatially in density and pattern and temporally in number or size and are quite dynamic (Vance personal observation). Distribution within a population, based on stem counts, may change from year to year, presumably because of new seedlings and/or new emergence or re-emergence of stems of an existing clone (Tamm 1991). Because different stems of older plants may re-emerge in subsequent years, it is difficult to ascribe mortality to those stems that do not re-emerge in any one year. The root crown of the rhizome below ground may develop a new shoot at one location on the rhizome, and in the following year, a different shoot. With only aerial stem counts as a demographic tool, it is difficult to ascertain a real trend in population change unless censuses are taken over multiple years.

Outside of Alaska, the number the number of tracked *Cypripedium montanum* occurrences has declined substantially over its entire range (50% to 75% decrease; Vrilakas 2002b). Because *C. montanum* is not tracked as rare in Montana, Washington, or Oregon by their respective state Natural Heritage Programs, population trends are largely unknown in those states. Unspecified anecdotal reports and herbarium records indicate that there were more *Cypripedium montanum* occurrences in western Oregon than there are today (Siddall et al. 1979, Meinke 1982). Members of the Oregon Native Plant Society have knowledge of *C. montanum* growing in the Willamette

Valley in the early nineteenth century, but efforts to relocate them have been unsuccessful (Stillwell 2000). Some populations in California cannot be relocated and is attributed to habitat loss (Coleman 1995). In long term visits (1-23 years) to northern California populations, 66% of the populations declined and 30–45% of populations became extirpated (Kaye and Cramer 2005).

The area managed under the Northwest Forest Plan (land managed USDA Forest Service and the USDI Bureau of Land Management) had 253 known occurrences before 1993 and an additional 127 were found by 2000 (USDA Forest Service and USDI Bureau of Land Management 2000). This increase was primarily due to an increase in the number and scope of surveys as required by Survey and Manage under the Northwest Forest Plan (USDA Forest Service and USDI Bureau of Land Management 1994a).

The decline outside of Alaska is thought to be gradual over the last century due to factors that include fire suppression, grazing and trampling by livestock, land use practices (e.g., logging, agriculture, urbanization), and collecting.

Habitat

Figure 7. Site location of Etolin Island (EO7) *Cypripedium montanum* population.

Cypripedium montanum occurs in a variety of montane forest and transitional habitats across the species' range. Generally, it is found in dry to moist open coniferous forest, but sometimes in deciduous forests (Luer 1975, Cribb 1977, Sheviak 2002). In Alaska, *C. montanum* is most commonly found in subalpine habitats, mesic and upper beach meadows, forest edges, and closed canopy deciduous forests. Slope can be variable as the Alaska subalpine and alpine populations occur on 30–45 degree slopes. Aspect is variable and recorded on all aspects except north. In the Alaska Region the soil in which *Cypripedium montanum* grows is typically associated with mesic calcareous-derived substrates, typically well-drained gravel limestone.

Nearly all of the Glacier Bay collections are from areas influenced by limestone. A subalpine population in Glacier Bay grows on a substrate of organics over sand, silt and rock; other subalpine populations are on limestone outcrops and in mesic meadows. Other Glacier Bay populations are found on bog edges, or in the understory of Black Cottonwood (*Populus trichocarpa*). In the valley west of Haines the orchid also grows in mesic to wet forested edges and understories of *P. trichocarpa* with graminoids and forbs. Other habitats include mossy upper beach meadows and open deciduous forests. The Etolin Island population (EO 7) grows in a *Sphagnum* wetland with limestone-influenced water, and an open mixed *Pinus contorta* forest (Figure 7). The Etolin Island population and upper beach meadow populations are in flat areas.

Reproductive Biology

There is little published research on the reproductive biology and genetics of *Cypripedium montanum*. However, studies of other *Cypripedium* species and other orchid genera provide insight into the biology of this species (Luer 1969, Case 1987, Hadley 1990, Sheviak 1992, Harrod and Knecht 1994, Knecht 1996, Proctor et al. 1996). The mating and breeding system of *Cypripedium montanum* has been characterized as self-compatible, but the species is reliant on pollinators of for successful pollination (Edens-Meier 2010, Bernhardt et al. 2014).

All *Cypripedium* are non-rewarding (no nectar or pollen benefits to the pollinator) and they achieve pollination by deception through attraction and structural design (Dressler 1981, Cribb 1997). In other deceptive non-rewarding orchids, increasing the floral density in a cluster of flowers may result in attracting more pollinators, resulting in greater reproductive success (Davis 1986). Increasing the number of flowering stems may be most successful in attracting pollinators if the population is scattered, but it may not be as effective as if flowering plants are clustered together in locally high abundance (Sabat and Ackerman 1996). Releasing specific volatile compounds during flowering may be one of the primary means of luring a pollinator into the lip of the orchid. Specialized scent-producing hairs are strategically located in the inner surface of the lip and continue around to the rear of the lip near the exit (Lee 2004). This odor may draw the insect to the back of the labellum and toward the exit adjacent to the anther. The scent of *Cypripedium montanum* has been reported as pleasant or sweet (Sheviak 1992, Coleman 1995, Cech 2002).

Pollination occurs when a visiting insect transfers pollen from the anthers to the stigma. In most flowering species, pollination can occur between multiple flowers and individuals since pollen are individual grains and a flower can produce thousands of pollen grains. In the case for orchids however, all of the pollen is compacted into a single sticky package, termed the pollinia. In this reproductive strategy, all of an individual’s pollen is transferred to the stigma in a one-time event.

Figure 8. Small bee exiting lip of *Cypripedium montanum* with yellow club-like pollinia attached to upper body. Photo by N. Vance.

This strategy is successful because it promotes outcrossing and floral visitors are limited and specialized to a few species. In *Cypripedium*, floral visitors enter the frontal orifice of the labellum and crawl to the back of the labellum. The insects are probably led by olfactory or visual cues through this one-way path. When the insect enters, they depress the elastic lip near the column base, creating a passageway that leads toward one of two openings at the base of the column. This passageway is directly under the stigma and pollinia. To exit the flower, the insect must crawl through the small basal opening of the labellum where the sticky pollinia is attached on the upper side of their thorax or occasionally, the head of the insect (Figure 8).

Although the “one-way street” pathway in *Cypripedium* ensures pollinia removal, transfer of pollinia to a new flower or fertilization may not always be successful. The reproductive success rate in non-rewarding orchids is typically lower than in orchids that provide a benefit to the pollinator (Tremblay et al. 2005). The average fruit set of North American nectarless orchids is around 20% (Lipow et al. 2002). Due to the complex and specialized pollination system, it was hypothesized that pollination is a rare occurrence and fruit production is lower in *C. montanum* (Correll 1950, Barker 1984). However, Coleman (1995), who followed fruit production in California populations over a four-year period, found that 792 flowers produced 483 capsules, an average of 61% fruit set over all sites and years.

Cypripedium montanum is dependent on pollinators for reproductive success (Bernhardt et al. 2014). Various insects are often observed sitting on petals and sepals of *C. montanum*, but this does not indicate pollination activity and are referred to as floral visitors (Figure 9). A variety of insects have been observed to visit *C. montanum* such as beetles (Coleoptera), flies (Diptera), and various bees (Hymenoptera), however only small solitary bees were found to exit the labellum with *C. montanum* pollen, a partial act of the pollination process (Bernhardt et al. 2014). In eastern

Oregon, *Andrena* sp., *Lasioglossum athabascense*, *Lasioglossum* sp., and *Ceratina acantha* were small enough (5–10 mm length) to crawl through the labellum to release the pollina (Bernhardt et al. 2014). Larger bees observed to visit *C. montanum* included *Osmia*, *Megachile*, and *Bombus* species, however they were too large to mechanically fit through the orchid pollination mechanism and therefore are inefficient pollinators of *C. montanum*.

Small bodied solitary bees are uncommon in southeastern Alaska, particularly in moist and partially forested habitats (Carlson pers. obs.); therefore, pollination rates and subsequent seed production for *C. montanum* in Alaska may be limited. However, in other regions of the *C. montanum* range, flies have been observed visiting the flower and exiting from the labellum via the same pathway taken by bees carrying pollinia or cluster of sticky pollen and therefore have the potential to be a pollinator (Vance pers. obs.). A pollinator study in the Alaska Region could determine the species and abundance of *C. montanum* pollinators.

Figure 9. Dipteran (fly) floral visitors of *Cypripedium montanum* in the Etolin Island population.

Geitonogamy, movement of pollen between flowers of the same individual (genetically self-pollination), is possible in *C. montanum*, however observations strongly indicate that xenogamy, outcrossing with other individuals, is predominately the mating system of *C. montanum* (Edens-Meier et al. 2010). *Cypripedium montanum* is pollinated by small generalist bees, a reproductive strategy that promotes the genetic exchange within and between populations.

Hybridization among other species in the genus is a possibility. A population of *C. parviflorum* var. *pubescens* has been found within 50 km of the *C. montanum* population on the Tongass National Forest. While there are barriers for pollen transfer such as distance and water bodies that would make it difficult for small bees to overcome, *Cypripedium parviflorum* and *C. montanum* can hybridize to form *C. × columbianum* Sheviak when the two species are growing in mixed or adjacent stands (Sheviak 2002). The maximum foraging distance varies between bee species and is highly correlated to body size, where longer or larger bees are capable of greater flight distances (Gathman and Tscharntke 2002, Greenleaf et al. 2007, Guédot et al. 2009). On average, the maximum foraging distance from nesting sites to food resources can range from 500 to 1800 m for various *Osmia* species (Gathman and Tscharntke 2002, Guédot et al. 2009), but only 50% of solitary bees within a population are capable of such flight distances and the preferential foraging distance is within a few hundred meters of nesting sites (Zurbuchen et al. 2011). Unless a population of *C. parviflorum* var. *pubescens* occurs within the pollinator flight distance of *C. montanum*, hybridization is not likely to occur on the Tongass National Forest population.

Life History

The flowering period for *Cypripedium montanum* in Alaska is May to July. The earliest herbarium record is a full flowering individual in early June at a low elevation site. Additionally, on a June 1 visit, the Etolin Island population was noted to be in the very early stages of flowering. The subalpine and alpine sites have full flowering plants in mid-July. A mid-August herbarium record from the Etolin Island population showed individuals had clearly senesced and possibly in a fruiting stage. Flowering of an individual stem may last several weeks depending upon the number of flowers in the inflorescence.

Huber (2002) observed that the first time a *C. montanum* plant flowers, the stem produces a single flower, and grows for two more seasons after that before it produces two flowers. For *C. fasciculatum*, a closely related species, the incidence of flowering and the number of flowers were related to the plant's size and age (Lipow et al. 2002). Plant size, maturity, and flowering are linked among individuals of a single *Cypripedium* species in the same environment; but in those environments that offer more favorable conditions, individual stems of a plant may grow more quickly and flower earlier (Cribb 1997). Although *C. montanum* usually produce one or two flowers, older *C. montanum* stems can produce three flowers on a single inflorescence and may do so year after year. The leaves are the primary photosynthetic organs that provide energy for flowering. Because flowering is an energy cost to *C. montanum*, the number of flowers on a stem appears to be related to the size and number of stem leaves. No three-flowered stem had fewer than seven leaves (Huber pers. com. 2006).

As is the case for most orchids, *Cypripedium montanum* has a floral life span that lasts about three weeks (Vance pers. obs. 2006). Fertilization occurs about three to four weeks after pollination (Bernhardt *pers. comm.* 2005). This is an unusually long interval between pollination and fertilization in an angiosperm. It appears to result from the delay in ovule maturity as the pollen germinates and pollen tubes grows down the style of the pistil to the ovary only to wait for a receptive ovule (Edens-Meier et al. 2010). By to mid-summer, swollen ovaries indicate that seeds are developing. When mature ovaries (capsules) desiccate and dehisce, they release thousands of nearly microscopic seeds. The decay-resistant flowering stems will remain on the ground and can be found in spring with opened capsules that still have seeds in them (Vance pers. obs. 2004).

Average seed number is not known for *C. montanum*, but an average of 3,874 seeds per fruit was found in *C. fasciculatum* (Harrod and Knecht 1994) and Correll (1950) reported an estimated 10,000 seeds per capsule in *C. parviflorum*. The capsule usually splits and the dormant seeds disperse. The seeds over-winter in the top layer of soil. If conditions are favorable and seeds are viable, they may germinate the following spring when soil temperatures rise, but shoots will not appear above ground for several years.

Cypripedium montanum seeds are 1 to 2 mm long and are very light, weighing no more 2 μg. They are waterproof and can float, suggesting possible dispersal by wind or water (Case 1987, Harrod and Everett 1993, Cribb 1997). Once seeds are dispersed, it is unknown how long they remain viable. The spatial distribution patterns of plants on sloping terrain suggest dispersal by surface flow from fall rains or spring snow-melt. The low density and scattered dispersion pattern of this species suggests that there may be multiple dispersal vectors.

Orchid seeds, unlike seeds of other flowering plants, lack a differentiated embryo, endosperm, and protective seed coat. A lacy, net-like outer seed coat covers an inner undifferentiated mass of cells (the proembryo). Because seeds do not have an endosperm, they may lack sufficient nutrients, energy reserves, metabolism, or metabolites to produce a seedling on their own and require a fungal symbiont (Arditti 1967, Rasmussen 1995). The largest group of fungi identified from mycelia isolated from *Cypripedium* roots is *Rhizoctonia*, an artificial genus that spans across multiple families in the Basidomycota (Shefferson 2005). For *C. montanum*, a narrow mycorrhizal association occurs with a symbiont in the Tulasnellaceae, a fungal family well known for many orchid symbionts (Shefferson 2005, Pecoraro et al. 2013).

Hyphae (fungal filaments) invade and digest the seed coat and outer layers of the cell mass. Digestion of these outer layers produces sugars that the inner cells utilize to grow and develop (Case 1987). This kind of fungal symbiont has been shown to be compatible with seeds germinated *in vitro* (Rasmussen 1995) and is postulated as necessary for germination and establishment of *Cypripedium* species in the wild. Steele (1996) reported *Cypripedium montanum* seed germination rates of about 0.1% when using methods that did not include a fungal partner. An unspecified quantity in the ‘thousands’ of *C. montanum* seed planted in natural environment setting have also seen low germination success, where up to 49 seedling plants emerged each year for the first three years of the study (Huber 2002).

If infected by its fungal symbiont, the germinating seed of *Cypripedium montanum* develops into a protocorm out of which grows the first rhizome and starchy roots. It may take several years for the protocorm to grow into a segmented, rhizomatous structure. The elongated rhizome produces a sympodial bud with an emergent aerial leaf (Cribb 1997, Cech 2002). The roots are initiated near the base of the shoot bud (Stoutamire 1991). Leaves emerge approximately 1.5 years after germination (Huber 2002). The amount of sunlight is critical for germination as it warms the soil, however young plants in full sunlight usually desiccate (Huber 2002).

Many native orchids are completely mycotrophic when immature, spending several years in a complex subterranean symbiotic state. In this state, plants rely on mycorrhizal fungi for water and nutrition (minerals and carbon) until sufficient growth occurs and stored food accumulates for leaf production (Case 1987, Rasmussen 2002). Mycorrhizal infection stays with *C. montanum,* and other *Cypripedium* species, long into adulthood and infect the root system of adults (Shefferson 2005).

Each year, the short, non-branching rhizome may produce a new bud at the terminal position with roots growing out from the ventral side of the rhizome just behind the bud (Curtis 1943, Stoutamire 1991). Rhizomes produce buds during the growing season that remain dormant through the winter. If conditions are favorable the next spring, each bud develops into an aerial shoot with a single stem and usually two leaves. The plant will only develop a shoot after adequate food is stored (Hutchings 1989).

The growth of the rhizome is sympodial, and older parts of the rhizome die off so that growth intervals of an excavated rhizome do not indicate the real age of the plant. Harrod (1994), dating orchid rhizomes by counting stem scars, estimated the rhizome he excavated to be from 25 to 30 years old. As an orchid plant matures, older buds may also develop stems, thus producing a clonal clump of aerial stems.

An aerial shoot may not emerge from a rhizome every year. Differences in local weather conditions or other factors may contribute to whether or not a shoot emerges (Peck 1961, Latham and Hibbs 2001). The Etolin Island population has been revisited several times over the years and stem number fluctuates drastically between each census. This failure to emerge is referred to in the literature as “dormancy,” a common phenomenon observed in terrestrial orchids in which the individual plant may revert to a mycotrophic state (Tamm 1991, Rasmussen 1995, Kull 1998). Tamm (1991) concluded in a long-term study of several orchid species that variations in flowering frequency and population levels were explained in part by differences in weather conditions between years.

Stem scars along the rhizome correspond to individual roots, many of which are senescent (Curtis 1943, Harrod 1994). The root crown is often found in the organic soil layer with roots that extend into mineral soil (Vance personal observation 2005). Rhizomes and roots of sampled *C. montanum* individuals that were excavated for a mycorrhizal study were located 3 to 7 cm (1.2 to 2.75 inches) below the soil surface. In the rich organic layer, roots displayed positive geotropism but were also oriented in varying directions. In at least some orchid species, root orientation appears not to have any detectable function other than to mine the soil for nutrients (Rasmussen 1995). However, the depth of duff, organic, and mineral soil layers, as well as soil texture, influence depth of the root crown and, to some degree, the orientation of the root system.

Spring growth arises from over-wintering buds produced the preceding growing season. However, if fire, late frost, foraging animals, disease, accident, or management practices destroy new spring growth, *Cypripedium montanum*, like other geophytes, cannot replace the lost tissues. Although dormant buds may be present, they will not initiate growth during the current growing season. They will emerge the following year if the perennating buds in the rhizome damaged, the root system may survive and a new bud may form, or a dormant bud may enlarge, but the plant will suffer a major setback and it may die (Sheviak 1990). *Cypripedium* species that lose all their aerial tissue (stems and leaves) before midsummer will commonly appear the next year but will not bloom (Primack et al. 1994, Vance 2002). Depending on how severely depleted their energy reserves are, plants may require two or more subsequent vegetative seasons before blooming (Case 1987, Primack et al. 1994). This suggests that a plant may require a critical level of carbon from photosynthesis the previous growing season to produce flowers.

It may take two or more years before a seedling produces enough growth to become a flowering plant. In a study of development of five *Cypripedium* species, Curtis (1939) found that 8 to 16 years elapsed from seed germination to flowering. The time interval to flowering varies within an orchid species due to differences in local weather or site conditions (Curtis 1939, Tamm 1991, Kull 1998, Huber 2002). Huber (2002) reported that at least four years elapsed from shoot emergence to flowering at his property in eastern Oregon. Harrod (1993) found that small *C. fasciculatum* plants could be 12 or more years old before they flowered.

Demography

There is little known about the demography of *Cypripedium montanum* as it has not been well studied. An orchid's life cycle reported by Tamm (1991) and others (Rasmussen 1995, Cribb 1997) is complex. Because *C. montanum* is heterotrophic and may spend part of its life alternating below and above ground, studies need years of observation to characterize the demography of this species.

Demographic assessment of a genetically and structurally complex population is problematic because aerial stems of a single individual do not always appear above ground each year and ramets are difficult to distinguish from genetically distinct individuals. Nevertheless, juveniles and seedlings should be distinguished from mature plants. It is important to find newly emergent seedlings, which, depending on the time of the year surveys are conducted, may be difficult to detect. Thus, the population structure can be assessed based on age and size as well as maturity. Through evaluating a set of developmental stages, the demographic data can show differences among years in the fundamental factors that determine population health: reproductive success and recruitment. A monitoring program of *Cypripedium fasculatum*, which spanned several years, provided data for a population viability analysis. Data indicated that small populations are quick to go to extinction, where population with less than10 individuals had a 40% chance of extinction within 5 years and 90% chance after 30 years (Gray et al 2012). However, populations of greater than100 had a near 0% chance of extinction, no matter the timeframe (Gray et al 2012).

A wide-ranging distribution across diverse habitats may contribute to increased natural selection and maintenance of genetic diversity (Hamrick and Godt 1989). Although the genetic diversity at the species or population level of *C. montanum* is not known, it could be high. Case (1994) conducted a genetic analysis and reported that the wide-ranging *C. calceolus* (greater yellow lady's slipper) had high levels of genetic diversity typical of a widespread, outcrossed, long-lived, herbaceous plant. Genetic analysis of plants sampled across the range of *C. fasciculatum* revealed relatively high genetic diversity. Genetic variation occurring within, more than among, populations (Aagard et al. 1999, Vance 2003) is indicative of outcrossing populations. Insect-pollinated plants sampled from Oregon populations of *C. fasciculatum* also exhibited relatively high reproductive success (Lipow et al. 2002). In a separate genetic study of Oregon populations of *C. fasciculatum*, the lowest genetic variation occurred in the most isolated population (Vance 2003).

Cypripedium montanum demography may be influenced by disturbance, succession or changing edge effects. Patchy, small populations of *Cypripedium montanum* occur across its range. Fragmented habitats and isolated populations pose special challenges for gene flow in rare plants due to the distance between populations and a reduction in the number of mates (Wilcock and Neiland 2002). Because *C. montanum* populations in Alaska are spatially disjunct from each other and from populations in British Columbia; the distribution of genetic variation over time may be affected. However, without a genetic study, this can only be inferred.

Community Ecology
In the Alaska Region, *C. montanum* has been described to grow in moist to dry open forest in steppe, montane, and subalpine habitats (Hultén 1968, Douglas et al. 2001). In Alaska occurrences, have been found in subalpine to alpine or open wet meadows. Associated species generally appear to be alder and willow scrub to mesic meadow forbs. Only two populations (EO 6 & 7) have associate species data. Specifically, EO 6 contains: *Alnus viridis*, *Artemisia* sp., *Salix sitchensis, Geranium erianthum*, *Salix* sp., *Anemone* sp., *Epilobium* sp., *Lupinus nootkatensis*, and *Sanguisorba stipulata.* The Etolin Island population (EO 7) does not have a complete plant associate species list because the grasses and sedges were not flowering during visits. The habitat has been described as a poor or calcareous *Carex aquatilis* var. *dives* fen surrounded by a poor productive *Pinus contorta* mixed forest (NRIS database). Based on limited plant association data and cover class, the microhabitat would be generally be classified as III.A.3 Wet graminoid herbaceous habitat (Viereck 1992; Figure 7; Table 4).

Table 4. Community data of Etolin Island (EO7) population of *Cypripedium montanum.*

Estimated Cover (%) in 2011 and 2012	Associated Species
Canopy Cover Tree: 5 and 5 Shrub: 5 and 10 Forb: 5 and 10 Graminoid: 65 and 80 Lichen: 0.5 and 5 Moss: 10 and 10 Ground Cover Litter: 60 and 25 Bare: 0 and 10 Water: 20 and 30	**Trees:** *Callitropsis nootkatensis, Juniperus communis, Pinus contorta* var. *contorta, Thuja plicata* **Shrubs:** *Gaultheria shallon, Ledum groenlandicum* **Forbs:** *Achillea millefolium, Agastache foeniculum, Dodecatheon pulchellum, Drosera rotundifolia, Menyanthes trifoliata, Nephrophyllidium crista-galli, Pinguicula vulgaris, Veratrum viride, Lysichiton americanus, Tofieldia glutinosa, Adiantum pedatum* **Graminoid:** *Carex aquatilis* var. *dives, Eleocharis palustris, Eriophorum angustifolium, Scirpus* sp., *Carex* sp.

Cypripedium montanum appears relatively intolerant of intense competition, and across its range, this species appears to reproduce best in microsites that lack a dense herbaceous layer (Vance personal observation). Aggressive colonizing species, such as *Pteridium aquilinum* with its extensive rhizomatous growth or graminoids that form dense mats, may create unfavorable habitat for the species. More study is needed to clarify the dynamics of *C. montanum* demography in relation to the plant community and the influence of other plants.

Cypripedium montanum is visited by a variety of animals, primarily insects, including members of the orders Diptera (flies) Lepidoptera (butterflies and moths), Coleoptera (beetles), and Hymenoptera (wasps, bees, ants). Only bees pollinate the orchid, so most other insect visitors are engaged in herbivory or are incidental. Many of these insects feed on pollen and nectar in flowering plants associated with *C. montanum* that also support the pollinating bees with food. Animal trails often meander through colonies of *C. montanum*, and browsing is reportedly light. However, ungulate browse can be severe (Karow *pers. comm*. 2005).

Like other orchid species, *Cypripedium montanum* forms a vital ecological relationship in its mycorrhizal association with fungi (Curtis 1939, Rasmussen 1995, Shefferson et al. 2005). Mycorrhizae associated with orchids are diverse but also may be fairly specific (Shefferson et al. 2005). More than one species can colonize orchid roots even after the orchid appears to be autotrophic (Kristiansen et al. 2001). Shefferson et al. (2005) found that 10 of 12 *C. montanum* plants sampled in northern California had fungi in the family Tulasnellaceae associated with their roots. Luoma (pers. com. 2005) noted that many of the sequenced samples of PCR-amplified DNA extracted from roots of plants growing in Oregon and Idaho closely matched organisms in the order Tulasnellales. Although they also found a sample that matched species of the truffle-forming genus *Rhizopogon*, the taxonomy of this fungal symbiont requires more clarification.

The relationship between mycorrhizal fungi and orchids is complex; it varies over the life cycle of the plant and is regulated by changes over a season (Anderson 1992). Orchid mycorrhizae are different from other mycorrhizal systems in which the green plant is the source of energy. In orchid mycorrhizal systems, the fungus is the source of energy until the plant becomes phototrophic (Rasmussen 1995). This enables the orchid to be heterotrophic throughout its life and helps to buffer changing habitat conditions.

The seeds of *Cypripedium montanum* plants, like those of other orchid species, require infection by a specific mycorrhizal fungus to germinate (Arditti 1967, Wells 1981, Doherty 1997). *Cypripedium* species are completely mycotrophic for several years after germination, existing in a subterranean condition. Immature plants rely on the fungus for water and nutrition until sufficient growth occurs and enough stored energy accumulates to allow leaf production (Rasmussen 1995). Once an orchid reaches maturity and becomes autotrophic, the degree of dependence on the symbiotic fungal species may decrease (Rasmussen 1995, Doherty 1997). Whitlow (1983) suggested that once *Cypripedium* becomes wholly autotrophic, the role of the fungus ceases. However, otherwise phototrophic individuals have been observed spending several years underground. Whether they return to a mycotrophic state in that leafless condition is not known, but it is suspected that they do (Rasmussen 1995, Smith and Read 1997). Although the relationship is not fully understood, symbionts may be necessary for adult plants as well as for establishment of seedlings and may be a more limiting factor to the persistence of populations and their spread than climate or other ecological factors (Cribb 1997).

Establishment of new populations requires suitable conditions for forest fungi. What constitutes suitable conditions is not known, but can be presumed to be shady, with adequate organic material to support growth of heterotrophic fungi, and moist at least for part of the growing season. Infection of plant roots occurs in the upper organic soil layers, suggesting that the mycorrhizae do well in aerated soil with woody debris or other carbohydrate sources available (Rasmussen 2002). The dynamic relationship between the plant and fungal symbiont is thought also to be affected by changes in the microenvironment (Sheviak 1990).

Orchid mycorrhizal fungi may also form mycorrhizae with roots of neighboring live, woody plants (Rasmussen 2002, Shefferson et al. 2005). Stable isotope analysis of orchid and non-orchid tissue of *Cypripedium fasciculatum* revealed that carbon was being made available to the orchid through digestion of the fungus in the root cells (Whitridge and Southworth 2005). Orchid mycorrhizal fungi may be saprophytic decomposers of herbaceous and woody debris, but may simultaneously be parasitic or symbiotic with other species. The association of *C. montanum,* a heterotrophic orchid, with western forest trees and woody shrubs suggests that its fungal symbionts may concomitantly form ectomycorrhizal associations with *Pinus*, *Populus*, or *Salix* species. Research is beginning to demonstrate that several fungal types associated with orchids play different functional roles, suggesting a strong ecological role that the subterranean fungi play in the demography, fitness, and distribution of the orchid (Rasmussen 2002).

CONSERVATION

Threats

In the Alaska Region, the primary threats to *Cypripedium montanum* are more likely to be inferred from its distribution, habitat, and ecology than from specific events. Having no historic measure of the species' range, distribution, or abundance precludes pinpointing the factors that may have led to its current status. The greatest threats can be generalized as those that result in the destruction of plants or that alter microsite conditions (e.g., soil, moisture, light regime) so that *C. montanum* cannot complete its life cycle. If a disturbance is widespread, an entire population could be jeopardized. Human activities, including those that involve mechanical alteration of the soil or removal of overstory, and plant collecting, appear to be the greatest potential threats to the persistence of *C. montanum*. Natural disturbances such as browsing or trampling by large animals and vegetation succession changes are also significant threats. The species is especially vulnerable to these threats in the Tongass National Forest because of its single population. There has been no formal analysis or assessment for *C. montanum* designed to evaluate the risk of extirpation or population viability loss from natural disturbances or other perturbations, such as succession, invasive species or human activities.

Cypripedium montanum may be negatively affected at different parts of its life cycle. Population vulnerability probably increases during the reproductive phase as plants are more susceptible to herbivory at this time. If the habitat does not support pollinators, *C. montanum* populations are at risk of not reproducing by seed thus losing genetic variability through failing to out-cross. If the habitat does not support the fungal symbionts required for seed germination and seedling development, then recruitment will fail. Although there are few demographic monitoring data, potential causes for failure to recruit seedlings include pollination limitation, seed inviability, seedling predation, and long maturation period before emergence (Curtis 1943).

Human activities
Potential threats of development such as trail maintenance, road building and maintenance affect substrates and foster invasive species encroachment. Timber harvest can alter the light regime and mechanized equipment used for logging can overturn soil substrates. Additionally plants and habitat can be adversely affected by off-road motorized recreation, and non-motorized recreation that expose plants to trampling (Latham 2001).

Mechanical activities or natural phenomena, such as colluvial or alluvial action, that disturb soil, remove duff, and expose or damage the rhizome and roots may kill *Cypripedium* plants (Harrod 1994, Knecht 1996). The adventitious roots of *C. candidum* were found to be particularly sensitive to disturbance; damaged roots were replaced only slowly from the youngest rhizome sections (Stoutamire 1991). The Etolin Island population occurs less than 50 meters of Forest Service Route 6545, specifically 15.2 meters downstream of a culvert. This makes the population vulnerable to rapid run-off from heavy rain storms or flooding streams when storms coincide with melting snow. Road construction and maintenance has modified the hydrology of the wet meadow *C. montanum* grows in (K. Dillman *pers. comm.*). The population's proximity to the road increases the access to the population by the general public. Road construction and maintenance can increase soil instability and alluvial soil movement and negatively impact the habitat.

Effects of mechanized equipment have been recently documented on a sub-population in Haines. The population had been stable until it was used as a boat launch by an outfitting guide. The population suffered a slight decline from impacts of trampling (M. Sapay *pers. comm.*). An improved boat launch was constructed by digging and grading the area, upturning the soil, and removing vegetation. A majority of the population was extirpated due to the construction. Only a few scattered individuals within the adjacent forested area remained and the remaining plants have been subjected to trampling from boat launch activity. Monitoring of the population is needed to determine the full effects of the construction.

Forest management activities may have variable effects on *Cypripedium montanum*. Knorr and Martin (2003) revisited *C. montanum* sites and found sites where logging disturbance had occurred, the population was extirpated due to logging disturbance that destroyed suitable habitat. The report noted that although protection may have occurred during logging, post-logging activities that included trail building, roadside salvage sales, replanting and subsequent thinning adversely impacted populations. Urban (1981 cited in Barker 1984) reported severe declines in local populations when canopy was removed. In a report to district rangers on the Klamath National Forest, field botanists indicated that while some populations tolerated partial cuts, this was the exception not the rule (Barker 1984). In Siskiyou County, California, a pre-logging survey by the USFS recorded two populations, totaling 560 plants (based on a count of aerial stems) in a planned clear-cut unit. A search of the area several years after timber harvest found that only five plants had survived, these were on the edge of the clear-cut (USDA Forest Service 2003a).

The tree harvest and road building can alter the species' habitat by compacting the soil, removing protective cover or duff, or exposing roots or the plant's rhizome. Demographic monitoring data indicated that individual orchids in a clearcut declined dramatically in number and performed poorly through seven years post-tree harvest (Kaye 1999). The author, however, cautioned that more data from replicated studies are needed, as this was a single specific example and should not be generalized.

The Final Supplemental Environmental Impact Statement on Management of Habitat for Late-Successional and Old growth Forest Related Species within the Range of the Northern Spotted Owl (USDA Forest Service and USDI Bureau of Land Management 1994b) suggests that fire suppression is an important factor in the overall decline of *Cypripedium montanum*. Seevers and Lang (1998) mention examples of severe damage to populations in logged areas in Oregon and California. In Alberta, where *C. montanum* is only found in the southwestern part of the province, estimated overall population decline was 20% (Vujnovic *pers. comm.* 2002). Population losses due to timber harvest have been documented in Oregon (Urban 1997). A pre-logging survey located two populations consisting of 260 and 300 *C. montanum* plants in an area scheduled to be clear-cut in Siskiyou County, California. A subsequent survey several years after timber harvest revealed that only five plants survived at the edge of the clear-cut (Coleman 1995).

Predation and competition

Insect-mediated seed predation and herbivory occur, but evidence of population impacts by any herbivore of *Cypripedium montanum* is rare. The intensity of ungulate browsing behavior on *C. montanum* plants is variable. Deer and elk trails often transect *C. montanum* populations where browsing activity has been observed to be generally haphazard and not heavy. The Etolin Island population on the Tongass National Forest has wildlife trails within it, but the trail did not appear to be traveled heavily enough to cause bare ground (NRIS database). Trampling of *C. montamum* from ungulate trail activity and bedding in 2011 was observed but no herbivory. Herbivory and trampling was observed at the Etolin Island population in 2012, but at a low rate where approximately 8% of the fruiting *C. montanum* population was affected (NRIS database). Ungulate activity appeared to be from Sitka blacktail deer and introduced elk that completely browsed the flowering stem. Insect herbivory affected the same number of plants as ungulates, but damage to the plant was concentrated on the vegetative parts such as the leaves. Similarly, in Oregon, elk and deer browse the upper portions of the plant, including flowers and fruits, but this occasional browsing was thought to have little impact on the viability of the species (Urban 1997). In contrast, a population on the Bighorn National Forest was so heavily browsed, a census could not be taken.

Insect herbivory of leaves and flowers generally injures but does not destroy the orchid; however, herbivory of flower parts, particularly the flower's labellum, early in flowering can prevent successful pollination. Monitoring early in the season can document low reproductive success as a result of insect herbivory to flowering parts.

Table 5. Non-native plant species observed on Etolin Island (AKEPIC 2015). Invasive ranks are scaled from 0 to 100, with '0' representing a plant that poses no threat to native ecosystems and '100' representing a plant that poses a major threat to native ecosystems. Taxa in bold have occurrences < 3 km of the *Cypripedium montanum* population.

Non-native Species	Common name	No. of Occurrence	Invasiveness Rank	Years Reported
Dactylis glomerata	**orchardgrass**	**7**	**53**	**2005**
Digitalis purpurea.	purple foxglove	1	51	2004
Gnaphalium palustre	**low cudweed**	**1**	**n/a**	**2005**
Hieracium aurantiacum	orange hawkweed	1	79	2004
Hieracium murorum	wall hawkweed	1	n/a	2009
Holcus lanatus	common velvetgrass	1	55	2005
Hypochaeris radicata	**hairy catsear**	**3**	**44**	**2004**
Leucanthemum vulgare	oxeye daisy	1	61	2004
Lotus corniculatus	birdsfoot trefoil	2	63	2005
Mycelis muralis	wall lettuce	1	31	2005
Phalaris arundinacea	**reed canarygrass**	**17**	**83**	**2004, 2005, 2009**
Phalaris canariensis	annual canarygrass	1	n/a	2004
Phleum pratense	**timothy**	**9**	**54**	**2005**
Plantago major	**common plantain**	**2**	**44**	**2004, 2005**
Ranunculus repens	creeping buttercup	1	54	2004
Rumex acetosella	common sheep sorrel	2	51	2005
Taraxacum officinale	**common dandelion**	**8**	**58**	**2004, 2008, 2009**
Trifolium hybridum	**alsike clover**	**2**	**57**	**2005**
Trifolium repens	white clover	1	59	2005

There is very little information on the presence of competitors in the form of non-native species or their proximity to *Cypripedium montanum*. No non-native plants have been observed at the *C. montanum* Etolin Island population, but 19 non-native species have been observed on the island since 2004 (Table 5; AKEPIC 2015). The observed non-native plant occurrences occur on the Forest Service Road and in areas that had timber harvest activity (AKEPIC 2015). Eight non-native species occur within 3 km of the *C. montanum* population with *Phalaris arundinacea* (reed canarygrass) having the greatest Invasivness Rank (*see* Carlson et al. 2008). *Phalaris arundinacea* is known to establish and form monotypic stands in wetlands displacing native vegetation and altering the soil hydrology (Carlson et al. 2008) and has expanded into muskegs elsewhere in southeastern Alaska. *Phalaris arundinacea* poses a threat so sensitive wetland species and has the potential to establish at the Etolin Island population due to the wet meadow habitat that *P. arundinacea* is associated with and the proximity of the road. The proximity of the Forest Service Road to the *C. montanum* Etolin Island population increases the chance of invasion of any non-native species because roads commonly serve as vectors for their spread.

In openings where herbaceous and shrub vegetation are dense, root competition for moisture and nutrients increases during dry years (Huber 2002). Below-ground competition is not well understood, but the fern *Pteridium aquilinum* has the potential to suppress growth and reproduction of *Cypripedium montanum* if it becomes dense and spreads throughout the orchid's rooting zone (Stewart 1975, McDonald et al. 2003, Vance personal observation 2005). *Pteridium aquilinum* overlaps in range distribution in southeastern Alaska and is known to occur in similar *C. montanum* muskeg wet meadow sites on the Tongass National Forest, however it has not been observed to be as dense.

Observations suggest that competition for light from overtopping species may limit *C. montanum* (Huber 2002). Indirect evidence may be inferred from studies of other *Cypripedium* species growing under shrub and tree canopies (Case 1987, Stoutamire 1991). Orchid plants growing under tree and shrub canopies that restrict direct sunlight from reaching the plant cease flowering and develop long and weak stems susceptible to breakage (Case 1987, Stoutamire 1991). Huber (2002) monitored the emergence of *C. montanum* for several years and noted that immature plants do not survive if light is limited by the overstory. Huber (*pers. comm.* 2004) also observed that open spaces on the forest floor covered with conifer needles but little other vegetation appeared to produce the most seedlings.

Natural vegetation succession is a potential threat to *Cypripedium montanum*. Except for one forested population, in Alaska, *C. montanum* is commonly found in recently glaciated areas. These habitats have yet to reach climax succession stages and have open canopies with more exposed light than forested areas. Shrub advancement into alpine habitat due to climate change has been observed in southcentral Alaska (Dial et al. 2016). Shrub encroachment will likely displace potential habitat in upper elevation for many *C. montanum* occurrences, however the Etolin Island population is not likely to experience this specific threat.

Plant and flower collection

Collection from the wild for horticultural, medicinal, or personal purposes can pose a direct and serious threat to *C. montanum*. Plants are either plucked off at ground level, or are dug up for garden transplant or for obtaining root extracts. The severity of these threats depends on the accessibility of the population and the intensity and method of collection. The Etolin Island population has easy access due to its proximity to the Forest Service Road. Most of the other populations that occur in southeastern Alaska are remote and do not have easy direct access (Figure

4). Glacier Bay populations occur near campsite areas, however collecting plant material is not allowed within National Parks.

Because of their beauty and long tradition of medicinal use in North America and eastern Asia, *Cypripedium* species historically have experienced extensive collection, causing critical declines in some populations (Cribb and Sandison 1998). The World Wildlife Fund (1995) listed the lady-slipper orchid genus (*Cypripedium*) among the world's ten most wanted plant or animal taxa, threatened by illegal and unsustainable trade. Specifically, collecting for ornamental and medicinal purposes has been identified as major threat of *C. montanum* (Rankou 2014). There has been an enduring tradition of using roots of *Cypripedium* species for medicinal purposes around the world (Koopowitz 2001). The roots of *Cypripedium* species were used by North American indigenous peoples for a variety of medical problems from back pain to stomach cramps and "female trouble" (Moerman 1998). Cypripedin is a well-known chemical extracted from the orchid's roots and used for nervous diseases. In the late 19th century, roots of *C. parviflorum* var. *pubescens* were collected in large quantities to produce this extract (Koopowitz 2001). The roots have compounds that were reputed to have a relaxing effect on the nervous system and able to promote calm sleep (Cech 2002). In North America, *C. pubescens* was listed in King's American Dispensatory (Felter and Lloyd 1898) as a medicine for treating hysteria, nervous headache, wakefulness, prostration in low fevers, epilepsy, and "indeed, in all cases of morbid irritability of the nervous system." Collecting the roots for making tinctures for medicinal use remains popular today (Willard 1992, Cech 2002). There has been no documented use of any orchid species by Alaska Natives (Garibaldi 1999).

Cypripedium species, prized for their form and beauty, are also widely collected for the ornamental plant trade. Although some species are successfully cultivated, others, like *C. montanum*, have not been successfully propagated, but the technology to do this is being developed (Smith and Smith 2004). As the worldwide trade in orchids continues to grow, the number of orchids taken from the wild and sold internationally is increasing. Based on CITES figures (2005), between 1983 and 1989, an average of nearly 5 million orchids were traded annually, of which about 80% were propagated artificially, leaving around one million that were collected from the wild. This estimate is only for orchids traded internationally and does not include those sold within countries. There are problems in tracking and record keeping because declarations may indicate wild-collected orchids as being artificially propagated or customs records fail to be species-specific (Robbins 1997).

Vulnerability of small populations

Some of the consequences of very small populations include decreased ability to attract pollinators, loss of fitness, and increased potential for genetic drift (Barrett and Kohn 1991). Small populations can be extirpated by perturbations that may affect only a small part of a large population (Harper and White 1974); therefore, smaller populations are more vulnerable to extinction from human and natural causes than larger populations.

Climate Change Sensitivity

As changing climates are already recognized to be affecting habitats and species worldwide (e.g., Parmesan 1996) and the rate of temperature increase in Alaska is approximately double the global average (Chapin et al. 2014), concern over the future status of rare species in the Alaska Region is warranted. Climate change vulnerability of a species is recognized to be a function of the exposure to (or degree of) climate change that populations will experience, the sensitivity of the species, and the capacity to adapt to the changes (Turner et al. 2003). A number of vulnerability assessment tools have been developed that incorporate all three elements (exposure, sensitivity, and adaptive capacity) such as NatureServe Climate Change Vulnerability Index 2.1 (Young et al. 2011) and the U.S. Forest Service System for Assessing the Vulnerability of Species (Bagne et al. 2011). However, these systems require substantially more information than is available on the sensitivity and adaptive capacity of the species, are not appropriate for plants and lichens, or require environmental data not developed for Alaska. Further these methodologies often do not produce similar vulnerabilities for the same species (Lankford et al. 2014). Due to these limitations, we focus on estimations of the degree of climate change expected in the species' current range (i.e. "exposure") in the Tongass in a qualitative manner and discuss any known or suspected sensitivities and adaptive capacities of the species in a light of the degree of expected change.

"Climate" incorporates a vast array of factors, such as mean annual temperature, summer precipitation, and maximum wind speed for example, of differing importance for any one species. It is impractical to attempt to review all potential factors that compose the climate and we therefore focus on two factors: average summer temperature and average annual precipitation and compare current and predicted 2060 conditions. For most plants and lichens at higher latitudes, summer warmth (or mean July temperature) is well correlated with their distribution (Young 1971, and see Walker et al. 2005), indicating a strong association of the measure with biological limitations. Additionally plants and the habitats they are found in are well-known to be sensitive to soil/substrate and air moisture, and mean annual precipitation as a climate variable is expected to be most correlated with substrate and air moisture.

The current and predicted 2060 climates were developed for Alaska and western Canada by the Scenarios Network for Alaska & Arctic Planning (SNAP) at University of Alaska Fairbanks (UAF). Climate data generated by SNAP is downscaled using the Parameter-elevation Regressions on Independent Slopes Model (PRISM) from the five best-performing General Circulation Models (GCMs) for Alaska. The data selected for this analysis is derived from the A2 emissions scenario, which represents a realistic future emissions projection based on current trends. Data are available at a 771 m grid. While this resolution is relatively fine-scale, interpretations are restricted to broad regions. Interpretations of micro-climate at population-sized sites for sensitive species are not appropriate. To avoid generalizing trends based on stochastic annual climate events, SNAP has provided decadal averages for all data (Fresco et al. 2014). Decade 2010–2019 is selected to represent the current time frame. The 2060s decade is selected to represent the future time-frame because 50 years in the future is far enough to observe meaningful trends without being so far in the future that it cannot be meaningfully compared to current management objectives.

Southeastern Alaska has a strong Pacific Maritime climate with low variation and relatively warm temperatures and high precipitation, much of which falls as rain at low to mid elevations. Both total annual precipitation and mean annual temperature generally decrease along a south to north gradient through the Tongass National Forest. Mean July temperatures is predicted to increase in the Tongass National Forest from the 2010s to the 2060s by between 1.0 to 2.0 °C (Figure 10). Areas around the Etolin Island population are expected to increase by approximately 2.0 °C in 50 years. The percent change is expected to remain largely constant throughout the region. Mean July temperature is predicted to increase 10 to 20% within the majority of the Tongass National Forest by the 2060s relative to the current mean July temperature (Figure 10).

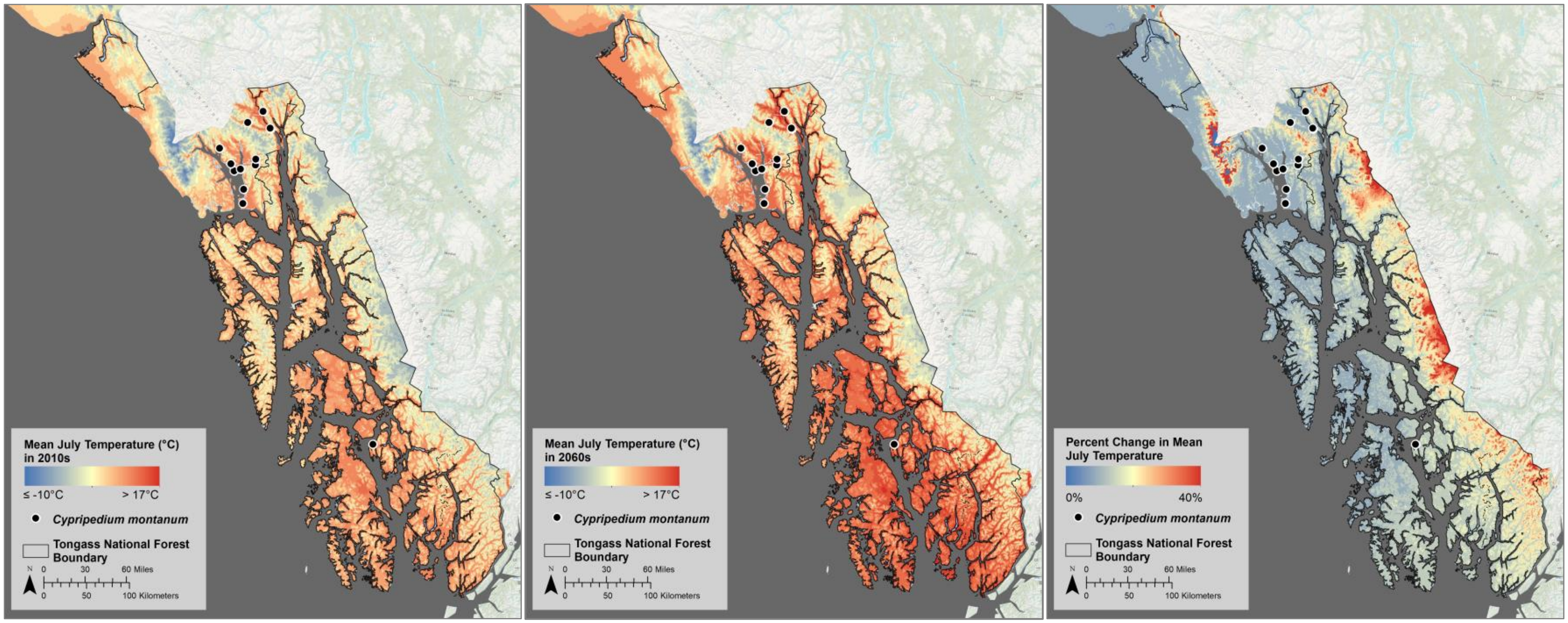

Figure 10. Current (left), predicted 2060 (center) and percent change (right) in mean July temperature (˚C) in the Tongass National Forest. Locations of *Cypripedium montanum* populations are shown as black dots.

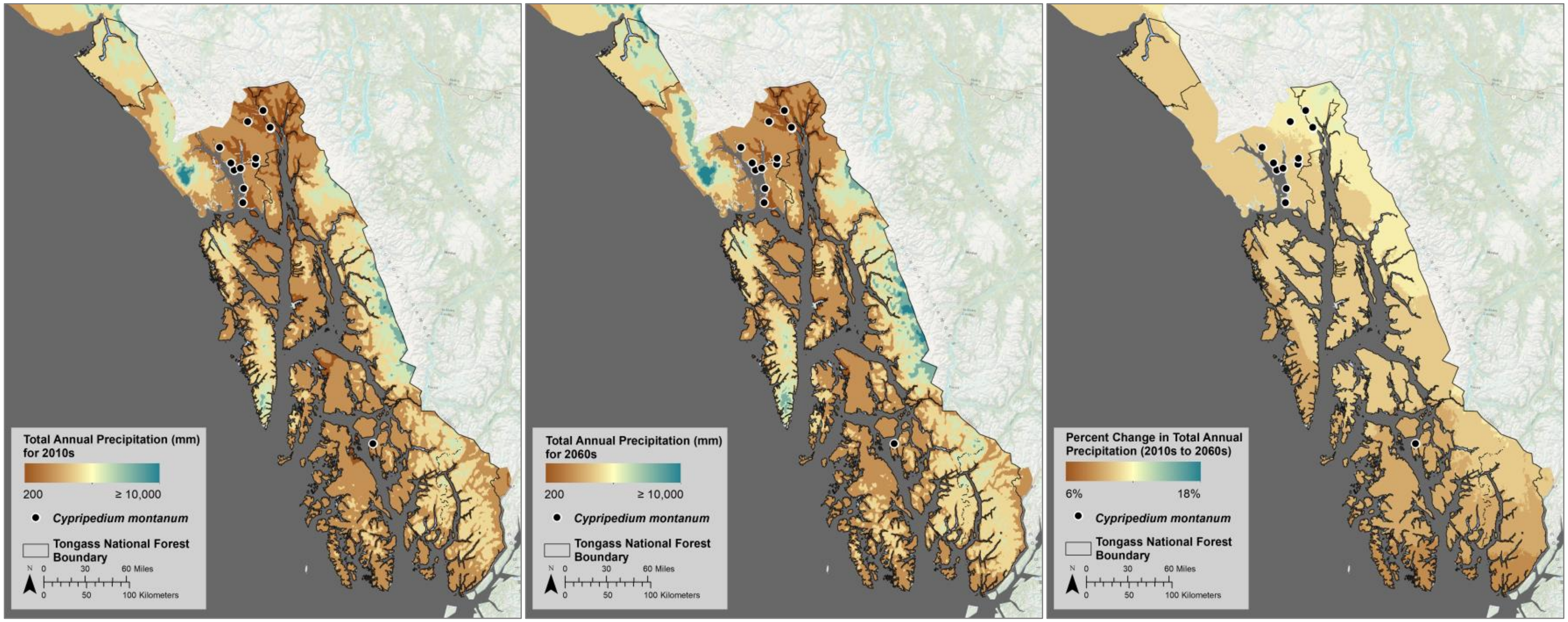

Figure 11. Current (left), predicted 2060 (center) and percent change (right) in mean annual precipitation (˚mm) in the Tongass National Forest. Locations of *Cypripedium montanum* populations are shown as black dots.

Annual precipitation is predicted to increase across the Tongass National Forest by the 2060s, but no regional gradients are apparent, largely because of competing patterns for summer and winter precipitation (Figure 11). Annual precipitation is predicted to increase by 9 to 12% for most of the Tongass National Forest. Precipitation is predicted to increase around the known population by approximately 237 mm; an increase in annual precipitation of approximately 10%.

The greatest percent increase in precipitation is predicted to occur during winter months. Increase in total summer precipitation is most pronounced in the northern portion of the Tongass National Forest, especially the Yakutat Ranger District. Annual precipitation is predicted to increase across the Tongass National Forest by the 2060s, but no regional gradients are apparent.

The increased precipitation may create more wet meadow habitat, increase the size of current meadows, or shift mesic grass and forb meadows to wet grass meadows. Increased rainfall may create more flooding and runoff from the Forest Service Road at the Etolin Island population. *Cypripedium montanum* is not found in standing water habitat and therefore individuals may shift to the outer edge or dry microhabitats of the meadow. Given the trends of increased temperature and precipitation and the overall climatic stability of the region, the vulnerability of *C. montanum* to climate change is likely low.

Conservation Status of **Cypripedium montanum**

It is not known if the distribution of *C. montanum* is increasing or decreasing, however given that the majority of occurrences are situated within recently deglaciated habitats and glaciers are notably shrinking in southeast Alaska, potential habitat may increase in area. However, vegetation success appears to be a natural threat and can decrease potential habitat. The broad range of *Cypripedium montanum* does not equate to abundance because populations are widely scattered and small in size (USDA Forest Service 1994, 2003b, IUCN 2015). Colonies reduced to single or a few plants increase the likelihood that these occurrences will not persist.

There is no documentation to indicate that Alaskan *C. montanum* populations are increasing but a population in Haines was observed to be stable until it was partially destroyed due to human activity. The *C. montanum* population size on the Tongass National Forest is unknown, but the Etolin Island population is estimated to have an upper range of 400 individuals. It is not known if the Etolin Island population size is decreasing or increasing due to the lack of a standard monitoring program and the dormancy traits of the species.

The Etolin Island population habitat is a calcareous fen in an open wet forest and potentially there is suitable habitat available nearby on the island and elsewhere in southeastern Alaska. The limestone influenced stream running through the population may be a limiting factor and restrict the availability of potential nearby habitat. Conversely, the calcareous fen may limit forest and shrub encroachment of the population. If the habitat is altered to favor forest and shrub encroachment, the Etolin Island population would be at risk of extirpation. The frequency and abundance of similar calcareous fen habitat on Etolin Island is unknown and status trends cannot be determined for the Alaska Region. Recent management practices such as road construction, road maintenance and timber harvest may result in some decline of the habitat quality and quantity.

Potential Management of **Cypripedium montanum**

Implications and potential conservation elements

Persistence of viable *Cypripedium montanum* populations in the Alaska Region depends on protecting populations. Desirable environmental conditions for conserving *C. montanum* include sufficiently large areas where the natural ecosystem processes on which the species depends can occur. The distribution of the species in southeastern Alaska (a few small occurrences distributed across a large area in a variety of habitats) represents a natural pattern.

Research on the ecology and distribution of *Cypripedium montanum* will help managers to develop effective approaches to management and conservation. Until there is a more complete picture of the distribution and ecology of this species, given the isolation and single occurrence in the Tongass, priorities lie not only with conserving the known occurrence but maintaining favorable habitat on Etolin Island.

Trends in the demography and the distribution of *Cypripedium montanum* populations in the Alaska Region are difficult to discern without knowledge of the range-wide or historic distribution and the rate of natural events that shape populations. Factors should be considered that are critical to maintaining the present populations, such as ensuring that all elements needed for reproduction and recruitment are identified as well as managing microsite and environmental factors that directly affect the orchid's life cycle. Preserving the habitat of the Etolin population by limiting practices that directly and indirectly alter and disturb the soil and hydrology of the site would have a positive to neutral/stabilizing effect of *C. montanum* on the Tongass National Forest. Those practices as discussed in the threats section include road construction and maintenance, timber harvest activity, and limiting establishment of non-native species. Natural events such as flooding are inevitable and dynamic with the environment, however the severity of such events can be increased due to the human activity. For example, storm runoff from the road could increase sedimentation, and allow for movement of non-native plant propagules into the *C. montanum* habitat.

Tools and practices

Surveys by botanists trained specifically for *C. montanum* survey, are an effective and inexpensive approach for finding new occurrences. Training is especially important because the vegetative form of *C. montanum* resembles that of other geophytic monocots. Survey for *C. montanum* can be complicated by the species' unpredictability of emergence each year due to potential dormancy the aerial stems.

The distribution of *Cypripedium montanum* in southeastern Alaska is documented in Forest Service NRM databases and the Alaska Rare Plant Data Portal managed by the Alaska Natural heritage Program. *Cypripedium montanum* can be documented best in a database format linked to other important spatial layers such as vegetation and soil maps using Geographic Information System (GIS) technology. These databases can be used for mapping and analyzing the species' distribution and enhance survey efforts.

Habitat modeling of *C. montanum* may be of limited value because the likely environmental variables of greatest predictive value are not available on a regional scale for Alaska; additionally with few occurrences, the confidence in the relationship between occurrence records and explanatory variables is reduced. The preferential microhabitat data of the species are not available on a regional scale for Alaska. For example, detailed soil maps would be useful for mapping and modeling potential calcareous bedrock and outcrops in subalpine to alpine areas or those outcrops associated with wet graminoid meadows within the Alaska Region.

Inventories designed for small perennial plant species, such as *Cypripedium montanum*, require an appropriate spatial scale for sampling and should be timed for maximum visibility. Training tools for species identification are important because the vegetative form of *C. montanum* resembles that of other geophytic monocots, particularly *Maianthemum racemosum*. An inventory for *C. montanum* can be complicated by the species' prolonged cryptic growth and the unpredictability of the aerial stems' emergence each year due to dormancy. A standardized training program and set of criteria for noting life stages that can be employed by managers across the species' range would increase the reliability and consistency of data assessments.

Spatial and temporal differences in survey methods complicate comparisons and summaries. Standardizing inventory procedures would allow a network of sample points across the region and provide valid comparisons at the summary level. Data could be assembled into meaningful regional groupings such as habitat types. A rich data set can be used to explore regional trends in weather, disturbance, or use parameters that can be related to population trends.

Population monitoring

A monitoring program that gathers demographic data and ecological information needed for population viability estimates is useful for land managers, but it is time consuming to implement and maintain (Pavlik 1996). Population trend monitoring, however, is commonly used by rare plant managers because it provides a basis for predicting future population viability at lower cost (Elzinga et al. 1998). A model that can detect population trends under different management and human use scenarios may be designed to be sensitive to disturbance. However, the single population of *C. montanum* on the Tongass would not give a model sufficient statistical power, so the population would be treated like a case study. Nevertheless, monitoring all southeastern Alaska occurrences could help to identify appropriate management practices that will ensure population persistence.

Annual monitoring would be most desirable for the first several years of a monitoring program in order to gain insight into the demographic dynamics of *Cypripedium montanum*. The longevity of *C. montanum* and length of time for an individual to complete its life-cycle may require repeated measures over a number of years in order to better determine long-term stability of the populations (Tamm 1991, Pavlik 1996). To document important demographic parameters (mainly seedling recruitment, adult stages, mortality, flowering, fruit set), two visits per growing season may be required: at first when seedlings have fully emerged and mature plants are flowering, and again after capsules have matured. These visits should occur in late June to early July and again in mid to late August. The second visit is necessary to determine pollination success, fecundity, and herbivory damage since flowers and fruits appear to be most susceptible. The most sensitive measure of population stability may be recruitment success. For large populations, using an appropriate sampling scheme can produce valid population trend data. Elzinga et al. (1998) offer additional suggestions regarding sampling design and protocol including the use of photo point monitoring.

A monitoring program that addresses population, habitat, and effects from human activities or natural disturbance might have the following elements:

- effects of disturbance to and adjacent to the population.
- demographic changes (e.g., patterns of recruitment, flowering and fruit set, mortality)
- long-term effects of particular types of management practices (e.g., road maintenance, timber harvest) to determine the impact of action on survival
- reporting changes in occurrence status including new occurrences to Alaska Natural Heritage Program and to the forest/district botanists.

An established monitoring system would allow land managers to monitor population declines and also the demography of the specie. Population monitoring of *C. montanum* is challenged by the fact that plants do not necessarily produce aerial stems every year. Population monitoring is also challenged by the clonal habit of *C. montanum* because it is difficult to determine if aerial stems are ramets of a clone from the same rhizomatous source. For monitoring purposes and to collect demographic information, each stem is treated as a countable unit. A clone of multiple stems (ramets) should be recorded as a clone and each stem noted individually as well. It is important that flowering when it occurs is recorded for each stem identified as being a ramet of a clone.

Small fixed labels or pins on a random sample of individuals in the population would be one of the most beneficial aspects to a monitoring program which contains a demography study for the species. This would allow the tracking of the dormancy of individuals that would allow land managers better estimate population sizes than relying on fluctuating data. It would also allow the tracking of flowering and reproductive success for a few individuals in addition to the population as a whole. Lastly, tracking the plant in various life history stages would further train individuals on identification. Alternatively, established line intercept transects can capture similar data of *C. montanum* population census with a less chance of losing samples due to not being able to find specific individuals again but loses the resolution of individual life cycles. Line intercept transects can also be used to monitor changes in vegetation and hydrology. However without fully understanding the dormancy cycle or physical attributes of dormancy stages of *C. montanum*, population estimates may have a high rate of error.

Habitat monitoring

Because habitat conditions influence demographic changes in populations (Lindborg and Ehrlén 2002), monitoring those conditions that are most directly related to the population dynamics of *Cypripedium montanum* would provide the most relevant and useful information. Identifying factors that constitute favorable habitat for the persistence of the species is a high priority, but difficult with only one known population. Those factors might include identifying at each occurrence, plant associations, density or cover of the herbaceous layer, physical site characteristics (e.g., aspect, elevation, soil type and substrate, proximity to water) and any disturbances from animal and/or human factors (Elzinga et al. 1998).

Habitat monitoring concurrently with population monitoring would be most convenient. The habitat and site information are incorporated into a single field form. These data could be compared with habitat identified as suitable but unoccupied by the orchid. Documenting habitat conditions that may change or are affected by disturbance is important in identifying if and how habitat changes are affecting population dynamics.

Recording invasive species augments understanding habitat requirements and management needs. Monitoring for invasive non-native species will provide needed information to take proactive measures and to prevent their spread.

Increasing awareness among USFS personnel and educating field staff in identifying the species and making habitat assessments would expedite species inventory. A network of informed observers would increase the probability of finding new occurrences and detecting adverse events on existing occurrences. Coordinating *C. montanum* work with the National Park Service and Bureau of Land Management would result in benefits to all three agencies and to the orchid.

Information Needs

Population issues

Knowledge of factors that affect *Cypripedium montanum* distribution is a key element to conserving the species because the population of *C. montanum* in the Alaska Region is small, making it vulnerable to extirpation. Although the known distribution of *C. montanum* is localized on Etolin Island, it may be underrepresented because potential habitats have not been surveyed. An accurate representation of the distribution of a species on the edge of its range is important in determining trends for the species as a whole. Because *C. montanum* populations in southeastern Alaska are at the edge of the species range, they may be more genetically divergent (Lesica and Allendorf 1995). To determine the relation between the populations' spatial distribution and the species' gene distribution, a genetic analysis should include regional sampling of the nearest populations in adjacent states and, ideally, across the species' full range. Using results of the genetic analysis it may be possible to track the history of *C. montanum* in southeastern Alaska.

Historic occurrences merit investigation to determine if changes in habitat could be associated with occurrence loss. However, as outlined above, locations of historic populations may be erroneous (e.g. the Stikine River sighting) or already relocated. A survey attempting to relocate the Stikine population was unsuccessful because of the erroneous location. The specimen was collected at Stikine Glacier “Station 14” (University of Minnesota Herbarium).

Despite a potential data gap, an analytical approach to evaluating diverse *C. montanum* habitats is also needed. Maps of potential habitats could be based on information from known occurrences and include habitats that match those in which *C. montanum* occur. In this way, core areas of distribution and key habitat areas could be defined.

The longevity of viable seed in a natural seed bank is unknown for *C. montanum*. Persistence of a seed bank depends on the species accumulating and maintaining more seed in the seed bank than the parent plant's annual seed production. This does not take into account fluctuations in the amount of seed produced each year. Complicating the ability to assess whether *C. montanum* seeds exist in a seed bank is the seed's almost microscopic size, light weight, and dispersal by wind and water (Arditti 1967).

Little is known about population trends of *C. montanum*, due to a lack of a standard protocol in the Alaska Region. Baseline population size data are difficult to acquire unless, at a minimum, an annual census of each population is taken for a number of years. Monitoring data on the Alaska Region is superficial, but still informative and can still serve as inferential data without being included into any demography statistics. Historic records as well as known occurrences are few in number, but with greater coverage by surveys and species specific inventories, more occurrences might be documented. Basic life history parameters need to be determined from which the viability of occurrences can be inferred.

Information generated from autecological studies would aid in developing more precise criteria for determining appropriate habitat. With a more precise definition of suitable habitat, interpretation of unoccupied habitat would be more accurate. Information on soil microbiology might yield valuable insights into the ecological requirements of *C. montanum*, which would facilitate effective habitat monitoring and conservation stewardship of this species. Evaluations of soil moisture and light parameters correlated to specific environmental conditions that limit *C. montanum* growth and life cycle would help in modeling the species' distribution.

The role of herbivory in the ecology of *Cypripedium montanum* is not understood. Current data are inadequate for forming conclusions as to whether insect predation or herbivory has a significant effect on biomass, reproductive success, or population viability. The role of herbivory by ungulates such as Sitka blacktailed deer and non-native elk on the Etolin Island population needs to be clearly defined. Climatic changes could create conditions for invasions of competitive plants and predatory insects.

Cypripedium montanum populations have not been evaluated to determine whether metapopulation structure and dynamics are critical factors in its long-term persistence at local or regional scales. Migration, extinction, and colonization rates of *C. montanum* are unknown; however, genetic analysis of populations in southeastern Alaska and adjacent British Columbia could shed light on these unknowns.

The population structure and demography of *C. montanum* occurrences have not been characterized. Little information on growth, survival, and reproduction rates has been collected in southeastern Alaska. Knowledge of species distribution is incomplete; therefore, demographic information needs to be gathered before local and range-wide persistence can be assessed with demographic modeling techniques. Short-term demographic studies, particularly for a species with a complex life cycle, result in misleading information; therefore, an approach that incorporates complementary information, such as historical data and experimental manipulations, should be included whenever possible (Lindborg and Ehrlén 2002).

Restoration methods

Restoration of sensitive or rare orchid species, whether through *in situ* or *ex situ* conservation, is controversial and debated in the literature (IUCN/SSC 1996, Koopowitz 2001). The IUCN/SSC Orchid Specialist Group (1996) recommended that protected areas include small as well as large habitat patches and once established, should be monitored and managed. Propagating orchids from collected seed for introductions in a forested habitat has been successful but can take several years for establishment and resilience (Huber 2002). Reintroductions require more information about seed management and handling and the proper timing, soil preparation, and techniques for sowing. Since the Etolin Island population is geographically isolated, it likely is undergoing its own evolutionary course and therefore seed should originate from this source alone. If other nearby populations of *C. montanum* are found on Etolin Island, they may serve as an additional source of seed.

Research priorities

Criteria for prioritizing research should be based on filling knowledge gaps discussed above. Research should also provide the ability to accurately project future scenarios for species persistence. Research could address, for example, the dependency of population dynamics of

C. montanum on specific mycorrhizal fungal relationships or pollinator relationships. Research that addresses increasing understanding of the species' life cycle, genetic structure, and essential elements of its habitat will help in not only maintaining the species but also provide capability to predict disturbance responses. Spatial analysis of distribution and habitat that include historic climatic and large disturbance effects also would aid in projecting future distribution and abundance of the species under different long-range climate scenarios.

The response of *Cypripedium montanum* to human impacts and disturbance has not been studied in southeastern Alaska. Gaining practical knowledge of how best to manage *C. montanum* populations is of considerable importance, given the rapid change in land use patterns, and increasing recreational use. Relevant research topics for *C. montanum* in the Alaska Region include the following:

- change and effects of disturbance on temporal and spatial distribution, abundance, and available habitat;
- habitat and environmental factors associated with seed germination and seedling establishment;
- factors that affect dormancy;
- pollinators on the Tongass NF and factors that affect pollination success and seed production;
- habitat requirements of pollinators
- factors that influence recruitment and seedling mortality;
- factors that affect fungal symbionts' association with *C. montanum;*
- genetic provenances and genetic structure; and
- *in situ* techniques for increasing small populations.

Definitions

Autotroph – organism capable of converting carbon dioxide into metabolic carbon for its own use (phototroph, through photosynthesis, chemotroph, through chemical metabolism).

Capsule – dry, dehiscent fruit.

Damping off – sudden plant death in the seedling stage due to the attack of pathogenic fungi; the extent of damage is related to the fungus, soil moisture, and temperature.

Effectiveness monitoring – monitoring that determines if management activities are effective in producing desired conditions.

Fusiform – elongated and tapered at each end like a football.

Geophyte – a perennial plant having perennating buds located below soil surface, for example, on a rhizome.

Geotropic – oriented in response to gravity.

Hybrid swamping – the concept that a common species can cause the extinction of a rare species by hybridizing with it and "swamping" the unique genetic profile of the rare species.

Implementation Monitoring – monitoring that determines if management activities are designed and carried out in compliance with forest plan direction and management requirements.

Insolation – reception of solar radiation.

Labellum – the pouch or lip of the orchid flower derived from a modified petal.

Mycorrhizae – symbiotic relations of plant roots and fungi.

Mycotrophic – living symbiotically with a fungus and nutritionally dependent on fungus.

Perennating bud – the bud of a perennial plant that overwinters in a dormant state and sprouts the following spring.

Perennial – a plant that normally lives for more than two seasons.

Phenotypic plasticity – the capacity for marked variation in the morphology of an organism as a result of environmental influences.

Pollinia – a mass of pollen grains packed as a single unit.

Protocorm – a pre-rhizoid structure that develops from the germinating embryo putatively with a fungal symbiont and from which roots and shoot eventually develop.

Pubescent – covered with hair.

Ramet – a member of a clone such as rooted cuttings or rhizomatous shoots that are identical genetically but can live independently.

Recruit – the addition of new members to a population through reproduction.

Rhizomatous – possessing underground stems that often produce roots and shoots.

Self-sustaining populations – populations that are sufficiently abundant, interacting, and well distributed in the plan area, within the bounds of their life history and distribution of the species and the capability of the landscape to provide for their long-term persistence, resilience, and adaptability over multiple generations.

Sensitive species – those species for which population viability is a concern and identified by a regional forester as requiring special management as directed in FSM2670.

Seral – pertaining to an early stage of succession.

Staminode – a sterile stamen and in *C. montanum* a structure that partially covers the pouch opening.

Symbiont – an organism that interacts in a relation with another organism − maybe, but not always, to their mutual benefit.

Sympatric – species or populations that inhabit the same or overlapping geographic areas

Sympodial bud – a lateral bud that forms just behind the tip of a composite axis, elongating the axis.

Synsepal – two fused or partially fused lateral sepals found in *Cypripedium* species.

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Authors Biography

The current version of the *Cypripedium montanum* Conservation Assessment was revised by the Botany Program of Alaska Natural Heritage Program (AKNHP), University of Alaska Anchorage (UAA). AKNHP collects, synthesizes, and validates information on Alaska's animal and plant species of concern and their habitats, ecosystems of concern, and invasive species. This information is provided by AKNHP to government, business, land managers, scientists, conservation groups, and the public.

The botany program conducts research on the biology of rare and invasive plant species and participates in citizen science initiatives. The program is directed under Dr. Matthew Carlson, who also teaches in the Department of Biological Sciences at UAA. Areas of research expertise for the botany program include habitat modeling, biogeography of rare and invasive plants, reproductive ecology and evolution, and ecological impacts of non-native plants. The botany program also offers a wide range of related services including field surveys, monitoring studies, mapping, and conservation planning services. The AKNHP botany program also manages the University of Alaska Anchorage Herbarium (UAAH) which holds an extensive representation of Alaska's flora, including rare Alaskan plants, non-native plants, and cryptograms. Over 14,000 specimens are in the collection and can be viewed online at: http://www.pnwherbaria.org/

The botany program has extensive experience with rare plant conservation in Alaska and is an authority figure for assigning state level conservation ranks. Notably, the Alaska Rare Plant Field Guide has been published to aid in the identification, distribution, and ecology for plants of conservation concern in Alaska. The botany program is also the central repository of biological information on Alaska's rare and invasive plant species and tracks over 600 plant species. Lists of vascular plants and lichens of conservation concern of selected rare plants of Alaska are located on the Rare Plants page. AKNHP works closely with botanists across Alaska in an effort to ensure the most comprehensive and accurate data sets.

Nan Vance, research plant physiologist (emeritus) was an employee of the USDA Forest Service for 20 years and a research plant physiologist for 17 years, serving as team leader of the Biology and Culture of Forest Plants Team, at the Pacific Northwest Research Station in Corvallis, Oregon for seven years. She has a Ph.D. from Oregon State University in plant physiology with a minor in biochemistry. She has 25 years of research experience and more than 40 publications in plant physiology, restoration, and reproductive biology on a variety of plants native to the Intermountain West and Pacific Northwest.