Malaxis brachypoda (A. Gray) Fernald (white adder's-mouth orchid): A Technical Conservation Assessment

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Author's Biography

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Cover Photo Credit

Malaxis brachypoda (white adder's-mouth orchid). Photograph by Bill Jennings, used with permission.

Orchids

They lean over the path,
Adder-mouthed,
Swaying close to the face,
Coming out, soft and deceptive,
Limp and damp, delicate as a young bird's tongue;
Their fluttery fledgling lips
Move slowly,
Drawing in the warm air.

And at night,
The faint moon falling through whitewashed glass,
The heat going down
So their musky smell comes even stronger,
Drifting down from their mossy cradles:
So many devouring infants!
Soft luminescent fingers,
Lips neither dead nor alive,
Loose ghostly mouths
Breathing.

–Theodore Roethke (1948)

Summary of Key Components for Conservation of *Malaxis brachypoda*

Status

Malaxis brachypoda (white adder-mouth's orchid) occurs in the Great Lakes Region, New England, and from Newfoundland west across Canada to British Columbia and southern Alaska, with disjunct populations in Colorado, California, and Japan. In USDA Forest Service (USFS) Region 2, *M. brachypoda* is known from four occurrences in Colorado. In 1895, it was discovered at an uncertain location in El Paso County, but it has not been seen since. It was found in Boulder County in 1906, where it is known from two occurrences last seen in 1970 and 1990 on land owned by the City of Boulder. A location was discovered on private land in Jefferson County in 1970 or 1971, and this occurrence was last seen in 1989. Attempts have been made to relocate all of these occurrences within the last 15 years, without success. None of the four occurrences is known from National Forest System land, but the likelihood of finding occurrences in Colorado's national forests is high. The largest population documented in Colorado consisted of seven individuals.

Malaxis brachypoda is a sensitive species in Region 2 because it is disjunct and extremely rare in Colorado, because potential habitat exists on National Forest System land, and because there are documented threats to the species and its habitat. *Malaxis brachypoda* is also a sensitive species in USFS Region 9. The global conservation status rank for *M. brachypoda* is G4Q (apparently secure, although with concern for its long-term viability). The Q indicates that there are questions regarding its taxonomic status. It is considered critically imperiled (S1) in Colorado. *Malaxis brachypoda* has endangered, threatened, or other status in ten U.S. states and one Canadian province.

Primary Threats

In order of decreasing priority, threats to *Malaxis brachypoda* in Region 2 include effects of small population size, hydrologic alterations, residential and commercial development, collection, fire, recreation, timber harvest and fuels reduction, road construction and maintenance, livestock grazing and herbivory, exotic species invasion, climate change, and pollution. These threats and the hierarchy ascribed to them are highly speculative, and the magnitude of specific threats differs at each occurrence.

Primary Conservation Elements, Management Implications and Considerations

Malaxis brachypoda is Colorado's rarest orchid. Existing data for *M. brachypoda* in Region 2 portray a species that is on the brink of local extinction due to demographic stochasticity and human impacts to its habitat. The failure to find any plants of this species since 1990 despite intensive surveys by experts, suggests that it may already be extirpated in Region 2, although it is possible that populations await discovery in South Dakota, Wyoming or Colorado. The challenges of finding this species are so great that other occurrences, if they exist, could easily remain undetected.

Even if other occurrences are found, the habitats of *Malaxis brachypoda* are threatened throughout Region 2. Given current distribution patterns, there is only a minute chance of natural reintroduction of *M. brachypoda* if an occurrence is extirpated. The need for conservation action is apparent and urgent. Protected land status designation would benefit *M. brachypoda* if any populations are discovered on National Forest System land in Region 2. The Wellington Lake occurrence on private land may benefit from additional protection.

Conservation elements for *Malaxis brachypoda* are understood to a limited extent through observations, mostly from outside Region 2. There has been very little quantitative research on this species. Human-induced habitat loss and disturbance, decreased canopy cover, increased soil temperature, competition, hydrologic change, and impacts to pollinators are all factors that would contribute to this species' decline. Hydrologic integrity of its habitat appears to be very important for its persistence, but many factors threaten this element throughout the species' range. Impoundment, ditching, roads, and trails all may be affecting critical hydrologic attributes within occurrences in Region 2.

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INTRODUCTION

This assessment is one of many being produced to support the Species Conservation Project for the Rocky Mountain Region (Region 2) of the USDA Forest Service (USFS). *Malaxis brachypoda* (white adder's-mouth orchid) is the focus of an assessment because it is a sensitive species in Region 2. Within the National Forest System, a sensitive species is a plant or animal 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 its distribution (FSM 2670.5(19)). A sensitive species may require special management, so knowledge of its biology and ecology is critical.

This assessment addresses the biology of *Malaxis brachypoda* throughout its range in Region 2, but because there is very little information of any sort on this species in Region 2, this assessment relies heavily on studies from outside Region 2 and on inference from close relatives of *M. brachypoda* that have been studied more closely. The broad nature of the assessment leads to some constraints on the specificity of information for particular locales. This introduction defines the goal of the assessment, outlines its scope, and describes the process used in its production.

Goal of Assessment

Species assessments produced as part of the Species Conservation Project are designed to provide forest managers, research biologists, and the public with a thorough discussion of the biology, ecology, conservation status, and management of certain species based on available scientific knowledge. 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 seek to develop specific management recommendations. Rather, it provides the ecological background upon which management must be based and 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 examines the success of those recommendations that have been implemented.

Scope of Assessment

The assessment examines the biology, ecology, conservation status, and management of *Malaxis brachypoda* with specific reference to the geographic and ecological characteristics of Region 2. Although a majority of the literature for the species may originate from field investigations outside the region, this document places that literature in the ecological and social context of the central Rocky Mountains. Similarly, this assessment is concerned with reproductive behavior, population dynamics, and other characteristics of *M. brachypoda* in the context of the current environment rather than under historical conditions. The evolutionary environment of the species is considered in conducting the synthesis, but placed in a current context.

In producing the assessment, peer-reviewed literature, non-refereed publications, research reports, and data accumulated by resource management agencies and other investigators were reviewed. The assessment emphasizes peer-reviewed literature because this is the accepted standard in science. Non-refereed publications or reports were regarded with greater skepticism, but they were used in the assessment because there is very little peer-reviewed literature that specifically treats *Malaxis brachypoda*. Unpublished data (e.g., Natural Heritage Program records, reports to state and federal agencies, specimen labels) 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.

Because there have been no studies of most facets of the biology of *Malaxis brachypoda*, literature on its congeners was used to make inferences in many cases. The peer-reviewed and non-refereed literature for the genus *Malaxis* and its included species is more extensive and includes other endemic or rare species. All relevant publications dealing with *M. brachypoda* are referenced in this assessment, and many of the experts on this species were consulted during its synthesis. We searched for specimens at University of Colorado Herbarium (COLO), CSU Herbarium (CS), Rocky Mountain Herbarium (RM), Kalmbach Herbarium, Denver Botanic Gardens (KHD), San Juan College Herbarium (SJNM), Carter Herbarium (COCO), University of Northern Colorado Herbarium (GREE), New Mexico State University Range Science Herbarium (NMCR), and University of New Mexico Herbarium (UNM). All available specimens of *M. brachypoda* in Region 2 were viewed to verify populations and to incorporate specimen label data.

Treatment of Uncertainty in Assessment

Science represents a rigorous, systematic approach to obtaining knowledge. Competing ideas regarding how the world works are measured against observations. However, because our descriptions of the world are always incomplete and our observations are limited, science focuses on approaches for dealing with uncertainty. A commonly accepted approach to science is based on a progression of critical experiments to develop strong inference (Platt 1964). However, it is difficult to conduct experiments that produce clean results in the ecological sciences. Often, observations, inference, good thinking, and models must be relied on to guide our understanding of ecological relations. While well-executed experiments represent a strong approach to developing knowledge, alternative approaches such as modeling, critical assessment of observations, and inference are accepted as sound approaches to understanding.

Treatment of This Document as a Web Publication

To facilitate use of species assessments in the Species Conservation Project, they are being published on the Region 2 World Wide Web site. Placing the documents on the Internet makes them available to agency biologists and the public more rapidly than publishing them as reports. Web publication will also facilitate the revision of the assessments, which will be accomplished based on guidelines established by Region 2.

Peer Review of This Document

Assessments developed for the Species Conservation Project have been peer reviewed prior to their release on the Web. This assessment was reviewed through a process administered by the Society for Conservation Biology, employing two recognized experts on this or related taxa. Peer review was designed to improve the quality of writing and to increase the rigor of the assessment.

MANAGEMENT STATUS AND NATURAL HISTORY

Management Status

Malaxis brachypoda was placed on the Region 2 sensitive species list in 1993 (USDA Forest Service 1993). Its status as a sensitive species in Region 2 was re-evaluated in 2002 (Burkhart 2002, Warren and Redders 2002), and it remained on the region's revised sensitive species list (USDA Forest Service 2003). *Malaxis brachypoda* was determined to warrant sensitive species status because it is disjunct and very rare in Region 2, because potential habitat may exist on National Forest System land, and because potential threats to habitat exist (Warren and Redders 2002).

Malaxis brachypoda's presence in Region 2 is limited to four occurrences in Colorado. While there is much apparently suitable habitat on national forests in Region 2, none of the known occurrences is on National Forest System land. The City of Boulder's Open Space and Mountain Parks Department manages two occurrences. These occurrences are protected from the direct effects of residential development and extractive land uses. Another occurrence was last seen in 1895 at Green Mountain Falls in El Paso County; its exact location and status is unknown. It may have been collected on the Pike National Forest. A fourth occurrence at Wellington Lake is on private land, very near the Pike National Forest.

Inclusion on the Region 2 sensitive species list would afford some protection to the species if it were to known to occur on National Forest System land. Species are designated as sensitive when they meet one or more of the following criteria:

- ❖ the species is declining in numbers or occurrences, and evidence indicates it could be proposed for federal listing as threatened or endangered under the Endangered Species Act if action is not taken to reverse or stop the downward trend
- ❖ the species' habitat is declining, and continued loss could result in population declines that lead to federal listing as threatened or endangered under the Endangered Species Act if action is not taken to reverse or stop the decline
- ❖ the species' population or habitat is stable but limited (USDA Forest Service 2003).

In the case of *Malaxis brachypoda*, the second criterion is most applicable, since there are no occurrences known from National Forest System land in Region 2.

Because it is designated sensitive in Region 2, the Regional Forester must give consideration to this species in order to maintain its habitat and occurrences (see Forest Service Manual 2670). Issues regarding sensitive species must be addressed in all environmental assessments within suitable habitat. Collecting sensitive species is prohibited without a permit (see Forest Service Manual 2670). The USFS can modify management plans, projects, or contracts to consider *Malaxis brachypoda* on a discretionary basis. Biological assessments and evaluations are conducted when applications for permits for various land uses are evaluated, and impacts to sensitive species can be mitigated.

Malaxis brachypoda is also considered sensitive in Region 9 on the Hiawatha and Huron-Manistee national forests (Schultz 2003). This species is not included on the Bureau of Land Management Sensitive Species List for Colorado (Bureau of Land Management 2000).

The global NatureServe rank for *Malaxis brachypoda* is G4Q (NatureServe 2005, Colorado Natural Heritage Program 2005). The global conservation status (G) rank is based on the status of a taxon throughout its range. A rank of G4 is ascribed to taxa that are apparently secure, but for which there is some cause for long-term concern due to declines or other factors (NatureServe 2005). These species may be uncommon or rare in portions of their range. The Q rank indicates that the taxonomic distinctiveness of this species at the current level is questionable. The taxonomic issues related to this species are discussed in the Classification and description section of this assessment.

Within the states of Region 2, *Malaxis brachypoda* is known only from Colorado. The subnational rank for this species in Colorado is S1. This rank is based on the status of a taxon in an individual state or province, using the same criteria as those used to determine the global rank. A rank of S1 is ascribed to taxa that are critically imperiled. This ranking reflects the extreme rarity and imperilment of this species in the state.

Malaxis brachypoda has protected status in ten states (**Table 1**). It is listed as endangered in Connecticut, Maine, Massachusetts, New Hampshire, New Jersey, and Pennsylvania. It is considered exploitably vulnerable in New York and threatened in Vermont (USDA Natural Resources Conservation Service 2005). It has legal status in five states (Connecticut, Maine, New Hampshire, Massachusetts, and Vermont) and in British Columbia. *Malaxis brachypoda* was added to the Minnesota Species of Special Concern list in 1995 because surveys indicated that only 18 small colonies remained extant (State of Minnesota 1995). California designates *M. brachypoda* as endangered, threatened, and rare, all of which have legal status. It also appears on Inventory List 1B in California, which includes species that are rare, threatened, or endangered throughout their range; this designation carries no legal status (Hickman 1993). Plants are not included as protected species under Colorado's endangered species law.

Malaxis brachypoda has no status under the Endangered Species Act of 1973 (U.S.C. 1531-1536, 1538-1540). It is not listed as endangered or vulnerable by the International Union for Conservation of Nature and Natural Resources (Ayensu and DeFilipps 1978, Hagstater and Dumont 1996), but there is concern for the viability of all orchid species (Koopowitz 2001).

Section 176 of the charter for the City of Boulder Open Space and Mountain Parks Department (OSMP) includes the preservation or restoration of natural areas based on outstanding or rare examples of native species, and the preservation of water resources in their natural or traditional state (City of Boulder 2005). The stated management goals of OSMP therefore protect *Malaxis brachypoda* from many possible impacts. The current Visitor Master Plan for OSMP includes new regulations prohibiting off-trail use by humans and dogs in the orchid's habitat (Wanner personal communication 2006).

At Wellington Lake, *Malaxis brachypoda* occurs on private land owned by the Wellington Reservoir Company. This occurrence is near a USFS road, although because there are no right-of-way easements along USFS roads, the Pike National Forest has no jurisdiction over this occurrence (Vest personal communication 2005).

Existing Regulatory Mechanisms, Management Plans, and Conservation Strategies

Adequacy of current laws and regulations

No federal or state laws explicitly protect *Malaxis brachypoda* in Region 2. As Colorado Native Plant Society (1997) noted, "This is another orchid that is uncommon, yet is afforded no federal protection." On privately owned lands, current laws and regulations may be inadequate to prevent occurrences and habitat from being damaged or destroyed. In the absence of formal laws, regulations, or a detailed conservation strategy, assessing the adequacy of current management practices is difficult due to the lack of quantitative information on population trends for *M. brachypoda*.

Table 1. Summary of global and subnational conservation status of *Malaxis brachypoda* in North America (Kartesz 1999, Catling and Magrath 2002, NatureServe 2005). Listing status is in bold for states and provinces where *M. brachypoda* is protected by law.

Nation	State/Province	Conservation Status Rank	State/ Province Listing Status	Population Status
USA	Alaska	SNR	None	
USA	California	S1	Proposed Endangered/ Threatened	
USA	Colorado	S1	None	
USA	Connecticut	SNR	**Endangered**	
USA	Illinois	S1 (should be SH)	None	Not seen in many years
USA	Indiana	SNR	None	Possibly extirpated
USA	Maine	SNR	**Endangered**	
USA	Massachusetts	S1	**Threatened**	
USA	Michigan	SNR	Special Concern	
USA	Minnesota	S3	Special Concern	
USA	Nebraska	not ranked	None	Erroneous report
USA	New Hampshire	SH	**Endangered**	Not seen in many years
USA	New Jersey	SH	None	Extirpated
USA	New York	SNR	None	
USA	Pennsylvania	S1	Proposed Endangered/ Threatened	
USA	Tennessee	SNR	None	Erroneous report
USA	Texas	SNR	None	Erroneous report
USA	Vermont	S2S3	**Threatened**	
USA	Wisconsin	S3	Special Concern	
Japan	Unknown	N/A	Unknown Status	
Canada	Alberta	SNR	None	
Canada	British Columbia	S2S3		
Canada	Labrador	SU	None	
Canada	Manitoba	S2?	None	
Canada	New Brunswick	S1	None	
Canada	Newfoundland	S3	None	
Canada	Northwest Territory	SNR	None	
Canada	Nova Scotia	S1	None	
Canada	Ontario	S4	None	
Canada	Quebec	S3	None	
Canada	Saskatchewan	S1S2	None	
Canada	Yukon Territory	SNR	None	

Adequacy of current enforcement of laws and regulations

There have been no documented cases in which an occurrence of *Malaxis brachypoda* was extirpated due to human activities or the failure to enforce any existing regulations in Region 2. Until very recently, there were no regulations designed specifically to protect *M. brachypoda*. The City of Boulder Open Space and Mountain Parks Department recently enacted a management plan that includes actions designed to protect the occurrence at Greenman Springs, including prohibiting off-trail hiking without a permit and unleashed dogs. However, there is no clear evidence that current regulations or their enforcement are adequate for its protection.

Outside Region 2, it appears that *Malaxis brachypoda* has declined in many parts of its range (see the Population trend section for details). It is unclear whether these declines resulted from inadequate enforcement of laws and regulations. It is also unclear whether enforcement of any law or regulation could have prevented these extirpations. Loss of peripheral and disjunct populations can reduce the genetic diversity of a species as a whole, as well as reduce its resilience in the face of genetic, demographic, and environmental stochasticity.

Biology and Ecology

Classification and description

Malaxis comes from the Greek word *malakos*, which means soft or delicate, perhaps in reference to the tender nature of the plant (Britton and Brown 1913, Munz and Keck 1968). *Brachypoda* is also derived from Greek, and means "short-foot," in reference to the short pedicel of the flower (Coleman 1999). Many authors classify *M. brachypoda* as a variety of *M. monophyllos*. The epithet *monophyllos* is Greek for "single leaf," in reference to the form of the plant (Coleman 1999).

Malaxis brachypoda is a member of the orchid family (Orchidaceae). The vast majority of orchid species are found in tropical rainforests, where the family has undergone tremendous adaptive radiation to become the most speciose family of vascular plants. Most orchid species are epiphytic, living exclusively attached to trees, although the epiphytic orchids evolved from terrestrial ancestors (Sanford 1974, Cameron 2005).

The genus *Malaxis* is included within the tribe Malaxideae (Dressler 1981). The Malaxideae contains about 1000 species, mostly in three genera: *Malaxis*, *Liparis*, and *Oberonia*. The Malaxideae contains a mixture of terrestrial and epiphytic species, but this tribe is interesting in that its terrestrial species appear to have evolved from epiphytic ancestors. Thus, the epiphytic habit appeared throughout this group, but some lineages returned to the ancestral terrestrial habit (Cameron 1999).

The Malaxideae is in the Cymbidioid Phylad with Calypsoeae, Cymbidieae, and Maxillarieae (Dressler 1993). These tribes all have distinct seed types, with longitudinal, rather than reticulate, thickenings and distinctive, emergent cell corners. *Malaxis* is in subfamily Epidendroideae and is most closely related to the Dendrobieae (Cameron et al. 1999). The Malaxideae are unusual among orchids because they have "naked pollinia" (Dressler 1981). In *Malaxis*, a single, terminal, incumbent anther usually contains four naked pollinia. Naked pollinia (i.e., devoid of accessory structures) are known from only a few other groups of higher epidendroid orchids, notably the Dendrobiinae and Collabiinae (Cameron 2005). See the Reproductive biology and autecology section for more information on the pollinia of *M. brachypoda*.

The classification of the Malaxidae has challenged taxonomists for many years. Dressler (1981) noted that the boundaries between *Malaxis* and *Liparis* are poorly defined. Among orchids, the characters of the flower have traditionally been those upon which all phylogenetic inference was based. However, Cameron (2005) found that among the Malaxideae, vegetative characters were more valuable for inferring phylogenetic relationships. In a preliminary cladistic analysis using both genetic and morphological data from 71 taxa, Cameron (2005) observed that *Malaxis* and *Liparis* mixed, but tended to form monophyletic subclades. The subclade that includes *M. brachypoda* contains all terrestrial species with conduplicate (folded in half lengthwise) leaves in *Liparis* and *Malaxis*. Cameron suggested that a reclassification of the tribe is needed that will include at least seven genera, but more taxa must first be sampled before the groups within the tribe can be resolved. Of the 71 taxa sampled by Cameron (2005), *M. brachypoda* was most closely related to *M. tenuis* of New Mexico and Arizona (Kartesz 1999) and *M. corymbosa* of Arizona (Kartesz 1999).

Many species of *Malaxis* have been described in the last century. Britton and Brown (1913) characterized *Malaxis* as a genus of 45 widely distributed species. Munz and Keck (1968) described it as a genus of 150 species. Now it is known to contain 250 (Catling and Magrath 2002) to 300 (Mabberley 1997) species.

Malaxis monophyllos was first described by Linnaeus in 1753 (as *Ophrys monophyllos*). This taxon was moved to the genus *Malaxis* by Olof Peter Swartz in 1800. In 1830, John Lindley, in his monumental *The Genera and Species of Orchidaceous Plants*, placed this taxon in the genus *Microstylis*. However, the genus *Microstylis* is no longer used today.

Lindley drew no distinctions between material from North America and Europe and included both within *Microstylis monophyllos* (Withner 1959, Luer 1975). In 1835, Asa Gray concluded that the North American plants differed enough from their European counterparts to warrant status as a separate species, *Microstylis brachypoda* A. Gray (Fernald 1926). In

1926, Fernald reinstated Gray's *Microstylis brachypoda* under *Malaxis* as *Malaxis brachypoda* (Fernald 1926).

The primary difference between the European and North American plants is the degree of twisting of the pedicel. The North American plants have pedicels that are twisted 180°, resulting in the lip being in the lowest position in the flower (resupinate). This condition is common throughout the orchid family. The pedicel of *Malaxis monophyllos* in Europe is twisted 360° so that the lip returns to the uppermost position in the flower, a condition referred to by Cameron (2005) as "hyper-resupinate."

There has been much contention on whether *Malaxis brachypoda* should be considered a full species or merely a variety of *M. monophyllos*. Fernald (1926) had noted differences in the relative size of the flowers and comparative length of the pedicels and capsules in describing differences between *M. monophyllos* and *M. brachypoda*, and noted that the inflorescences of *M. brachypoda* were shorter on average than those of *M. monophyllos*. These differences, as well as the differences in resupination discussed above, were the basis upon which Fernald distinguished these taxa at the species level.

Morris and Eames (1929) reduced *Malaxis brachypoda* to a variety of *M. monophyllos* (= *M. monophyllos* var. *brachypoda*). Fernald responded to this in 1933 with a paper in which he presented photographs of the specimens he measured when describing *M. brachypoda*, and criticism of Morris and Eames' circumscription. Ames (1938) in turn was critical of Fernald's reinstatement of *M. brachypoda* as a full species, noting several errors in his circumscription. Ames (1938) noted that Fernald's measurements of *M. monophyllos* were based on a single specimen, and in re-measuring the dimensions reported by Fernald (1926, 1933), Ames arrived at different dimensions that are similar to those reported for *M. brachypoda*.

Fernald (1926) noted that the primary difference between North American *Malaxis brachypoda* and European *M. monophyllos* was the degree of resupination of the flowers. However, Ames (1938) pointed out that in *M. monophyllos*, the pedicel gradually untwists as the fruit matures. To Ames, this suggested that the taxonomic value of resupination in delimiting species was low, and that *M. monophyllos* and *M. brachypoda* were probably conspecific. Ames (1938) concluded that the basis for elevating *M. brachypoda* to the rank of species was weak. Resupination and column length have been used for defining many groups within the Orchidaceae, but these appear to be of little taxonomic value because they are highly labile (Ames 1938, Cameron 2005). The use of superficial floral characters such as this has resulted in an unnatural system of classification within the Malaxideae (Cameron 2005).

Experts today refer to this taxon both as a species (*Malaxis brachypoda*) and as an infraspecies (*M. monophyllos* var. *brachypoda*). The taxonomic treatment approved by the Flora of North America Editorial Committee is that of Catling and Magrath (2002), *Malaxis monophyllos* var. *brachypoda*. This treatment is also recognized by many experts in the Orchidaceae in important papers and monographs (e.g., Ames 1938, Luer 1975, Correll 1978, Smith 1993) and floras (e.g., Gleason and Cronquist 1991). However, others, including Cameron (2005), use *M. brachypoda*. *Malaxis brachypoda* is the name used by USDA Natural Resources Conservation Service (2005) and Kartesz (1999), and is therefore used throughout this assessment. Ongoing phylogenetic research is likely to result in other nomenclatural changes among the Malaxidae that may affect *M. brachypoda*. Some sources (e.g., Scoggan 1957, Hultén 1968, Brackley 1985, Case 1987) use the name *M. monophylla* var. *brachypoda*. However, *monophyllos* is the correct epithet, as the specific epithet must agree in gender with the genus to conform to the rules of botanical nomenclature (Schultz 2003). **Table 2** is an annotated list of all synonyms of *M. brachypoda* and their sources.

History of knowledge in Region 2

Malaxis brachypoda was first documented in Colorado in El Paso County in 1895 and collected in Boulder County in 1906. It was not found again in Colorado for 64 years, when it was rediscovered in 1970 at Panther Canyon, Boulder County. *Malaxis brachypoda* was found in Jefferson County in 1970 or 1971. The El Paso County occurrence has never been rediscovered and may have been destroyed by development (Colorado Native Plant Society 1997). Intensive searches in other likely sites in Boulder County have been unsuccessful in documenting any new populations (Hogan 1993).

Green Mountain Falls, El Paso County (CO EO #1)

Ernst Athearn Bessey made the first collection of *Malaxis brachypoda* in Colorado at Green Mountain Falls in El Paso County on July 13, 1895. He made this collection while he was a student at the University of Nebraska and at the beginning of his long career

Table 2. Synonyms for *Malaxis brachypoda*. The original source appears in the Citation column; sources using a particular name appear in the "Sources Using Name" column. The currently accepted nomenclature (USDA Natural Resources Conservation Service 2005) is in bold type.

Name and Authority	Citation	Sources Using Name
Ophrys monophyllos Linnaeus pro parte	Species Plantarum 1753 pl. 947	—
Malaxis monophyllos (L.) Sw. pro parte	Kongliga Svenska Vetenskaps Akademiens Handlingar 21:234. 1800	—
Microstylis monophylla Lindl.	Bot. Reg. pl. 1290. 1829	—
Acroanthes monophylla (L) Greene pro parte	Pittonia 2: 183. 1891	Daniels 1906, Rydberg 1907
Malaxis monophyllos var. *brachypoda* (Gray) Morris & Eames	Our Wild Orchids p. 358 1929	Luer 1975, Correll 1978, Gleason and Cronquist 1991, Smith 1993, Catling and Magrath 2002
***Malaxis monophyllos* var. *brachypoda* (Gray) Morris & Eames**	**Rhodora 28: 176. 1926**	**Brown 1997, Chapman 1997, Kartesz 1999, USDA, Natural Resources Conservation Service 2005**
Malaxis monophylla var. *brachypoda*	(not found)	Brackley 1985, Case 1987
Malaxis monophyllos ssp. *brachypoda* (A. Gray) A. Löve and D. Löve	(not found)	Weber and Wittmann 2001
Microstylis brachypoda A. Gray	Ann. Lyceum Nat. Hist. New York 3: 228 1835	—
Monorchis ophioglossoides Mentzel pro parte	Pugil. t. 5 fig. 2	—
Epipactis monophyllos F.W. Schmidt pro parte	Meyer, Phys. Aufs. p. 245 t. iii 1791	—

as a botanist and mycologist (Ewan and Ewan 1981). *Malaxis brachypoda* has not been seen in this area since Bessey's discovery. There have been only casual attempts to search this area for *M. brachypoda*, and suitable habitat for *M. brachypoda* may remain (Jennings personal communication 2005, Olson personal communication 2005). Kim Regier searched without success along the main trail to Green Mountain Falls and along the Thomas Trail on July 27, 1998 (Colorado Natural Heritage Program 2005). Richard Bunn, a botanist from Green Mountain Falls, has not seen *M. brachypoda* in this area despite repeated searches (Kelso personal communication 2005). The area around Green Mountain Falls has been profoundly altered since the late 1800s, and it is likely that *M. brachypoda* no longer exists at this location (Colorado Native Plant Society 1997, Kelso personal communication 2005).

Early collections on Green Mountain, Boulder County

Malaxis brachypoda was first collected on the north slope of Green Mountain on July 9, 1906 by Francis Potter Daniels (*#342* at University of Missouri St. Louis (MO)), and again by Daniels on July 24, 1906 (also *#342* MO). Although both specimens have the same collection number, the locality description and collection date differ (Jennings 1989). The July 9 specimen was from "deep canyons, north slope, Green Mountain, near Boulder, 7000 feet." while the July 24 specimen is from a "Canyon, north slope Green Mountain, 7500 feet." It appears that Daniels collected *M. brachypoda* twice, but whether it was at the same place or at different locations is unknown. He included *M. brachypoda* in his *Flora of Boulder*, *Colorado*, *and Vicinity* (1911), in which he described the habitat of *M. brachypoda* as "Deep canyons on north slope of Green Mountain, very scarce, 6500 to 8100 feet." A photograph of the specimen at University of Missouri Columbia is housed at the University of Colorado Herbarium (COLO).

Greenman Springs, Boulder County (CO EO #2)

The occurrence of *Malaxis brachypoda* at Greenman Springs is the best documented site in Colorado. *Malaxis brachypoda* was found at Greenman Springs in 1978 by Bill Jennings, although this may also be one of the Daniels 1906 localities. Five plants were observed at Greenman Springs in 1978 (Jennings

1989). *Malaxis brachypoda* was collected at Greenman Springs on July 19, 1981 by Lucian M. Long (#*38* at KDH), who reported "a few plants" at this site.

The most recent observation of *Malaxis brachypoda* at Greenman Springs for which details are available was in 1989 by Bill Jennings, Tim Hogan, and Harold Dahnke (Hogan 1989, Jennings 1989). Seven individuals were seen at this location on two different days (Jennings 1989, Jennings personal communication 2005). To find these seven individuals took one full day of searching by each of three individuals (Jennings personal communication 2005). The Greenman Springs element occurrence record states that one plant was seen on July 14, 1990, but the source of this observation is uncertain. Hogan (1993) wrote, "about ten plants seen over the past three seasons," suggesting that *M. brachypoda* was seen more recently than 1989 at this site, but there are no specifics regarding the year or dates of these observations. Hogan (personal communication 2005) does not recall details regarding these observations.

Bill Jennings and Ann Armstrong searched the Greenman Springs site on hands and knees in the summer of 2004; although they saw *Botrychium virginianum*, a good indicator for *Malaxis brachypoda*, the search for *M. brachypoda* was unsuccessful (Jennings personal communication 2005). The area was searched again in 2005 by Chris Wanner, Megan Bowes, and Bill Jennings, again without finding *M. brachypoda* (Crawford personal communication 2005).

Wellington Lake, Jefferson County (CO EO #3)

Steve Blecher discovered *Malaxis brachypoda* at Wellington Lake in Jefferson County in 1970 (Jennings 1989), but the Colorado Native Plant Society (1997) states that this occurrence was discovered in 1971. Blecher revisited this occurrence on June 27, 1971, when he collected a live plant. This plant was grown in a pot until it was pressed on July 10, 1971 by Carlyle Luer and John Long (#*s.n.* at COLO). This is the only specimen from this location, but unfortunately, the number of plants and other information about the occurrence were not documented. Jennings (1989) wrote, "the late Lucian Long of Colorado Springs mentioned visiting the site a few times, but was unable to locate more than one or two plants." On July 15, 1989, Bill Jennings revisited Blecher's site, finding it with some difficulty (Jennings 1989) and finding six individuals within an area of ten square feet. *Malaxis brachypoda* has not been seen again at this location. There have been limited efforts to find plants at this occurrence since 1989. Steve Vest (personal communication 2005) searched for this site in the 1990s but did not find it; he speculates that this occurrence may have been extirpated.

Panther Canyon, Boulder County (CO EO #4)

Steve Blecher reported five *Malaxis brachypoda* plants in Panther Canyon and made a collection (#*s.n.* at COLO) on July 12, 1970 (Jennings 1989). Five days later, William A. Weber and Anna Bujakiewicz made a second collection (#*14099*) at the same site (Weber 1995). While Blecher's collection may be the first observation of *M. brachypoda* at this location, it is possible that Francis Daniels may have collected this species at Panther Canyon in 1906.

Malaxis brachypoda has not been seen at Panther Canyon since Weber and Bujakiewicz's visit, despite many efforts to find it there. Bill Jennings searched this area on July 19, 1982 and although he found no *M. brachypoda*, he did find the frequently associated species *Listera convallarioides*. Jennings searched Panther Canyon, Long Canyon, and another unnamed canyon again on July 21, 1982 without success. Panther Canyon was searched yet again by Bill Jennings on August 26, 1989. Conditions at this time were reportedly "too dry," and no *M. brachypoda* was found. Tim Hogan has searched for *M. brachypoda* in Panther Canyon numerous times over the last 15 years without finding it (Hogan personal communication 2005). Panther Canyon contains excellent habitat for *M. brachypoda* (Jennings personal communication 2005).

Technical description (from Catling and Magrath 2002)

> "**Plants** 3 to 30 cm. **Pseudobulbs** 4 to 8 mm diameter. **Leaves** 1 (to 2, rarely), petiolate base sheathing stem; blade light green, ovate-elliptic, keeled abaxially, 1.5 to 9.5 x 1 to 5 cm, apex acute. **Inflorescences** floral bracts lanceolate, 1.5 to 2 mm; pedicels 2 to 4.5 mm. **Flowers** resupinate, green or greenish white; dorsal sepal ovate-lanceolate, 1.5 to 2.5 x 1 to 1.4 mm, margins revolute, apex acuminate; lateral sepals oblong-lanceolate, slightly falcate, 1.5 to 2.5 x 0.5 to 1.2 mm, apex acuminate; petals strongly reflexed, filiform to narrowly linear-lanceolate, 1.4 to 2.5 x 0.3 to 0.4 (0.5) mm, apex rounded; lip broadly triangular, concave, 3-lobed, middle lobe ovate, apex acuminate, lateral lobes auriculate, thickened, curved upward; disc with

2 low, thickened, elongate calli, 1.3 to 2.2 x 1.2 to 1.8 (2) mm; column 0.4 to 0.6 x 0.4 to 0.6 mm. $2n$=28".

Non-technical description

Malaxis brachypoda is a small, one-leaved orchid (**Figure 1**, **Figure 2**, **Figure 3**). Colorado Native Plant Society (1997) described this species: "*M. brachypoda* bears a single leaf, the base of which loosely sheaths a very slender, fragile spike of minute, greenish flowers. In the main part of its range, the plant can be up to a foot tall, but it rarely exceeds 3 or 4 inches in Colorado [**Figure 4**]. The flowers are barely larger than a typewritten asterisk (*) [**Figure 5**, **Figure 6**, **Figure 7**]. Its small size and totally green coloration make it virtually indistinguishable from the rest of the streamside vegetation." *Malaxis brachypoda* has one of the smallest flowers in the orchid family (Case 1987). Morris and Eames (1929) said the flowers looked like mosquito nymphs that had crawled up out of the swamp and left shreds of moult clinging to the stem. The flower pedicels twist 180° so that the lip is lowest in the flower. The pedicel can twist to the right or to the left (Ames 1938, Correll 1978).

In Region 2, *Malaxis brachypoda* is most easily confused with *Lysiella obtusata* and species of *Listera* (Spackman et al. 1997). *Lysiella obtusata* also has a single leaf, but it has spurred flowers while those of *Malaxis* are spurless and smaller. *Listera* species have two opposite stem leaves; *M. brachypoda* has a single leaf near the base (Spackman et al. 1997). The lip of the flower of *Listera convallarioides* is broadly bilobed, unlike that of *M. brachypoda*, which is pointed at the apex (**Figure 8**; Coleman 1999). Coleman (1999)

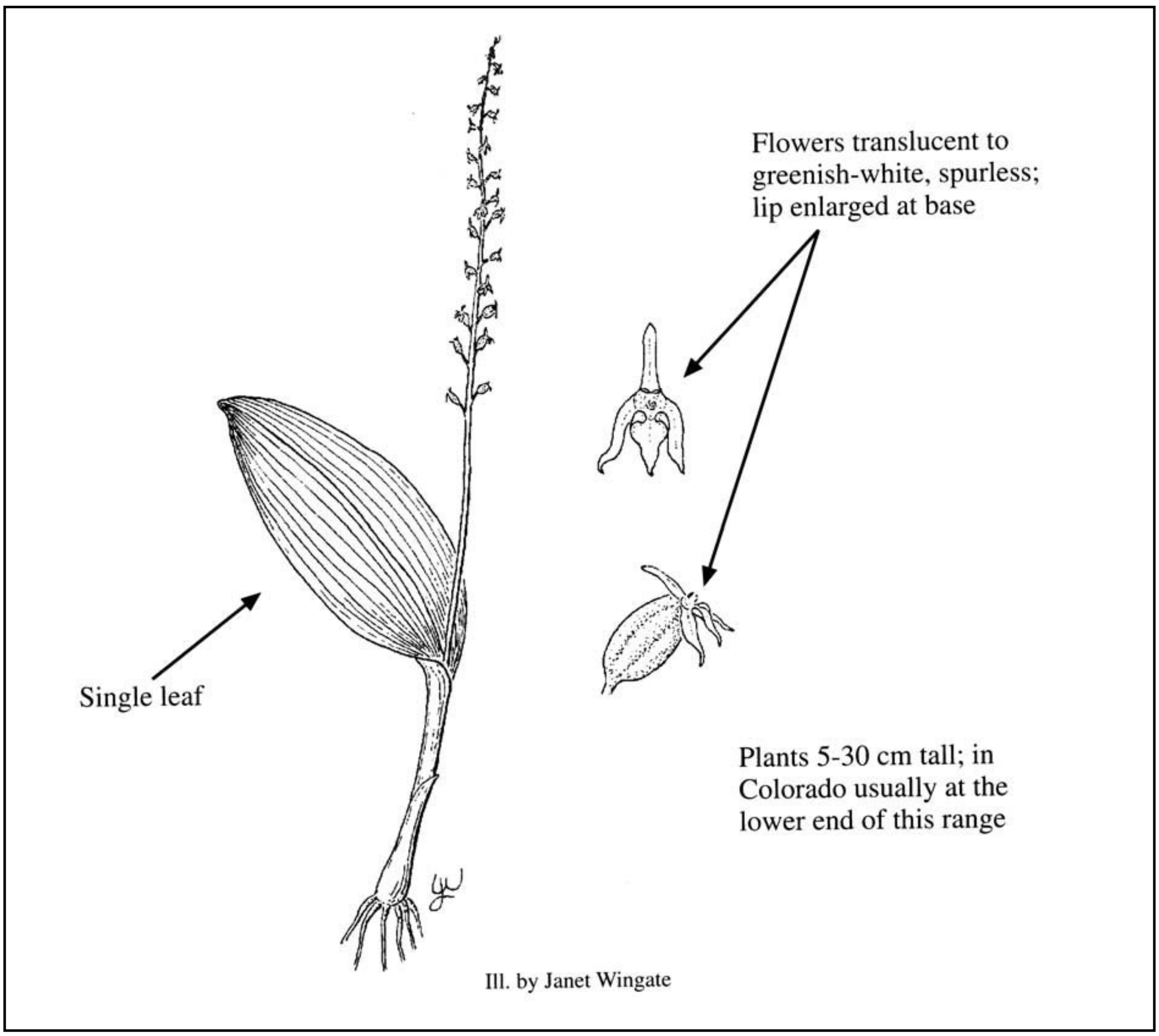

Figure 1. *Malaxis brachypoda*, illustrating the species' diagnostic characteristics. Illustration by Janet Wingate (from Spackman et al. 1997).

Figure 2. *Malaxis brachypoda* at Greenman Springs, Boulder County, Colorado. Photograph by Bill Jennings, used with permission.

Figure 3. *Malaxis brachypoda* at Greenman Springs, Boulder County, Colorado, with its pseudobulb lodged in moss, as is often reported throughout its range. Photograph by Bill Jennings, used with permission.

Figure 4. *Malaxis brachypoda*, with a scalar object included to illustrate the tiny size of this species. Photograph by Bill Jennings, used with permission.

Figure 5. A macrophotograph of the inflorescence of *Malaxis brachypoda*, showing the flowers and ripening ovaries. The inflorescence of *M. brachypoda* is indeterminate, with flowers opening first at the bottom of the inflorescence. Photograph by Bill Jennings, used with permission.

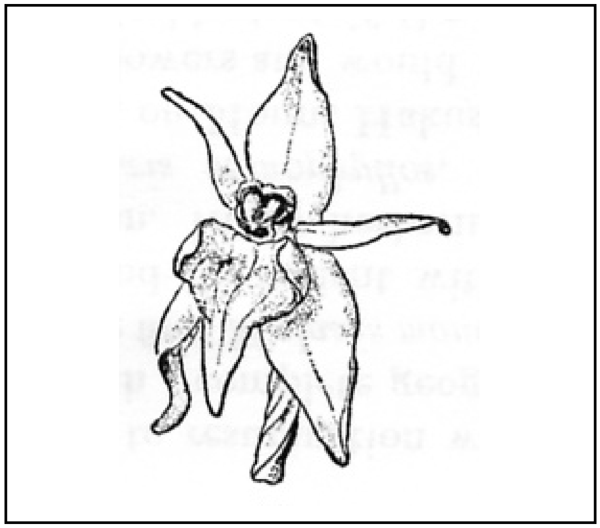

Figure 6a. Flower of *Malaxis brachypoda*, from a specimen collected in Vermont. The lip is 2.5 mm long. Note the twisted pedicel, which causes the flower to be presented upside down (resupinate). This feature is common among many orchid taxa. From Ames (1938), used with permission.

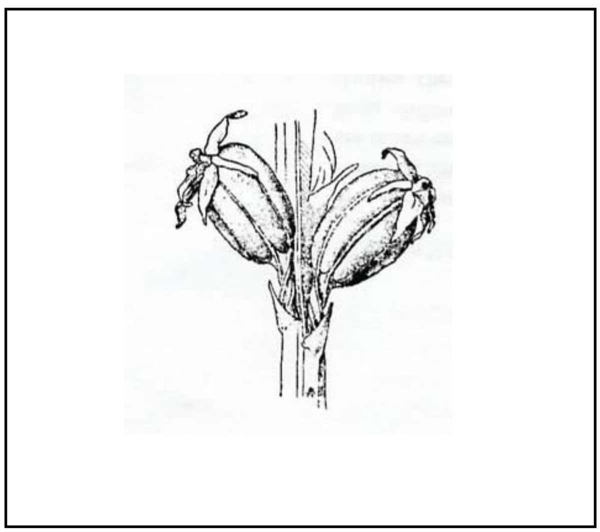

Figure 6b. Detail of the fruits of *Malaxis brachypoda* from a specimen collected in Vermont. The capsules are 5 mm long; the pedicels are 3 mm long. From Ames (1938), used with permission.

cautions that the flowers of *Malaxis* are so small that identifying the distinguishing characters requires a microscope, and it is therefore best to rely on the overall structure of the plant if attempting identification in the field.

Outside Region 2, the range of *Malaxis brachypoda* overlaps with that of *M. unifolia*, which might be confused with *M. brachypoda*. *Malaxis brachypoda* has an elongate inflorescence and an acute labellum (lip). *Malaxis unifolia* has a capitate inflorescence and a three-toothed labellum. In fruit, *M. brachypoda* has pedicels that are shorter than the ovaries, while the pedicels of *M. unifolia* are longer than the ovaries (Voss 1972, Smith 1993, Hapeman 1996, Schultz 2003). *Malaxis brachypoda* and *M. unifolia* cannot be distinguished in their vegetative state or when the inflorescence is not fully developed (Schultz 2003).

Within North America and outside of Region 2, two other species of *Malaxis* may be confused with *M. brachypoda*. A two-leaf form of *M. brachypoda*, forma *bifolia* (Mousley) Fernald, occurs in the northeastern United States (Fernald 1950, Brown 1997). In *M. brachypoda* forma *bifolia*, a smaller second leaf is below the usual one (Fernald 1950). Schultz (2003) describes

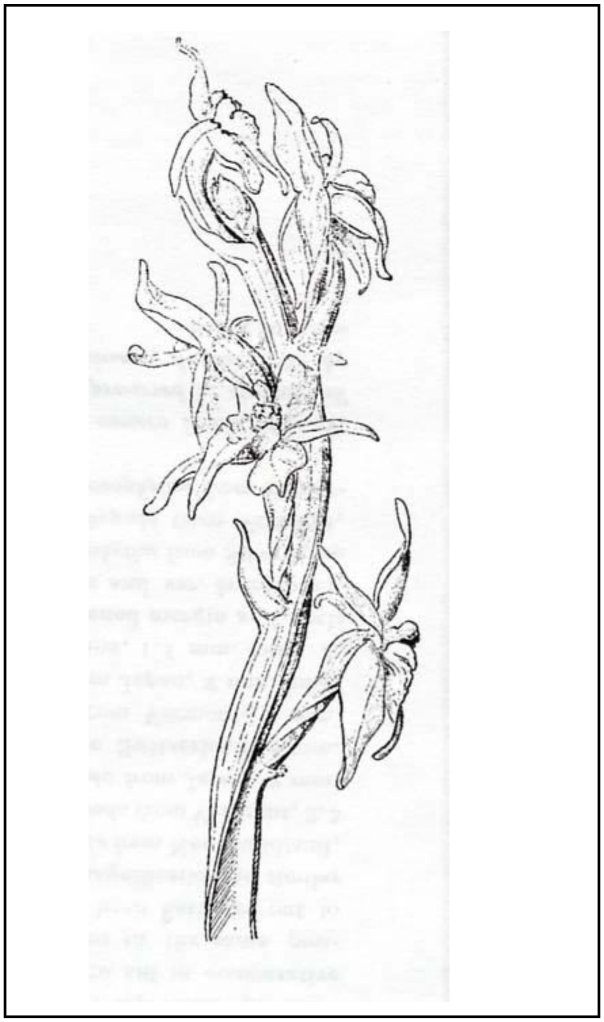

Figure 7. Detail of the inflorescence of *Malaxis brachypoda* from a specimen collected in Vermont. No scale was provided in the original image. From Ames (1938), used with permission.

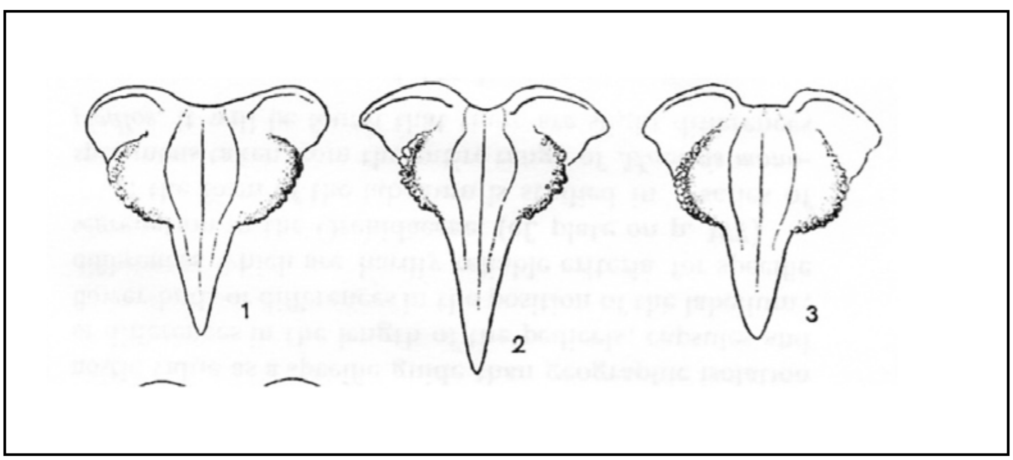

Figure 8. Detail of the lip of *Malaxis brachypoda*. The three lips shown above are from specimens collected in Newfoundland (#1, 2mm long), Vermont (#2, 2.5mm long), and Japan (#3, 2mm long). From Ames (1938), used with permission.

the occurrence of this form in Region 9 and elsewhere. The second similar species, *M. paludosa*, has two to five leaves instead of a single leaf (Smith 1993).

Sources of photographs, illustrations, keys, and descriptions

In Region 2, Weber and Wittmann (2001) and Spackman et al. (1997) are the best resources to aid in the identification of *Malaxis brachypoda*. Kelso et al. (1999) includes an illustration, description, and diagnostic information, but it is not readily available. Catling and Magrath (2002) provide a key to the *Malaxis* species of North America, but no illustration of *M. brachypoda*. Unfortunately, the key in Catling and Magrath (2002) appears to have an error; it indicates that *M. brachypoda* has at least two leaves, even though the description for *M. brachypoda* (included in this assessment) is correct in describing the species as typically having only a single leaf. Brown (2003) is a useful resource and includes keys, a photograph, and a small illustration of *M. brachypoda*. The most detailed treatment of the orchids of North America is that of Luer (1975), which remains a resource for identifying *M. brachypoda* and other orchids in Region 2. Long (1965) is a useful source for some Colorado orchids, but because he could not find *M. brachypoda* to photograph, it only appears in a key to Colorado orchids in that book.

There are many sources of illustrations of *Malaxis brachypoda*. Ames (1938) includes excellent illustrations of flowers and close-up drawings of the lip of *M. brachypoda*. These are included in this assessment (**Figure 6**, **Figure 7**, **Figure 8**). Hultén (1968) provides a small illustration and range maps of *M. brachypoda*. Newcomb (1977) includes an illustration of the habit and flower of *M. brachypoda*. Britton and Brown (1913) have an illustration of this species that is in the public domain and is available for downloading from the internet at USDA Natural Resources Conservation Service (2005). Reddoch and Reddoch (1997) have a very good illustration with a detail of the flowers. Hickman (1993) has a good, but small illustration. Williams and Williams (1983) include a description and a good watercolor illustration of the plant and a close-up of the flowers of *M. brachypoda* and *M. diphyllos*. Folsom (1997) provides an illustration of the habit of *M. brachypoda*. Sood (1991) presents technical illustrations and descriptions of the embryology of *M. saprophyta*, which may be relevant to *M. brachypoda*.

There are several sources with photographs of *Malaxis brachypoda* that are useful for familiarizing oneself with the species as well as for diagnosis. Luer (1975) has a diagram of the flower of *M. brachypoda* and very good close-up photographs of the inflorescence and plant. Coleman (1990) and Coleman (1999) have photographs of plants in California. Coleman (1999) also includes photographs and descriptions for comparing and distinguishing *Listera convallarioides* from *M. brachypoda*. House (1934) has a black-and-white photograph and a brief description. Hapeman (1996) is an online source of a good description and photographs. Fernald (1933) includes comparative photographs of *M. brachypoda* and *M. monophyllos*.

Descriptions of *Malaxis brachypoda* appear in several sources not mentioned above. These include Fernald (1950), Munz and Keck (1968), Hickman (1993), and Ridley (1888) (in Latin).

Distribution and abundance

Most of the 250 to 300 species of *Malaxis* worldwide are found in Asia and the East Indies (Catling and Magrath 2002). Catling and Magrath (2002) list 11 species of *Malaxis* in North America north of Mexico. The only species of *Malaxis* occurring in the states of Region 2 is *M. brachypoda*, but it is sympatric with other species of *Malaxis* in the heart of its range in much of northern North America. The range of *M. brachypoda* overlaps that of *M. unifolia* in eastern North America, and it overlaps with *M. paludosa* from Ontario and Minnesota to Alaska (Kartesz 1999). *Malaxis monophyllos* is known from Siberia, China, and Europe. Hultén (1968) and Catling and Magrath (2002) include Alaska and British Columbia within the range of *M. monophyllos*, but Kartesz (1999) and USDA Natural Resources Conservation Service (2005) recognize these occurrences as *M. diphyllos* Cham. *Malaxis diphyllos* is a synonym of *M. monophyllos* var. *monophyllos* according to Catling and Magrath (2002).

Malaxis brachypoda occurs in the Great Lakes Region, New England, and west from Newfoundland across Canada to British Columbia and southern Alaska, with disjunct populations in Colorado, California, and Japan. It was recently discovered in the Northwest Territories, 650 miles from the next closest occurrence in British Columbia (Cody and Johnston 2003). In the United States, *M. brachypoda* occurs in or has been reported in Alaska, California, Colorado, Connecticut, Illinois, Indiana, Maine, Massachusetts, Michigan, Minnesota, Nebraska, New Hampshire, New Jersey, New York, Pennsylvania, Tennessee, Texas, Vermont, and Wisconsin (Britton and Brown 1913, Kartesz 1999, Schultz 2003, NatureServe 2005). Catling and Magrath

(2002) do not include Nebraska, Tennessee, Texas, Connecticut, and New Jersey within the range of *M. brachypoda*. Details regarding the reports from within Region 2 (in Colorado and Nebraska) are discussed in the following sections.

Reports of *Malaxis brachypoda* from Texas, Tennessee, and Nebraska are apparently erroneous. The report of *M. brachypoda* in Texas may be the result of a misidentification of a Central American species in Big Bend National Park (Schultz 2003), or it may have been a misidentification of *M. unifolia*, which occurs in eastern Texas (Liggio and Liggio 1999, Jennings personal communication 2005). Although Fernald (1950) reported *M. brachypoda* from Tennessee, there are no records or specimens to support this report, and it is presumed to be erroneous (Schultz 2003). The report of *M. brachypoda* in Nebraska is discussed in the following section.

Although Catling and Magrath (2002) do not include Connecticut and New Jersey, specimens and element occurrence records document *M. brachypoda* in these states (Correll 1978, Schultz 2003). *Malaxis brachypoda* is extirpated or historic in New Jersey (Kartesz 1999). Maps of the distribution of *M. brachypoda* are included in Hultén (1968), which includes global range maps for *M. brachypoda* and *M. monophyllos*, Luer (1975), and Catling and Magrath (2002). Online sources of distribution maps for *M. brachypoda* are available in Schultz (2003), NatureServe (2005), and USDA Natural Resources Conservation Service (2005). Schultz (2003) offers a thorough overview of the distribution of *M. brachypoda* throughout the United States by state.

Besides Colorado, California is the only western state where *Malaxis brachypoda* is known to occur. It has been found along the South Fork of the Santa Ana River in the San Bernardino Mountains and in the Tahquitz Valley in the San Jacinto Mountains (Munz and Keck 1968, Hickman 1993). It was not seen in California for 42 years until Ronald Coleman rediscovered it in 1989 in the San Bernardino Mountains (Coleman 1990, Coleman 1999). The population in the San Jacinto Mountains is presumed to be extirpated (Coleman 1990, Hickman 1993, Coleman 1999).

Distribution in the states of Region 2

Malaxis brachypoda is known from four occurrences in Region 2, in Boulder, Jefferson, and El Paso counties, Colorado (**Table 3**, **Figure 9**). The two occurrences in Boulder County are within 1 mile of each other. It is oddly coincidental that at each of the three areas where *M. brachypoda* occurs in Colorado, the plants are either on or adjacent to a feature named Green Mountain.

Malaxis brachypoda is disjunct in Region 2. The nearest occurrences to those in Colorado are approximately 750 miles away, in southern California and northern Minnesota, and 850 miles away in Illinois.

Malaxis brachypoda is an eastern woodland-prairie element in Colorado (Weber 1995). Weber (1995) defined woodland-prairie relicts as "remnants of the flora that once stretched across the present area of the Great Plains and now are isolated in small mesic pockets in wetlands, gulches, and cool ravines." Weber (1965) included *M. brachypoda* among a list of oroboreal species. These species were present during the last glaciation in river drainages of the plains, but following post-Pleistocene climate warming, they have persisted in mountain refugia. They are present today in the Black Hills and in mesic, north-facing ravines of the Colorado mountain front. Correll (1978) hypothesized that *M. brachypoda* survived glaciation close to the margins of the ice sheet, and then migrated far north into Canada after the ice sheets receded.

Clues to possible locations of <u>Malaxis brachypoda</u> in Region 2

The precise location of Bessey's 1895 collection at Green Mountain Falls in El Paso County, Colorado (CO EO #1) is not known; his specimen label bore only "Green Mountain Falls." Bessey may have collected *Malaxis brachypoda* on private land or on what is now the Pike National Forest. He reported the elevation as 7,500 ft., placing his collection in the valley of Fountain Creek in near Chipita Park, approximately 3 miles downstream of Green Mountain Falls. The means and accuracy with which Bessey determined the elevation of this site are not known. This entire area has been extensively developed since Bessey's visit.

Jennings (personal communication 2005) believes that *Malaxis brachypoda* was probably not collected in the current town of Green Mountain Falls, but most likely along one of the northeast-flowing creeks to the south or west of Green Mountain Falls. These include Crystal Creek, South Catamount Creek, North Catamount Creek, and Crystola Creek. All of these creeks except Crystola Creek have been impounded. Green Mountain Falls is situated along Catamount Creek below the dams and above the confluence with

Table 3. Summary information for all occurrences of *Malaxis brachypoda* in USDA Forest Service (Colorado). Source ID is Colorado Natural Heritage Program occurrence number.

Source ID	County	Location	Owner	Date Last Observed	Abundance	Elevation (ft.)	Habitat and Notes
CO EO#1	El Paso	Green Mountain Falls	Unknown; possibly USDA Forest Service Pike National Forest or private	13-Jul-1895	Unknown	7,500	Not reported.
CO EO#2	Boulder	Greenman Springs	City of Boulder Open Space and Mountain Parks	14-Jul-1990	1 to 7	7,200	Geology: Precambrian granite. Aspect: North. Associated taxa: *Botrychium virginianum, Pyrola picta, Listera convallarioides, Platanthera hyperborea*, and mosses. Plants occupy a very small area (about 500 ft. by 5 ft.).
CO EO#3	Jefferson	Wellington Lake	Private: Wellington Reservoir Company	15-Jul-1989	6	8,030-8,080	On southwest side of a stream under a small spruce tree and associated with aspen, birch, and *Goodyera repens*; plants within a 5 by 5 foot area; logging is occurring on the dry hillside about 100 ft. to the east of the population; marshy nature of the creek side habitat will probably save it from logging; possibly more populations in the area; surveys are needed to look for other occurrences in the vicinity.
CO EO#4	Boulder	Panther Canyon	City of Boulder Open Space and Mountain Parks Department	17-Jul-1970	2	7,500	Series of pools and falls with mossy streamside banks; in wet moss, with *Listera convallarioides*.

Fountain Creek. It is possible that Bessey collected *M. brachypoda* in areas that are currently underwater, although the elevation of these reservoirs (9,200 and 9,400 ft.) is considerably higher than Green Mountain Falls and the elevation reported by Bessey. In 1895, many collectors listed the nearest town or landmark as the location of their collection. Rydberg (1907) erroneously reported the El Paso County occurrence as "Glen Mountain Falls."

Malaxis brachypoda has often been documented with *Listera convallarioides*, another tiny orchid, and *Botrychium virginianum*, a fern in the Ophioglossaceae. Jennings (personal communication 2005) notes that when these species are found, it is probably a good place to search for *M. brachypoda*. *Listera convallarioides* was reported with *M. brachypoda* at Panther Canyon and Greenman Springs, and *B. virginianum* is also found at Greenman Springs. *Listera convallarioides* also occurs with *M. brachypoda* in the San Bernardino Mountains of California (Coleman 1999) and at one location in British Columbia (NatureServe 2005). *Botrychium virginianum* is found with *M. brachypoda* at four locations in Minnesota, two in Wisconsin, and one in British Columbia (NatureServe 2005). However, both species are far more common than *M. brachypoda*. Nonetheless, there is value in using known occurrences of these species as starting points for surveys of *M. brachypoda*. **Figure 9** illustrates the distribution of *M. brachypoda* in Colorado relative to that of *B. virginianum* and *L. convallarioides*.

Edgar Wherry collected *Botrychium virginianum* somewhere near Green Mountain Falls in 1937 (CO EO #5). The precise location of this collection is even less specific than that of Bessey's ("in moist minimacid soil at 8400 feet on a steep, wooded slope"), and this occurrence has not been found since it was first reported. This collection cannot provide a possible location to search for *Malaxis brachypoda*. There are no collections of *Listera convallarioides* from the Pikes Peak area. Additional surveys are needed on the Pike National Forest (Jennings personal communication 2005).

Malaxis brachypoda could be in the Black Hills of Wyoming and South Dakota, where there is much suitable habitat for the species (Jennings personal communication 2005). Many plant species are disjunct in the Black Hills from the Great Lakes Region. One of these is *Listera convallarioides* Kartesz (1999). *Botrychium virginianum* is widespread throughout North America, and is found in the Black Hills.

Nebraska

Britton and Brown (1913) included Nebraska but not Colorado within the range of *Malaxis brachypoda*. House (1934) also reported *M. brachypoda* in Nebraska, probably based on Britton and Brown (1913). No other reports of this species are known from Nebraska, and Britton and Brown (1913) did not cite sources or specimens, so this report cannot be verified. This report is almost certainly erroneous, arising either from a typographical error or from a misidentification (Jennings personal communication 2005). Rydberg (1922) included *M. unifolia* in Nebraska, but not *M. brachypoda*; more recent sources (e.g., Luer 1975, The Great Plains Flora Association 1986, Kartesz 1999) do not include any species of *Malaxis* in Nebraska. Searches of numerous herbaria (see the Introduction for the complete list) did not yield any specimens of *M. brachypoda* from Nebraska. It is possible that E.A. Bessey's affiliation with the University of Nebraska led to confusion over the origin of his collection at Green Mountain Falls.

Abundance

Malaxis brachypoda is extremely rare in Region 2, where it has been seen at only two locations with very low numbers (Weber and Wittmann 2001, Burkhart 2002). It is the rarest orchid in Colorado (Hogan 1989, Hogan 1993, Colorado Native Plant Society 1997, Hogan personal communication 2005). Colorado Native Plant Society (1997) wrote "A banner year for *M. brachypoda* in Colorado was 1989 when thirteen plants were found" at Wellington Lake and Greenman Springs.

Schultz (2003) provided a range-wide overview of the abundance of this species throughout North America. *Malaxis brachypoda* is known from at least 423 occurrences in the United States and Canada; the number of occurrences in Minnesota and Newfoundland is unknown because this species is not tracked. Of the 423 element occurrences, 166 are in Canada and 257 are in the United States..

The number of individuals within an occurrence varies throughout its range, but populations are never large. The greatest abundance of *Malaxis brachypoda* was documented by Fernald (1933) who wrote, "Apparently more abundant in western Newfoundland than in most areas on the continent, often in colonies of hundreds (sometimes thousands) of plants." Brown (2003) also noted that *M. brachypoda* is locally common in western Newfoundland. Williams and Williams (1983) described it as "locally abundant." Morris and Eames (1929) noted that *M. brachypoda* is most abundant in northern latitudes, but in New York and Pennsylvania, it is extremely rare.

While the populations described by Fernald (1933) are relatively large, they are small with respect to typical minimum viable population sizes determined through population viability analysis. Populations of *Malaxis brachypoda* do not often exceed 50

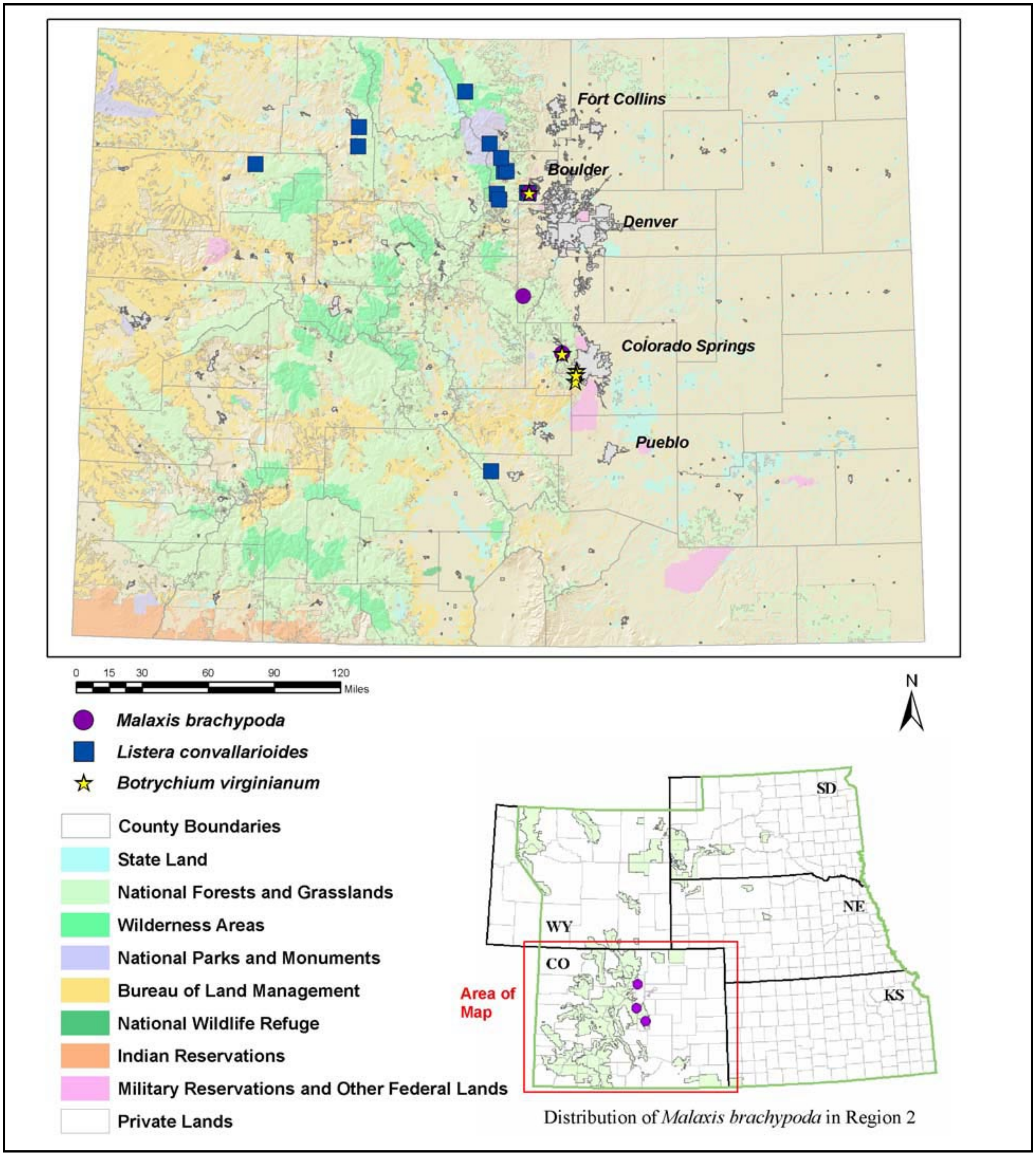

Figure 9. Distribution of *Malaxis brachypoda* in Colorado, showing land status and the distribution of two commonly associated species, *Listera convallarioides* and *Botrychium virginianum*. Inset map shows the distribution of *M. brachypoda* in the states of Region 2. All three species occur together at Green Mountain southwest of Boulder.

individuals (Schultz 2003). The majority of element occurrence records throughout the species' range report one to five individuals. Even where it is thought to be more abundant in eastern Ontario and western Quebec, populations typically consist of fewer than 50 individuals (Reddoch and Reddoch 1997). In 117 occurrences studied, populations observed by Reddoch and Reddoch (1997) ranged from one to 275 plants. Within a population, plants are typically scattered, with only a few plants seen together (Schultz 2003). The extent of populations is also typically small and does not usually exceed 1 acre (Schultz 2003). In the Great Lakes Region, Case (1987) noted that *M. brachypoda* is always local and spotty, and that plants tend to be scattered and seldom in clumps. This has also been observed in Region 2.

Population trend

The population trend of *Malaxis brachypoda* in Region 2 and elsewhere is unknown. Evidence suggests that this species is declining throughout its range, but data are sparse. Many of the 423 element occurrences known range-wide were documented more than 20 years ago and have not been seen since. *Malaxis brachypoda* is extirpated or historic in New Jersey, (Kartesz 1999), New Hampshire (NatureServe 2005), and probably Indiana (Schultz 2003). In many other states (e.g., California, Illinois, Minnesota, Wisconsin, Colorado), *M. brachypoda* is known from occurrences that have not been seen in more than 20 years, and in many locations it has not been seen in more than 100 years. The State of Minnesota (1995) wrote, "Recently, intensive surveys of suitable habitat within the heart of its range discovered only 18 small, widely scattered colonies in six counties. A historic population decline cannot be documented from the available data, but [*M. brachypoda*] is vulnerable to wetland drainage, logging, and land conversion." *Malaxis brachypoda* is "apparently declining" in eight of the northeastern United States (Brown 1997). It is presumed to be extirpated in the San Jacinto Mountains of Riverside County, California (Hickman 1993), where searches in 1989, 1990, and 1992 failed to find any plants at the known location (Coleman 1999).

There are many possible explanations for the lack of recent information regarding these occurrences. In some cases, such as in Indiana, the site where *Malaxis brachypoda* was initially documented has been destroyed (Schultz 2003). In many cases, it is probably due either to the extreme difficulty of detecting this species, or to benign neglect and lack of surveys to reassess occurrences.

Many observers have noted the difficulty of detecting *Malaxis brachypoda* in the field. Brackley (1985) wrote that it "is so well camouflaged by its surroundings that it is surprising that this species is ever found by orchid hunters." Kott and Kott (1974) suggest that *M. brachypoda* is "probably more often overlooked than rare." This plant is small, may not appear above ground every year, and occurs in densely vegetated, shady, wet areas (Brackley 1985, Case 1987, Jennings personal communication 2005). Enumerating population size may be complicated by periods of a year or more during which the plant grows mycoparasitically underground without producing a shoot aboveground. This phenomenon is discussed in the Cryptic phases section. The ephemeral nature of safe sites for germination may require that populations shift over time (Schultz 2003). *Malaxis brachypoda* populations are typically small and consist of scattered individuals, which compounds the difficulty in finding them (Case 1987). There are very likely to be many more populations of *M. brachypoda* than have been documented (Schultz 2003).

Of the four known sites in Region 2, only two have been seen within the last 20 years (Burkhart 2002). *Malaxis brachypoda* was last seen at Green Mountain Falls in 1895, at Panther Canyon in 1970, at Wellington Lake in 1989, and at Greenman Springs in 1990. *Malaxis brachypoda* may have been extirpated at the Green Mountain Falls location by recreation and development. There is a note in the folder for *M. brachypoda* at COLO regarding the Green Mountain Falls occurrence: "The locality, near Colorado Springs, is now overrun with tourists and the colony has probably been extirpated." However, suitable habitat remains in this area on the Pike National Forest (Jennings personal communication 2005, Olson personal communication 2005). Much of the habitat is difficult to access because of steep terrain. Vest (personal communication 2005) speculates that the Wellington Lake occurrence may also be extirpated.

Some efforts to relocate occurrences were rewarded by finding the missing plants. For example, in 1989, Coleman (1990) found *Malaxis brachypoda* in the South Fork Meadows area in the San Bernardino Mountains, where it had not been seen in 42 years and was thought to be extirpated. Searches in Colorado on Green Mountain were also successful and led to the documentation of two occurrences (CO EO #2 and 4) in the vicinity where Daniels first collected it in 1906. However, many other searches of areas where *M. brachypoda* has previously been documented, and searches of apparently suitable habitat have been fruitless in Colorado and elsewhere (Jennings personal communication 2005). The absence of evidence of this plant is not necessarily evidence of its decline because it is extremely difficult to detect (Hogan personal communication 2005).

The scant available data suggest that populations in Region 2 fluctuate. Repeated visits to Greenman Springs suggest that this population is variable, but differences in sampling effort and observer skill add uncertainty to these observations (**Table 4**). There has been little change in the habitat at Greenman Springs since the 1970s, but drought in 2002 may have caused

Table 4. Summary of abundance data for *Malaxis brachypoda* at Greenman Springs, Boulder County, Colorado reflecting all known observations.

Observer(s)	Date	N	In flower	Vegetative
Frances Potter Daniels	1906	"very scarce"	unknown	unknown
Bill Jennings	1978	5	unknown	unknown
Lucian M. Long (#38 KDH)	17-Jul-1981	"a few"	unknown	unknown
Bill Jennings, Tim Hogan, Harold Dahnke	15-Jul-1989	7	7	0
Uncertain	14-Jul-1990	1	1	0
Tim Hogan	early 1990s	0	n/a	n/a
Bill Jennings, Ann Armstrong	2004	0	n/a	n/a
Bill Jennings, Chris Wanner, Megan Bowes	2005	0	n/a	n/a

some mortality (Jennings personal communication 2005). Long-term population monitoring is needed to determine whether populations of *Malaxis brachypoda* are decreasing, increasing, or stable (Schultz 2003). Monitoring plants in Colorado would clarify normal population fluctuations relative to actual long-term declines, but the impacts of monitoring may cause more harm than good.

Habitat

General habitat description

Malaxis brachypoda is typically found in wetland sites, including bogs, mires, swamps, swales, and wet meadows (Catling and Magrath 2002). It is also known from crevices in shady wet cliffs and on ledges (Schultz 2003). Morris and Eames (1929) described the typical *M. brachypoda* habitat as "…low wet floors of wooded swamps - spots that are actually under water in the spring, remain pretty well saturated till June or July, and never wholly dry out. It has a very great fondness for shallow depressions carpeted with flannelly green moss. We have often found it so situated in wet cedar swamps and occasionally in thickets of alder and low moist poplar belts." Luer (1975) reported it "in the cold wet humus of a wooded mire." In Wisconsin, it is often found in bogs on mats of *Sphagnum*, underneath a canopy of *Thuja* or *Abies* (Hapeman 1996). In Minnesota, it is most often found in wetter sites than *M. paludosa* or *M. unifolia* (Reeves personal communication 2005).

In California, *Malaxis brachypoda* was reported from montane coniferous forests in the San Bernardino Mountains (Munz and Keck 1968). It prefers cool, damp areas, wet meadows, hillside bogs, wet riverbanks, and is often among grasses (Coleman 1990). Coleman (1990) described his rediscovered occurrence, "In streamside habitat in moderate to heavy shade, growing in short grasses near a clump of corn lilies on a silty hump. A small streamlet ran near the base of the hump. The entire area looked like it might be under water during periods of peak run-off." Schultz (2003) includes a thorough summary of the habitat descriptions for all known occurrences of *M. brachypoda* in North America.

Region 2 habitats

Habitat descriptions for *Malaxis brachypoda* in Region 2 are similar to those in other parts of its range. These include "moist ground" (Harrington 1954), "in woods" (Rydberg 1907), "shaded streamsides, mossy wet areas" (Spackman et al. 1997), "shaded streamsides or areas that are wet and mossy" (Kelso et al. 1999), and "Growing along small streams in the lower mountains, *M. brachypoda* usually is found rooted in mosses kept perpetually wet by stream spray" (Colorado Native Plant Society 1997) (**Figure 10**). *Malaxis brachypoda* is not likely to occur where streams are cascading over rocks; it tends to grow where streams flatten out (Hogan personal communication 2005). At Wellington Lake (Vest personal communication 2005) and possibly at other occurrences in Colorado, sites occupied by *M. brachypoda* appear to be periodically inundated.

The habitats of *Malaxis brachypoda* in Colorado are very similar to those of *Listera convallarioides*. However, *L. convallarioides* is found in many places where *M. brachypoda* is not (Hogan personal communication 2005, Jennings personal communication 2005). Similarities in habitat have also been noted between *M. brachypoda* and *Botrychium virginianum* (Jennings personal communication 2005). The Distribution and abundance and Community ecology sections of this assessment contain details regarding the co-occurrence of *M. brachypoda* with these and other species.

The distribution of *Malaxis brachypoda* in Region 2 is constrained in part by the limited distribution of suitable habitats, although many

Figure 10. Habitat of *Malaxis brachypoda* at Greenman Springs, Boulder County, Colorado. Photograph by Harold Dahnke, provided by Tim Hogan and used with permission.

apparently suitable sites are unoccupied. In Colorado, *M. brachypoda* is found in sites where water flow is perennial and vegetation is dense; these places are good areas to search for this species (Jennings personal communication 2005). A cloud veil often forms over the mountains west of Boulder including Green Mountain, and orographic effects create locally humid environments. These effects are best developed in the deep, north-facing canyons. The cool, moist environs of these canyons serve as refugia for eastern woodland species and species more common to higher elevations and latitudes (Hogan 1989).

Light

Malaxis brachypoda is most often reported in areas that are characterized as heavily shaded (e.g., Case 1987, Coleman 1990). Luer (1975) stated that it "seeks the cover of wooded swamps." Hickman (1993) described habitats in California as "wet meadows, shaded places, coniferous forest." It is usually reported from heavily wooded sites in shade (Britton and Brown 1913, Schultz 2003). At Greenman Springs, Panther Canyon, and Wellington Lake, *M. brachypoda* was reported in shaded sites. *Malaxis brachypoda* may also occur in open sites. Coleman (1990) found *M. brachypoda* in a meadow that he had previously passed through, thinking that the habitat was unsuitable.

Disturbance

Evidence suggests that within a limited range of conditions, *Malaxis brachypoda* can colonize disturbed sites. Morris and Eames (1929) describe finding *M. brachypoda* on the wall of a ditch draining a spruce bog, growing from a very wet spongy rotting stump (which was "soft, juicy, and green with its decay"). Morris and Eames (1929) also wrote, "Not seldom it springs up in the spongy foot-paths and logging trails that penetrate our heavily wooded northern swamps." Luer (1975) described the habitat of *M. brachypoda* as "shallow mossy depressions, often around the base of trees, and oddly enough, in soggy footpaths or deer trails through the woods." House (1934) described habitats where *M. brachypoda* is found as woods, thickets, and recent clearings, the latter suggesting a degree of ruderality. Very little information is available on which to base any statements regarding the effects of disturbance on *M. brachypoda*.

Elevation

In most of its range in northern North America, *Malaxis brachypoda* is found at elevations below 1,200 ft. (Catling and Magrath 2002, Schultz 2003). It occurs up to 550 ft. in Vermont (Correll 1978) and 760 ft. in Connecticut (Schultz 2003). The highest elevations known for *M. brachypoda* are in California (7,200 to 9,000 ft.; Correll 1978, Hickman 1993) and Colorado (7,100 to 8,080 ft.; Rydberg 1907, Jennings 1989, Colorado Natural Heritage Program 2005).

Soil and pH

Habitat descriptions suggest that *Malaxis brachypoda* does not tolerate highly acid conditions.

Of habitats in the western Great Lakes Region, Case (1987) wrote that *M. brachypoda* occurs in "cold, wet soils, mainly neutral in reaction and usually shaded." In this region, *M. brachypoda* is not found in highly acidic peatlands, including peaty sphagnum bogs or on sphagnum mats surrounding glacial pothole lakes (Schultz 2003).

Observers have noted an affinity for calcareous conditions for *Malaxis brachypoda* throughout its range, but it may occur in other circumneutral settings. Correll (1978) reported that this species occurs mainly in "circumneutral, more or less calcareous swamps." *Malaxis brachypoda* has been reported from calcareous fens in southeastern Alaska (McClellan et al. 2003), damp calcareous gravels, talus, peats, swales, and bogs in eastern North America (Fernald 1950), and "in damp woods and bogs (chiefly calcareous)" in Canada (Scoggan 1978).

Morris and Eames (1929) characterized the soil preference of *Malaxis brachypoda* as "neutral or slightly acid; very abundant in limestone regions." In swamps dominated by *Thuja*, *Abies*, and *Picea*, *M. brachypoda* occurs over marly soils, growing with mosses or sedges (Case 1987).

Soils data are available for the Green Mountain Falls and Wellington Lake areas of Colorado, but these data are not specific to the microhabitats where *Malaxis brachypoda* occurs. Soils at these locations are in the Legault Family. They are typically found on steep slopes and consist of well-drained loams with approximately 35 percent rock fragments. They have low acid precipitation buffering capacity and are strongly acid (Cargill and Boone 2005). It is possible that local geology buffers the pH. Case (1987) noted a tendency to find *M. brachypoda* in locally neutral microhabitats: "although [*M. brachypoda*] occurs in many sphagnous-acid situations, it does not grow in strongly acid soil, but rather in pockets or 'microhabitats' of neutral reaction." In general, the primary factors that assure the survival of many orchid species are soil that is acid or sterile enough to prevent soil fungi from taking over the plant and its symbiotic mycorrhizae, and the absence of competition (Case 1962).

Geology

The Greenman Springs and Panther Canyon areas are underlain by Boulder Creek granite, a dark gray, faintly banded Precambrian granodiorite (Hogan 1989). Faulting has exposed a narrow band of the Fountain Formation, a Pennsylvanian arkosic sandstone and conglomerate, near the summit of Green Mountain (Lovering and Goddard 1950, Chronic and Chronic 1972, Hogan 1989). This exposure may have a buffering effect on the water emerging from Greenman Springs. The Green Mountain Falls and Wellington Lake areas are underlain by rocks of the Pikes Peak Batholith (Tweto 1979). Here as well, it is possible that sedimentary surface geology influences hydrogen ion concentrations. Near the Wellington Lake *Malaxis brachypoda* occurrence, there are outcrops of bouldery Tertiary gravels representing erosional surfaces. No such outcrops are evident in the Green Mountain Falls area.

Moisture

Malaxis brachypoda is classified as a facultative wetland plant in the United States, indicating that it occurs in wetlands 67 to 99 percent of the time (U.S. Fish and Wildlife Service 1988). Regional wetland indicator status for *M. brachypoda* is summarized in **Table 5**.

Habitats where *Malaxis brachypoda* has been reported are usually places that are kept constantly moist by their proximity to flowing water or to a high water table. *Malaxis brachypoda* is probably sensitive to fluctuations in the water table (Schultz 2003). Soil moisture, along with temperature, is a critical factor for the survival of all terrestrial orchid species (Correll 1978). Organic matter, pH, and low competition are critical habitat variables in many orchid species of the western Great Lakes (a naturally humid area); as long as these requirements are met, these species may be found regardless of moisture availability (Case 1987). Many orchids require sterile, acid conditions, such as in bogs (Case 1962).

Temperature and climate

Malaxis brachypoda is "completely winter hardy" and is not tolerant of soil warming in summer (Correll 1978). Of the importance of temperature for *M. brachypoda*, Schultz (2003) wrote, "cool soil is a more critical factor than shade in the habitat of *M. brachypoda*. In the Great Lakes Region, the necessary soil temperature is best met in shaded habitats cooled by extensive evaporation. That water, per se, is not the main requirement can be seen from the fact that the plant occasionally occurs in upland habitats, on shaded cliffs, on north facing sand banks and enclosed dunes woods close to Lake Superior in habitats that are much drier than bogs." Reeves and Reeves (1984) noted that deep snow cover throughout the winter is probably

Table 5. Wetland indicator status for *Malaxis brachypoda* (U.S. Fish and Wildlife Service 1988).

USFWS Region	Region Name	Geographic Areas in Region	Wetland Indicator Status
1	Northeast	CT,DE,KY,MA,MD,ME,NH,NJ,NY,OH, PA,RI,VA,VT,WV	FACW
3	North Central	IA,IL,IN,MI,MN,MO,WI	FACW
8	Intermountain	CO (Western), NV, UT	NI
O	California	CA	FACW
A	Alaska	AK	FACW
		Wetland Indicator Status Explanations:	
FACW	Facultative Wetland	Usually occurs in wetlands (estimated probability 67 to 99 percent), but occasionally found in non-wetlands	
NI	No Indicator	Insufficient information was available to determine an indicator status	

important for protecting *M. paludosa* from low winter temperatures in Minnesota, which approach -40 °C. This is probably true for *M. brachypoda* in other states with snow cover throughout the winter (Schultz 2003).

Along the Colorado Front Range, storms occur in spring and autumn when wet air masses from the Gulf of Mexico are forced up against the mountain front. Monsoonal afternoon thunderstorms typically occur between July and September (Marr 1961, Barry 1973). Winds are predominantly from the west, with strong, warm, dry chinooks occurring in the winter months (Hogan 1989). The city of Boulder has an annual average precipitation of 19.17 inches, with maximum moisture occurring in April and May (Western Regional Climate Center 2005). Temperatures are probably 5 to 10 °F cooler at Greenman Springs and Panther Canyon (Hogan 1989). July is the warmest month (74 °F average) and January the coldest (30 °F average). Colorado Springs averages 16.2 inches per year of precipitation (Western Regional Climate Center 2005). Temperature profiles are similar at Colorado Springs to those at Boulder, with July and January the warmest and coldest months, respectively.

Reproductive biology and autecology

In the Competitive/Stress-Tolerant/Ruderal (CSR) model of Grime (2001), characteristics of many orchid species most closely approximate those of stress-tolerant ruderals. Like many epiphytes, lichens, bryophytes, and some ferns (especially the Ophioglossaceae), they are characterized by small stature, slow relative growth rates, and small, often minute propagules. A distinguishing characteristic of plants in this category is that stressful conditions are experienced during growth. Orchids produce hundreds or thousands of tiny seeds, as do other r-selected species (using the classification scheme of MacArthur and Wilson 1967), although their longevity and slow growth are not typical of r-selected species. These attributes are characteristic of stress-tolerant species in the CSR model. The small stature, slow growth rate, and tiny seeds of many orchids, including *Malaxis brachypoda*, are related to the low productivity of their habitats (Grime 2001). *Malaxis brachypoda* is "nonaggressive and noncompetitive" (Case 1987). While disturbance may play a role in the creation of safe sites for this species (Schultz 2003), a few reports (e.g., House 1934, Case 1987) suggest that *M. brachypoda* persists in areas with limited disturbance. See the Habitat section for details regarding the role of disturbance in the life history of *M. brachypoda*.

Reproduction

Studies of relatives of *Malaxis brachypoda*, and limited direct observations of the species, suggest that it is an obligate outcrosser and is not capable of self-fertilization. In unpublished pollinator exclusion experiments, Linda and Tim Reeves observed that *M. brachypoda* and *M. unifolia* require an outside pollen vector in order for pollination and fruit set to occur (Reeves personal communication 2005). This was also observed in *M. paludosa* (Reeves and Reeves 1984). Catling (1983) observed no evidence of autogamy in his examination of *M. brachypoda*, *M. unifolia*, and *M. paludosa* in Ontario, noting that the "rostellar tissue was sufficiently well developed to prevent the pollinia and the stigma from coming into contact." *Malaxis paludosa* was found to be an obligate outcrosser in extensive studies by European botanists (Catling and Catling 1991). *Malaxis massonii* is self-incompatible and an obligate outcrosser (Aragón and Ackerman 2001). It is likely that *M. brachypoda*, like *M. paludosa*, is incapable of self-fertilization and requires an external pollen vector for pollination. There have been no investigations of the breeding system of *M. brachypoda*.

Referring to orchids in general, Catling (1983) suggested that some areas may have autogamous local races. An example of this might be found at range limits and disjunct sites where autogamy would offer a selective advantage. He suggests that further study is necessary throughout the range of an orchid species to determine if particular plants of that species may actually be autogamous in some geographical locations.

Although *Malaxis brachypoda* reproduces primarily by seed, it may also produce an annual shoot arising from a perennial corm (Case 1987, Schultz 2003). The pseudobulb of the past year is often still present, and may give rise to a shoot (Case 1987). Quoting a personal communication with Case, Schultz (2003) noted that it is not uncommon to find plants in early spring before growth, lying loose on the ground with the living pseudobulb attached to the previous year's dead inflorescence.

Pollination ecology

> "Why do Orchids have so many perfect contrivances for their fertilisation? I am sure that many other plants offer analogous adaptations of high perfection; but it seems that they are really more numerous and perfect with the Orchideae than with most other plants."
> –Charles Darwin (1888)

Luer (1975) provided a summary of floral morphology and pollination in North American *Malaxis* species:

> "The column is short and erect, bearing four waxy pollinia on the dorsal or front surface. In bud the pollinia are covered by a protective anther-covering which promptly withers as the flower opens, exposing them as two pairs snugly fitted into a pouch on either half of the presenting side. The pollinia are flattened, with tapering ends which project to the top of the column.
> "On the other side of the column and facing the lip, is the stigma, which is in a pocket-like groove. Immediately above and between two bulges produced by the pouches of the pollinia on the dorsal surface is the flattened rostellum. The rostellum produces a microscopic droplet of viscid fluid on its upper edge or the top edge of the column, which comes in contact with the projecting ends of the pollinia.
> "As a minute insect reaches behind the column for nectar at the base of the lip, he invariably touches the viscid droplet. Upon departure he withdraws one or both pairs of pollinia sticking to his head or proboscis. He carries them to the next flower where he unwittingly pushes them down into the stigmatic pocket as he again reaches deeply into the flower."

Pollinia are tightly packed masses of pollen found in most orchids that are transported as a unit by pollinators (Tremblay et al. 2005). Pollinia solve the problem created by the need to fertilize large numbers of seeds in a single orchid fruit. A single pollinium from another plant, deposited in a single pollinator visit, is sufficient to produce a full seed complement. Were it not for pollinia, numerous (possibly thousands) of pollinator visits would be required to fertilize all the ovules in a single fruit (Rasmussen 1995, Tremblay et al. 2005). Most orchid pollinia are attached to other structures (e.g., rostellum, viscidium, caudicle) that are removed with the pollinia by a pollinator. A pollinium with its accessory organs is called the pollinarium. The organs attached to the pollinia help to prevent selfing. Some pollinaria are capable of movement that causes the pollinium to make contact with a stigma of a flower once it is deposited. The viscidium is often sticky and causes the pollinarium to adhere to an insect or another agent (Dressler 1981).

Taxonomists have relied heavily upon the structure of the pollinarium in delimiting orchid genera. The pollinia of the Malaxideae are tiny, often clavate, and they have no caudicles or other accessories.

As the buds swell in *Malaxis brachypoda*, the pedicels twist 180° to the left or right (Ames 1938), which orients the lip in the lowermost position (resupinate) and providing a place for insect visitors to land (Correll 1978). The Malaxideae all have very small flowers borne on a terminal inflorescence, and are probably fly-pollinated (Cameron 2005). Reeves (personal communication 2005) suspects that because of characteristics of the flowers, a moth pollinates *M. brachypoda*, but the pollinator was not observed during their studies in Minnesota. Others speculate that fungus gnats and possibly small flies are the pollen vectors for *M. brachypoda* (Brackley 1985). "Gnat flower" is the common name for the typical variety of *M. monophyllos* in Europe (Brackley 1985). Based on the small size of the flowers, their color, and habitat, pollination of *M. brachypoda* might be by fungus gnats (Hapeman 1996).

Pollinia of *Malaxis paludosa* were found on a fungus gnat (*Phronia digitata* Hackman (Diptera, Mycetophilidae)) in Minnesota (Reeves and Reeves

1984). The pollinia were found on the ventral-anterior portion of the thorax behind the mouthparts of a single individual. *Phronia digitata* has been collected at least three times in Colorado. Many other species of *Phronia* are also known from Colorado and elsewhere in western North America. *Phronia digitata* is very small, with wings 2.8 to 3.2 mm in length, a brown body, and yellow legs. The female of this species is unknown. They are most often caught flying above the forest floor, especially along damp ravines (Gagné 1975). Reeves and Reeves (1984) observed various dipterans and a mosquito (*Aedes* sp.) visiting *M. paludosa* flowers, as well as a buffalo gnat (*Simulium* sp.) (Reeves personal communication 2005). Schultz (2003) noted that there are morphological, physiological, chemical, and habitat differences between *M. paludosa* and *M. brachypoda*, so pollination characteristics of *M. paludosa* may or may not apply to *M. brachypoda*. In *M. paludosa*, the pedicel twists 360°; *M. brachypoda* only twists 180° (Ames 1938). Because the orientation of *M. paludosa* flowers is 180° different from that of *M. brachypoda*, as well as other floral differences between these taxa, it is likely that the two species are specialized for pollination by different species of insects (Cameron 2005).

Many orchid species are pollen-limited. Hand pollination resulted in 50-fold increases in seed production (Tremblay et al. 2005). *Malaxis massonii* typically has very low fruit set (1.3 to 3.4 percent), and it has been shown to be pollen-limited (Aragón and Ackerman 2001). Aragón and Ackerman (2001) observed density dependent effects on the reproductive success of *M. massonii*. Pollinarium removals declined at higher densities, suggesting that the pollinator pool became saturated. However, observations of *M. paludosa* suggest that it is an effective pollinator attractor. Darwin (1888) observed that nearly all of the pollinia are taken from *M. paludosa* flowers. Reeves and Reeves (1984) also noted that almost all of the pollinia from *M. paludosa* flowers in their Minnesota study were gone by the end of the season.

Most orchid species secrete nectar from the labellum (lip) that is eaten by pollinating insects (Chapman 1997). Flowers of *Malaxis paludosa* have a sweet smell and produce nectar at the base of the lip and column (Reeves and Reeves 1984). The rewards and attractants of the pollinators of *M. brachypoda* have not been studied in detail, but Reddoch and Reddoch (1997) reported that no fragrance was detected emanating from the flowers of this species in Canada.

Phenology and development

The seeds of *Malaxis brachypoda* probably germinate in the spring, based on observations of *Liparis loeselii*, which is very similar to *Malaxis* in many respects (Rasmussen 1995). Lichens, mosses, and liverworts can provide suitable sites for germination of terrestrial and epiphytic orchid seeds (Sanford 1974). Quoting a personal communication with Case, Schultz (2003) suggests that *M. brachypoda* "is continually moving about because, although perennial, its best germination sites are highly ephemeral due to rapid succession after minor disturbance."

Tatarenko and Kondo (2003) reported general phenological and developmental stages in orchids with summer-green leaves and pseudobulbs in Japan, including *Malaxis monophyllos*. They observed, "Apices or renewal buds in these species occurred in the spring. However, the first-year buds were dormant during the first growing season of the species. They began to expand very rapidly in the next growing season in the following spring, and formed pseudobulbs and inflorescences inside the buds by early the following summer. These buds each produced a shoot above the ground and new roots during the next spring. All of the species included in this group throughout their geographic distributions had common flowering periods in June or July. Their green leaves withered in August or September. Their pseudobulbs lasted for 2 to 4 years, and their roots lived for 1 to 2, sometimes 3 years. *Malaxis monophyllos* in Russia began to develop new shoots under the ground 1 month earlier than in Japan, although its plants in both countries demonstrated a similar rhythm of shoot growth above the ground."

Through the periodic regeneration of their vegetative organs, orchids, as noted by Harper (1977), "spend their perennial life in a state of perpetual somatic youth." The production of new pseudobulbs may also help the plant keep from becoming covered by its mossy substrate. In *Malaxis paludosa*, the withering pseudobulb produces a new stem and leaves in the spring. After flowering, a new pseudobulb develops on the stem above the position of the old pseudobulb, allowing the plant to move upwards and compensate for the growth of moss (Reeves and Reeves 1984). Structural analysis of the pseudobulb of *M. monophyllos* shows that it is a thickened internode of the main shoot axis (Kozhevnikova and Vinogradova 1999).

Malaxis brachypoda blooms in midsummer throughout its range (**Table 6**). Coleman's (1999) description of the phenology of *M. brachypoda* in California is relevant for Colorado as well: "Blooms from early July to the latter part of August. The prime season is mid-July, although peak blooming varies slightly from year to year." All specimens of *M. brachypoda* from Colorado were collected in flower in July. Reeves and Reeves (1984) observed that *M. paludosa* flowered one week earlier following a wet spring than it did in the prior dry year. However, timing of fruit set in both years was similar. Variations in annual climate may affect the phenology of *M. brachypoda* (Schultz 2003). Reeves (personal communication 2005) observed that *M. paludosa* and *M. unifolia* bloom one week before *M. brachypoda* in Minnesota, which accounts in part for the lack of hybridization between these species where they are sympatric.

Malaxis brachypoda produces an average of 25 flowers per plant in Minnesota (Reeves and Reeves 1985) in an indeterminate inflorescence. Flowering begins with the lowermost bud and continues up the inflorescence (**Figure 5**; Schultz 2003). In Minnesota, the flowers of *M. brachypoda* did not last beyond the receptive period for pollinators (Reeves and Reeves 1984). In Ottawa and Quebec, *M. brachypoda* released orange-white seeds in early October (Reddoch and Reddoch 1997).

Dispersal

The seeds of orchids are described as "dust seeds" and are among the smallest seeds of any plant. They have a large volume to weight ratio due to an inflated air –filled testa (seed coat) that often has a long tapering end (referred to as "scobiform"). This seed physiognomy is found in several other plant families and is characteristic of wind dispersal. The seeds are readily carried by the wind, and numerous cases of long-distance dispersal of orchid species have been documented (Rasmussen 1995). Orchids appear to be capable of migrating further than any other wind-dispersed flowering plant (Ridley 1930). The seeds of orchids also float; this mode of dispersal may also be important for species in wet habitats (Rasmussen 1995) including *Malaxis brachypoda*. There is very little evidence of dispersal of orchid seeds by animals other than humans (Sanford 1974).

Cryptic phases

Many orchid species exhibit dormancy, sometimes for extended periods. Dormancy usually lasts longer than one year in orchid species (Lesica and Steele 1994), and some species may remain dormant for 15 years (Tamm 1972). Chilling can induce *Cypripedium* species to remain dormant for two growing seasons. During this time, the plant does not produce shoots or leaves.

Table 6. Summary of phenological data for *Malaxis brachypoda* from across its range.

Area	Phenology	Citation
Northeastern North America	June-early August	Fernald 1950
Northeastern North America	July	Britton and Brown 1913
North America North of Mexico	Summer	Catling and Magrath 2002
North America	June to August	Williams and Williams 1983
California	Blooms from Early July to the latter part of August. The prime season is mid-July, although peak blooming varies slightly from year to year	Coleman 1999
Northeastern North America	June till August according to season and climate	Morris and Eames 1929
Northeastern United States	5 June to 20 August	Brown 1997
Eastern Ontario/ Western Quebec	8 June to 29 July [average 23 June – 15 July (38 records)]	Reddoch and Reddoch 1997
New Hampshire	Mid-June to mid-July	Brackley 1985
Ontario	Mid-June to late-July	Whiting and Catling 1986
Minnesota	20 June to 29 July	Smith 1993
Wisconsin	20 June to 1 August	Fuller 1933, Hapeman 1996
Northeastern United States	Third week of June to third week of July	Chapman 1997
Maine	Late June to July	Wallace 1951
British Columbia	June to August	Szczawinski 1959

The plant persists heterotrophically while developing another rhizome segment (Rasmussen 1995).

Trauma to the growing bud of an orchid from frost, grazing, insects, trampling, or other factors can cause growth to stop until the other buds experience a prolonged cold period (vernalization), which breaks their dormancy (Case 1987). This usually does not occur until after the end of the growing season, so that the plant remains dormant through one growing season. In a study of the life history of *Cypripedium parviflorum* ssp. *parviflorum*, Shefferson et al. (2003) reported that dormant individuals suffered significantly higher mortality than flowering individuals, and were more likely to remain dormant.

It is not known if *Malaxis brachypoda* is capable of extended periods of dormancy through one or more growing seasons. Of the occurrences in Boulder County, Colorado, Weber and Wittmann (2001) wrote that *M. brachypoda* "may not appear for several years on end, depending on the season." This and other observations suggest that *M. brachypoda* may remain dormant in some years. While the sporadic observations of *M. brachypoda* in Colorado and elsewhere suggest dormancy, there are many reasons for not finding this species in a given year. Case (1987) suggests that when an orchid reappears above ground after years of supposed dormancy, it is most likely that the original plant perished and the plant appearing above ground grew from seed.

Desiccated orchid seeds can remain viable for long periods if kept at cool temperatures. Seeds of some species can remain viable for at least ten years (Sanford 1974). The longevity of *Malaxis brachypoda* seeds has not been measured.

Because of their tiny size, orchid seeds have limited food reserves to support seedling growth. However, the nutrient supply of orchid seeds is concentrated, and many species can remain alive for days or weeks without receiving external nutrients. This period between germination and infection by a compatible mycorrhiza is informally referred to as the "waiting time." Seed germination takes place prior to fungal infection (Rasmussen 1995).

Mycorrhizae

Orchids are known for their strong mycotrophic relationships. This relationship begins shortly after the seed germinates; orchids generally require colonization by mycorrhizae to develop beyond the seedling stage. Orchids begin as parasites on saprophytic fungi (Sanford 1974). Very little is known about the apparent gain of independence from fungi after the seedling stage. Following inoculation of the seedling by mycorrhizae, a protocorm forms and may survive for several years underground, obtaining nourishment from the fungus. Under natural conditions, the orchid protocorm will eventually send up a photosynthetic shoot and leaves. Although the mycorrhizal relationship may remain, these structures produce most of the nourishment (Rasumussen 1995).

Observations of the mycorrhizae of orchids suggest that in general, the orchid remains the primary beneficiary of the relationship, with little benefit realized by the fungus (Rasmussen 1995, Zettler 1997). In orchidoid mycorrhizae, fungal hyphae proliferate within the root cortical cells of the orchid, where they form coils called pelotons. The pelotons are digested within the cells of the orchid as new pelotons are formed (Rasmussen 1995).

Terrestrial orchids have simple root systems, and each plant usually develops only a few roots. Orchid roots are thick and unbranched, as is typical of mycorrhizal plant species. The roots of orchids are brittle because of the predominance of cortical cells that are heavily colonized by endomycorrhizal fungi (Rasmussen 1995). Terrestrial orchids remain mycorrhizal throughout their life.

Malaxis paludosa and *M. monophyllos* have an internal root that carries the fungus across the barrier between one rhizome segment and the next (Fuchs and Ziegenspeck 1927 as cited in Rasmussen 1995). Because the infection is transferred from one segment of the rhizome to the next, it is likely that a plant is infected with the original fungus throughout its entire life. As plants mature, the infection is transferred from the rhizome to the roots.

Malaxis paludosa is unique in the genus *Malaxis* in having vegetative reproductive structures on the leaf tips called foliar embryos. These structures have no fungus associated with them but soon establish a mycorrhizal symbiosis (Taylor 1967, Mabberley 1997).

Rhizoctonia repens Bernard (= *Epulorhiza repens* Moore), an anamorph of *Tulasnella calospora* (Boudier) Juel. has been isolated from the roots of *Malaxis brachypoda* (Kulikov and Filippov 2001). The symbiotic specificity of *M. brachypoda* appears to be high. Kulikov and Filippov (2001) observed normal development of sprouts of *M. brachypoda* only with its natural symbionts. Seed germination and sprout growth did not occur when inoculated with root isolates from other orchid species. The only mycorrhizal fungus species isolated from *M. brachypoda* was *R. repens*. Muthukumar et al. (2003) observed orchid mycorrhizae characterized by pelotons in *M. latifolia* in southwest China, but did not identify the species of fungus. Rasmussen (1995) provides an extensive review of this topic.

Hybridization

Hybridization is relatively common in the Orchidaceae. One in ten of the horticultural hybrids registered before 1947 had a counterpart in the wild state (Adams 1959). Given the tight relationship between many orchids and their pollinators, this is somewhat counterintuitive. Sanford (1974) noted three factors that contribute to the ease with which many orchid species hybridize:

- the huge number of ovules and pollen tubes present in each flower
- the rapidity of orchid evolution, which has resulted in the formation of a number of species not yet diverged far enough to be incompatible
- faulty definition of species and genera resulting in a situation where so-called hybridization is not hybridization at all.

Hybridization has not been observed between *Malaxis brachypoda* and other sympatric species of *Malaxis* (Reeves and Reeves 1985).

Physiology

Malaxis monophyllos was included in a study of the enzymatic production of nitric oxide in non-leguminous plants (Xu and Zhao 2003). The authors showed that nitric oxide formation in non-leguminous plants is primarily due to an enzyme system rather than the result of chemical reactions. The authors suggest that nitrogen reductase reduces NO_2- to NO in *M. monophyllos*.

Demography

Population biology

Little is known about the population biology of *Malaxis brachypoda* (Schultz 2003). Recruitment, survival, and other vital rates have not been measured for this species. There have been limited studies of other taxa of *Malaxis*, but the inferential value of these studies for *M. brachypoda* is questionable because of important differences in their breeding systems and autecology. **Figure 11** is a diagram of the life cycle of *M. brachypoda*, with a summary of known demographic information.

All populations of *Malaxis brachypoda* in Region 2 are small enough for the consequences of demographic, environmental, and genetic stochasticity to be important considerations. A discussion of these factors is paraphrased here from Decker (2005) as they relate to *M. brachypoda*. Demographic stochasticity (the chance variation in vital rates such as reproduction and survival) becomes a concern in populations of 50 or fewer plants (Menges 1991). Environmental stochasticity (temporal variation in reproduction and survival as a consequence of rare external events such as weather, herbivory, pollinator availability, and other biotic or abiotic factors) may also lead to local extinction (Lande 1998, Oostermeijer et al. 2003). The potential effects of small population size include inbreeding, loss of genetic variation due to genetic drift, and the accumulation of deleterious mutations (Matthies et al. 2004). Inbreeding depression, or a loss of fitness due to decreased heterozygosity, results from an increase in matings between closely related individuals. In isolated populations, matings are necessarily between individuals that are more closely related than are two randomly chosen members of the species. In isolated populations, loss of genetic variation by drift is not compensated for by immigration of seeds or pollen from other populations (Oostermeijer et al. 2003). Gene flow among populations in Region 2 is extremely unlikely due to the distances between them. The pollination of *M. brachypoda* is mediated exclusively by insect pollinators, but no insect pollinator is likely to travel the distances necessary to permit gene flow among Region 2 populations.

No population habitat viability analysis (PHVA) has been done for *Malaxis brachypoda*. Expert panels addressed this species to determine whether population viability assessment is needed to help manage it on national forests (Mighton et al. 2000). Although it was determined that a PHVA is needed, this research has not been conducted.

Populations of many terrestrial orchid species are highly variable (Wells 1981). Wells (1981) observed large variations in population size of *Spiranthes spiralis*. Population sizes observed at a single occurrence of

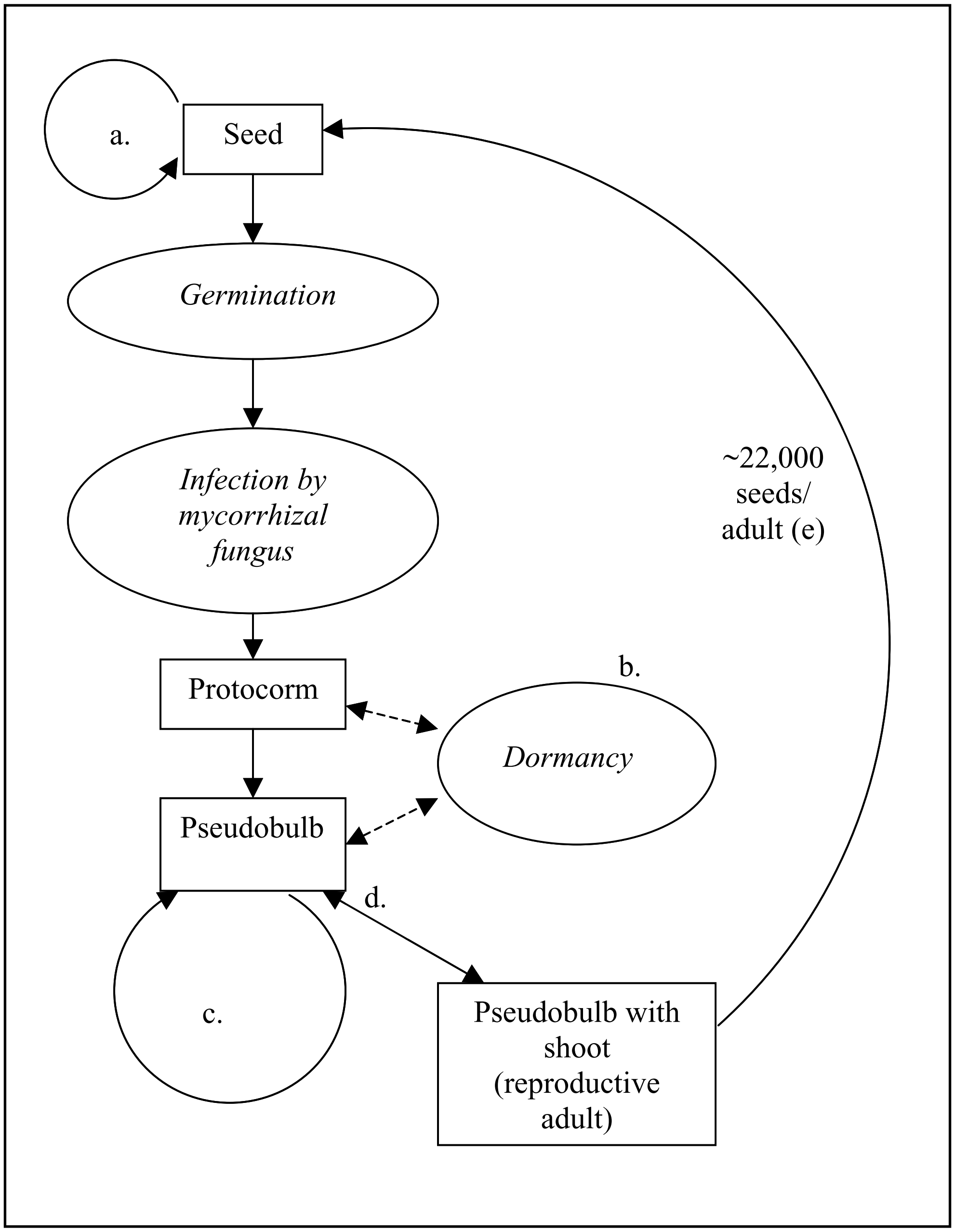

Figure 11. Life cycle graph (after Caswell 2001) for *Malaxis brachypoda*. Squares represent physical features, and ovals represent processes or events. Dotted lines indicate uncertainty. Seed longevity of *M. brachypoda* is unknown, but the seeds of other orchid species are known to persist for up to 10 years under controlled conditions (a). Dormancy has not been observed in *M. brachypoda*, but observations of other orchids suggest that it may occur (b). The pseudobulb of *M. brachypoda* probably persists more than one year (c), but eventually it withers and a new pseudobulb is produced by the reproductive adult (d). The only demographic variable that can be estimated for *M. brachypoda* is fecundity (e). An adult produces an average of 25 flowers (Reeves and Reeves 1985). Using the number of seeds counted in a single fruit of *M. paludosa* (873) (Reeves and Reeves 1984), a reproductive adult of *M. brachypoda* could produce approximately 22,000 seeds. However, Reddoch and Reddoch (1997) observed that due to predation, only 40 percent of flowers produced fruit in their study area in Ontario and Quebec.

S. diluvialis in Colorado varied between 1 and 2000 (Colorado Natural Heritage Program 2005). Population size appears to be highly variable in *Malaxis brachypoda* as well, but there have been no demographic studies in Region 2 or elsewhere to provide quantitative data on its population dynamics. See the Cryptic phases section for possible explanations of these observations.

Metapopulation dynamics

At least one account suggests the existence of metapopulations in *Malaxis brachypoda*. Schultz (2003) quoted a personal communication with Case, who noted that *M. brachypoda* "is continually moving about because, although perennial, its best germination sites are highly ephemeral due to rapid succession after minor disturbance." It is not clear that metapopulation dynamics are in fact operating in the disjunct populations of Region 2. *Malaxis brachypoda* grows as scattered populations within its range due to the discontinuous patterns of its required wetland habitat (Schultz 2003), leaving them naturally isolated from one another.

Vital rates and demographic variables

In typical orchid populations, the amount of seed produced is so great as to cause massive increases in the number of plants if it were not for limitations acting on germination and seedling establishment (Rasmussen 1995). A single orchid fruit may contain in excess of one million seeds (Correll 1978). Areas of unsuitable habitat for *Malaxis brachypoda* undoubtedly act as sinks when seeds disperse to these areas. Dispersal by wind entails losses because many seeds either never reach the ground or land on unsuitable substrates. Luer (1975) wrote that the chances of a seed becoming a plant are "one in a million" because of the remote chance that it will land in a suitable habitat with the appropriate fungal symbionts. Nonetheless, *M. brachypoda* depends upon reseeding for its persistence (Schultz 2003). Reeves and Reeves (1984) counted 873 seeds in a single *M. paludosa* capsule. Numbers of seeds per capsule will vary, even within a single species, depending on the vigor of the individual (Case 1987). The fecundity of *M. brachypoda* has not been quantified. An average reproductive adult with 25 flowers (as observed by Reeves and Reeves (1985) in Minnesota) would produce approximately 22,000 seeds if its seed yield per capsule were similar to that of *M. paludosa*.

In the only study of the fruiting success in *Malaxis brachypoda*, an average of 40 percent of the flowers on 29 individuals in eastern Ontario and western Quebec produced fruits, but the results were highly variable (Reddoch and Reddoch 1997). In their two-year study of *M. paludosa*, Reeves and Reeves (1984) observed a high degree of fruit loss (39.22 percent in the first year and 34 percent in the second) due to predation, probably by rodents and insects.

Malaxis brachypoda is a polycarpic (iteroparous) perennial, flowering multiple times throughout its lifespan. Because orchids renew their vegetative body, the age of the individual is only loosely correlated with fecundity (Wells 1981). A mild winter and a wet spring and early summer appear to favor flowering in *Spiranthes spiralis*, another terrestrial orchid (Wells 1981).

Lifespan and life history

Many orchids are potentially long-lived. At the Royal Botanic Gardens, orchids have persisted in cultivation for more than 100 years (Koopowitz 2001). The mean longevity of *Spiranthes spiralis*, a terrestrial orchid, is 53 years (Wells 1967, 1981). Jennings (personal communication 2005) suggested that *Malaxis brachypoda* is probably long-lived. The survivorship curve of *S. spiralis* is approximately flat, suggesting that there is a more-or-less constant risk of death in this species (Wells 1981).

Malaxis monophyllos takes five years (or possibly less) to form typical bulbs (Fuchs and Ziegenspeck 1927 as cited in Rasmussen 1995). The age of *M. brachypoda* at reproductive maturity has not been measured. Schultz (2003), citing a personal communication with Case, noted that *M. brachypoda* might flower in one to three years, or even less, under ideal conditions, but it is likely to take longer to reach reproductive maturity under less favorable conditions. Case also noted that although *M. brachypoda* is a perennial, it typically occurs in unstable microlocations within swamps in the Great Lakes Region, suggesting that adult plants do not persist for many years, and that population persistence depends upon constant reseeding.

Community ecology

Malaxis brachypoda is found in a variety of wetland habitats, where it usually occurs as small populations in microsites that fall within a narrow range of habitat attributes. It is often found in sites that are floristically rich, with other rare or uncommon species (Hogan 1993, Schultz 2003, Colorado Natural Heritage Program 2005). The sites where it occurs in Boulder County are the richest communities in the area (Hogan 1993). Spring-fed streams and other mesic sites on

Green Mountain in Boulder County support many state-rare plant species, including *Listera convallarioides*, *Botrychium virginianum*, *Aralia nudicaulis*, and *Pyrola picta* (Hogan 1989, Jennings 1989, Hogan 1993, Colorado Natural Heritage Program 2005, Jennings personal communication 2005).

Malaxis brachypoda habitats in Region 2 are surrounded by coniferous forests, whose composition varies depending on local conditions. On Green Mountain in Boulder County, *Pseudotsuga menziesii* (Douglas-fir) dominated forests are most common at higher elevations on north-facing slopes, where conditions are cooler and more mesic. Drier, south-facing slopes are dominated by *Pinus ponderosa* (ponderosa pine), while intermediate sites support mixed forests (Hogan 1989). *Pinus ponderosa* woodlands and montane dry-mesic mixed coniferous forest dominate the landscape in the vicinity of Green Mountain Falls, with a narrow corridor of montane riparian woodland along creeks. At Wellington Lake, small areas of *Populus tremuloides* (aspen) forest are interspersed among *Pinus ponderosa* woodlands (Comer et al. 2003).

Case (1987) characterized *Malaxis brachypoda* as being "nonaggressive and noncompetitive." This species never assumes a dominant role in the plant communities it inhabits. Its shaded habitats have limited light resources for photosynthesis, and they are not typically inhabited by highly competitive species. As is common among both terrestrial and epiphytic orchids, *M. brachypoda* is often most closely associated with cryptogams such as mosses and lichens. Of this phenomenon, Sanford (1974) wrote "it is extremely doubtful that lichens, mosses, or liverworts are ever orchid competitors; rather they are necessary for providing a suitable environment for seed germination and subsequent seedling growth." Thus, even sites with considerable cover of cryptogams may be considered "open" for orchid colonization.

Malaxis brachypoda is often found with other regionally rare species. *Botrychium virginianum* and *Listera convallarioides* have been documented with *M. brachypoda* repeatedly in Region 2 and elsewhere (see **Figure 9** and the Distribution and abundance section). Sanford (1974) noted that wherever any one terrestrial orchid species is abundant, other orchids are likely to occur. Orchid species occurring with *M. brachypoda* in California include *Platanthera dilatata* var. *leucostyachys* and *L. convallarioides*, both of which grow in nearby meadow habitats and bloom around the same time as *M. brachypoda* (Coleman 1990, Coleman 1999). Jennings observed *Corallorhiza striata* at Panther Canyon on July 21, 1982, but *M. brachypoda* was not seen at that time (Jennings 1989). *Platanthera hyperborea* and *L. convallarioides* grow at Greenman Springs, and *Goodyera repens* occurs at Wellington Lake (Jennings 1989, Colorado Natural Heritage Program 2005). Other vascular plant species observed with *M. brachypoda* in Region 2 include *Polypodium amorphum*, *P. hesperium*, *Pyrola picta*, *Populus tremuloides*, and *Picea engelmannii* (Jennings 1989). **Table 3** includes information on the locations where associated species were observed.

Malaxis brachypoda may have an affinity for certain moss species, or may merely share habitat preferences with them. Hogan (personal communication 2005) always found *M. brachypoda* with *Brachythecium rivulare*. This is a common, cosmopolitan moss species, whose habitat is described as "submerged in springs and slow-flowing brooks or growing on wet soil, rocks, humus, or rotten logs, on brook banks, in wet meadows and seepage areas from the valleys to the higher mountains" (Flowers 1973). Case (in a personal communication to Schultz 2003) noted that he has never seen the pseudobulb of *M. brachypoda* "embedded in living *Sphagnum*, although *Sphagnum* may be only a few inches away." Instead it occupies "neutral to alkaline microhabitats, and is either buried in muck, alkaline loving mosses, or perched atop the substrate of such."

Conservation

Threats

In order of decreasing priority, threats to *Malaxis brachypoda* in Region 2 include effects of small population size, impoundments, water diversions, and altered hydrologic regimes, residential and commercial development; collection and over-utilization, fire, recreation, timber harvest and fuels reduction, road construction and right-of-way maintenance, livestock grazing and herbivory, exotic species, climate change, and pollution. These threats and the hierarchy ascribed to them are highly speculative, and the magnitude of specific threats differs at each occurrence.

In Minnesota, *Malaxis brachypoda* is vulnerable to wetland drainage, logging, and land conversion (State of Minnesota 1995). In a detailed examination of threats to *M. brachypoda* on the national forests of Wisconsin and Minnesota, Schultz (2003) noted that major threats include agricultural drainage, gravel mining, wetland drainage for residential development, peat mining, and draining and infilling of *Sphagnum* peatlands, and other activities that alter the wetland hydrology of its habitats. Human-caused drainage or impoundment, or fluctuations caused by beaver or climatic changes, are very likely to impact *M. brachypoda* negatively, as it does not tolerate fluctuations in the water table (Schultz 2003). Schultz (2003) includes an extensive discussion of threats to *M. brachypoda* in Region 9, using information from throughout the range of *M. brachypoda* in assessing threats. Information from Schultz (2003) is included in the sections below where relevant to Region 2. Assessment of threats to this species will be an important component of future inventories and monitoring. The following paragraphs describe the specific threats to habitat and individuals.

Influence of management activities or natural disturbances on habitat quality and individuals

Small population size

Malaxis brachypoda populations in Region 2 are extremely small and highly susceptible to stochastic processes (see the Demography section for details). The largest occurrence documented in Region 2 had seven individuals; other observers only reported a single individual (**Table 3**, **Table 4**; see the Abundance section for details). By even the least conservative measures of population viability, these populations are at great risk of inbreeding depression and genetic drift. As an obligate outcrosser, the effects of small population size are exacerbated, and the potential for reproductive success is reduced. Small, scattered populations risk reduced fitness though low pollinator visitation rates (Sih and Baltus 1987), pollen loss via interspecific pollination (Feinsinger et al 1986), shortage of potential mates (Murawski et al. 1990, House 1993), or inbreeding (Aizen and Feinsinger 1994). The probability that any population documented in Region 2 can remain extant for 100 years appears to be very low.

Impoundments, water diversions, and altered flow regime

Two occurrences, at Green Mountain Falls and at Wellington Lake, are near impoundments and other hydrologic alterations that potentially affect their viability. Three of the northeast-flowing creeks (Crystal, South Catamount, and North Catamount) that constitute potential *Malaxis brachypoda* habitat near Green Mountain Falls have been impounded for drinking water for Colorado Springs and surrounding communities. Crystola Creek is not impounded.

The dams that form Crystola and South Catamount Reservoirs were completed between 1935 and 1937; the dam that forms North Catamount Reservoir was completed in 1960. Storage rights were obtained approximately two years prior to the construction of these dams. Water in these reservoirs is piped in from the Blue River above Breckenridge. The natural flow of these creeks is augmented, and the reservoirs are generally kept full. Seepage and accretion flows vary with temperature and reservoir depth, but they keep the creeks below the dams flowing constantly (Eklund personal communication 2005, Scherff-Norris personal communication 2005). Although outflow from the dams was limited during drought events such as in 2002, seepage from the dams supports a minimum stream flow, and riparian areas below the dams have not dried out in recent years. It is possible that during or after dam construction, the riparian areas below the dams may have dried in some years, but there are no records available from which to determine this. At times, outflow from the dams exceeds the original stream flow, but this has evidently not destabilized the channel downstream of the dams (Eklund personal communication 2005).

Although water supply appears fairly constant in the possible locations where this occurrence was documented, fluctuations in stream levels resulting from reservoir management may be detrimental to *Malaxis brachypoda*, since it does not tolerate fluctuations in the water table. The area around Green Mountain Falls has been extensively modified hydrologically, and in some places, the stream course has changed (Kelso personal communication 2005).

Some hydrologic modifications have occurred near the Wellington Lake occurrence. Jennings (1989) reported an unused ditch near the occurrence, and roads in the area may also be affecting the hydrology. Construction or refurbishing of ditches could affect occurrences of *Malaxis brachypoda* directly by disturbing the ground surface, or indirectly through hydrologic alteration and invasion of exotic species.

Residential and commercial development

The two occurrences in Boulder County are on public land (owned by the City of Boulder) and are protected from the direct effects of urban development. However, they remain vulnerable to indirect impacts, such as recreation and increased acidity due to air pollution. See the Threats section for further discussion of these topics. At Wellington Lake, *Malaxis brachypoda* is known from private land owned by the Wellington Reservoir Company. Plans for the development of this area are not known, but it is possible that future residential or commercial development could affect this area. The occurrence at Green Mountain Falls may have been on private land, or it may have been on what is now the Pike National Forest. Between 1990 and 2000, the population of El Paso County grew 30.2 percent (U.S. Census Bureau 2003). Residential development has destroyed much of the potential habitat in the Green Mountain Falls area at the elevation reported by Bessey (Kelso personal communication 2005), leading experts to suggest that this occurrence is probably extirpated.

Collection and over-utilization

> "Nothing in science can account for the way people feel about orchids. Orchids seem to drive people crazy. Those who love them love them madly. Orchids arouse passion more than romance. They are the sexiest flowers on earth."
> –Susan Orlean (1998)

The orchid industry is worth billions of dollars annually. The development of methods for propagating orchids through cloning and axenic culture has reduced impacts on wild populations, but the threat of over-collection is second only to habitat destruction for many orchid taxa (Koopowitz 2001). Some (e.g., Beckner 1979) have asserted that unrestricted collection of orchids is acceptable due to their biology and the ephemeral nature of some of their habitats. However, such arguments fail to account for the demographic consequences of over-collection (Catling 1979). The impact of the collection of wild plants is greatest on showy species. *Malaxis brachypoda* is difficult to find and is not a showy or particularly desirable species. However, there has been some cultivation of this species by orchid enthusiasts. Correll (1978) mentions that this species is cultivated in northern gardens. Large-scale collection of mosses for gardens and craft projects could also threaten *M. brachypoda* (USDA Forest Service 2000 as cited in Schultz 2003).

The issue of collection for scientific purposes is a difficult one for *Malaxis brachypoda*. The existing voucher specimens are extremely important scientifically and historically, and they serve as unequivocal proof of the existence of this species in Colorado. However, current knowledge of this species in Region 2 suggests that none of the known populations in Colorado is large enough to support collection of plants for any purpose. Specimens of *M. brachypoda* housed at KDH and COLO represent a significant fraction of the total population that has been documented in Region 2. In recent years, botanists have been mindful of the potential impacts of collecting this species, and no specimens of *M. brachypoda* have been collected in Colorado since 1981. If plants are collected for scientific purposes, care should be taken not to remove more than 5 percent of the plants present in small populations (Wagner 1991, Pavlovic et al. 1992).

There was a high level of visitation by botanists looking for this species on Green Mountain in Boulder County after the location was accidentally publicized, but this problem appears to have diminished with time (Hogan personal communication 2005).

Malaxis acuminata is an important indigenous medicine and is included in the Ayurvedic pharmacopoeia of India. Its tubers purportedly have aphrodisiacal properties, act as a febrifuge, and have a cooling effect (Rai et al. 2001). There is potential for over-utilization of *M. brachypoda* if it becomes sought after for medicinal purposes.

Fire and other processes

Fire, blowdown, insect outbreaks, and other processes that open the forest canopy may threaten *Malaxis brachypoda* in Region 2. Secondary impacts of these events, especially sedimentation resulting from fire or timber harvest, also potentially threaten *M. brachypoda*. See the section on Timber harvest and fuels reduction in this assessment for further discussion of this topic.

Occurrences of *Malaxis brachypoda* in Region 2 fall within the montane zone. *Pinus ponderosa* is the most common dominant forest tree near the known occurrences, but *M. brachypoda* is found in mesic microsites where it is not directly associated with this species. *Pinus ponderosa* forests are more susceptible to fire than all other forest types in the Southern Rocky Mountains and have a shorter fire return interval. Fires may have occurred every eight to 15 years in these woodlands and savannas of the Southern Rocky Mountains (Mehl 1992, Harrington and Sackett 1992 as cited in Rondeau 2001).

Fire has not occurred within the known occurrences of *Malaxis brachypoda* in Region 2 since their discovery, but this type of event is likely within a management timeframe. The Buffalo Creek fire burned just north of Wellington Lake in 1996. The Hayman Fire of 2002 came within 2 miles of Wellington

Lake. Another fire burned recently in the Lost Creek Wilderness (Olson personal communication 2005).

Recreation

Recreation threatens occurrences of *Malaxis brachypoda* in Boulder County and at Green Mountain Falls. There is a chance of trampling by hikers traveling off-trail as well as off-leash dogs running in the creek through the occurrence of *M. brachypoda* at Greenman Springs. The City of Boulder now forbids both hiking off-trail and having unleashed dogs in this area (Wanner personal communication 2006). There are no hiking trails in the immediate vicinity of the Wellington Lake occurrence, but this area is accessible to off-highway vehicles. A note in the folder for *M. brachypoda* at COLO regarding the Green Mountain Falls occurrence (probably written by W.A. Weber) reads "The locality, near Colorado Springs, is now overrun with tourists and the colony has probably been extirpated." Green Mountain Falls has been a popular tourist destination for many years. Intensive recreational use, such as heavy foot traffic, can lead to soil compaction and can accelerate erosion (Schultz 2003). Although it is likely that recreation has affected *M. brachypoda* to some extent, there have been no observations reporting direct impacts from recreation.

Timber harvest and fuels reduction

Schultz (2003) noted that hydrological disturbances and canopy removal logging are major threats to *Malaxis brachypoda*. In Region 9, 50 percent or greater canopy cover is best for *M. brachypoda* (USDA Forest Service 2000 as cited in Schultz 2003). Clear-cutting and thinning reduce canopy cover, which increases sunlight and causes the soil to dry out (Schultz 2003). *Malaxis brachypoda* has been known to disappear following logging in Maine (Schultz 2003). In clear-cut areas, orchids cannot regenerate due to soil compaction and lack of shade, pollinators, parent stock, and favorable microclimates (Hagsater and Dumont 1996). However, *M. brachypoda* is known from swamplands in Minnesota where some orchid regeneration occurred following logging (Schultz 2003 citing personal communication with Case).

At Wellington Lake, the slopes above this occurrence were being logged when *Malaxis brachypoda* was last seen at this site in 1989 (Jennings 1989, Colorado Natural Heritage Program 2005). The owners of this property had contracted with the state to do fuels reduction in this area (Vest personal communication 2005).

Aggressive fuels reduction activities are taking place throughout the South Platte Ranger District near Wellington Lake (Bohon personal communication 2005). Before the Buffalo Creek Fire (1996), openings were created at the headwaters of Green Mountain Creek near Wellington Lake to reduce fuels and to create snags for wildlife (Bohon personal communication 2005). The USFS analyzed proposed forest restoration actions in the Upper South Platte watershed on the Pike National Forest. The proposed treatments include mechanical timber harvesting, prescribed burning, revegetation in the Buffalo Creek burn, obliteration and reclamation of unnecessary roads, and trail improvements (Piehl 1999). Piehl (1999) determined that no impacts to *Malaxis brachypoda* or its habitat is expected under the action alternatives since riparian areas will be protected by a buffer. Riparian area restoration in the Buffalo Creek burn area will stabilize stream banks and increase opportunities for orchid establishment.

National Environmental Policy Act compliance work is on the planning horizon for the Buffalo Creek watershed. The need for this work has yet to be evaluated. Fuels reduction work is often done in a buffer strip around private land, but this can be modified to avoid areas with sensitive resources. A 100-foot buffer is typically planned around streams, within which there is no mechanical treatment. Forests dominated by *Pinus ponderosa* and *Pseudotsuga menziesii* are targeted for future fuels reduction activities in the Buffalo Creek area. The treatments are not imminent, and no fuels reduction activities are currently underway within the watershed (Culver personal communication 2005). Some salvage logging of burned timber has taken place in the Wellington Lake area, but there are no plans to cut more (Olson personal communication 2005).

Colorado Springs Utilities is doing fuels reduction work near Green Mountain Falls on lands that were deeded to watershed interests before the USFS was formed and for which an Environmental Impact Statement is not required (Kerrigan personal communication 2005). Community wildfire protection plans are in the early planning stages for Cascade and Crystal Park, which will involve fuels reduction near these municipalities (Kerrigan personal communication 2005, Tapia personal communication 2005).

The Trout-West Fuels Reduction Project includes seven areas on the Pike National Forest. Occurrences of *Malaxis brachypoda* are not known within the project area, but it includes the Woodland Park area northwest of Green Mountain Falls. It was determined that while this project may affect individual plants or habitat, it will not likely contribute to a trend towards federal listing or loss of viability to the populations or species (Pike National Forest 2002).

Because *Malaxis brachypoda* is a wetland species within Region 2 it is unlikely that it will be directly impacted by timber harvest or fuels reduction activities. Thus, the threat of these activities to *M. brachypoda* in Region 2 appears to be considerably less than in other portions of its range.

Road construction and right-of-way maintenance

Roads near wetlands can increase and concentrate surface runoff, reducing infiltration and aquifer recharge, and increasing erosion as well as pollutant inputs (Forman and Alexander 1998). Alternatively, roads can also impede drainage, blocking runoff and increasing surface water levels. Flooding caused by road construction can adversely affect orchid habitat (Reddoch and Reddoch 1997). Gravel pits near occurrences can also lead to hydrologic alteration of orchid habitats (Schultz 2003).

Livestock grazing and herbivory

The Wellington Lake occurrence of *Malaxis brachypoda* is within the Buffalo Creek grazing allotment, and it is the only occurrence of *M. brachypoda* in Region 2 within an active allotment. This allotment has been vacant since approximately 1993. However, the Pike National Forest has developed a new grazing management plan, in which it is possible that Buffalo Creek will be used on a reserve basis. Under this plan, the Buffalo Creek allotment could be used for livestock grazing in emergency situations when another allotment becomes unusable because of fire or drought. The permittee would be required to install temporary fencing, which decreases the likelihood that this allotment would actually be used (Bohon personal communication 2005, Lamb personal communication 2005). Because *M. brachypoda* is known from private land within this allotment, it is likely that the known occurrence will not be directly affected by grazing on the Pike National Forest.

Browsing by deer may affect *Malaxis brachypoda* (Reddoch and Reddoch 1997); deer threaten at least one occurrence in Wisconsin (Schultz 2003). Trampling (by humans and animals) and grazing (presumably by deer or other foraging animals) were observed in meadows inhabited by *M. brachypoda* in California (Schultz 2003).

The impacts of grazing on *Malaxis brachypoda* are not known. Allowing livestock grazing in the small populations of *M. brachypoda* in Region 2 is risky, since these occurrences are extremely vulnerable to extirpation. *Malaxis brachypoda* is threatened by any damage to the perennating bud, because growth for the season will cease until vernalization occurs again (Schultz 2003). Reeves and Reeves (1984) observed a high degree of fruit loss (39.22 percent and 34 percent) in *M. paludosa* due to predation, probably by rodents and insects. It is possible that these animals eat *M. brachypoda* fruits as well. On the other hand, removing 50 percent of the leaf of *M. massonii* had no effect on phenology or reproductive effort, and plants in dense populations were not more likely to be damaged than those in low density populations (Aragón and Ackerman 2001).

Exotic species

Malaxis brachypoda has not been documented with any exotic species in Region 2. However, threats to its habitat from exotic species are well documented. Riparian areas and some wetland types are particularly susceptible to invasion by noxious weeds, including Canada thistle (*Cirsium arvense*) and yellow toadflax (*Linaria vulgaris*), both of which are common near each occurrence of *M. brachypoda* in Region 2. Both species tolerate the shady conditions preferred by *M. brachypoda*. Canopy removal and ground disturbance can contribute to an increase in the number of exotic plant species. All occurrences of *M. brachypoda* in Region 2 are near residential developments, roads, and trails, which act as corridors for weed invasion (Forman and Alexander 1998).

In the Great Lakes Region, *Malaxis brachypoda* habitats are being invaded by glossy buckthorn (*Rhamnus frangula*), which forms dense thickets. It is possible that the shade cast by this tall shrub may benefit *M. brachypoda* and other shade-loving orchid species (Schultz 2003). Earthworm invasion is also occurring in the deciduous forests of the Great Lakes Region and northeastern United States, and this may threaten occurrences of *M. brachypoda* in these areas. The activity of earthworms alters soil layers, reduces litter and duff, alters water relations (particularly near the soil surface in upland forests), and changes the mycorrhizal fungal community (Hendrix and Bohlen

2002, Schultz 2003). These changes have caused the near-extirpation of *Triphora trianthophora*, and they threaten many orchid species in the region (Schultz 2003 citing a personal communication with Case). Because earthworms are limited primarily to upland sites, they are unlikely to affect *M. brachypoda* directly.

Climate change

Global climate change is likely to have wide-ranging effects in the near future for all habitats, but the direction of projected trends is yet to be determined. Predictions vary based on environmental parameters used in models. The prevailing scientific opinion, based on numerous studies, is that global temperatures are increasing and will continue to increase through the next century, due in part to anthropogenically increased levels of atmospheric CO_2 (Reiners 2003). The upper limit of global temperature increase over the next century is estimated to be 6 °C (Reiners 2003). Climate change scenarios for the Rocky Mountains offer varying predictions of precipitation quantity and pattern. Some scenarios indicate that annual precipitation over the next 100 years will increase, but growing season precipitation will decrease. Other scenarios indicate that parts of the Rocky Mountains are likely to become drier.

Any of these scenarios could change the hydrology of *Malaxis brachypoda* habitats in Region 2. Global warming would probably adversely affect *M. brachypoda* by causing habitat loss and increasing the risk of fire (USDA Forest Service 2000 as cited in Schultz 2003). *Malaxis brachypoda* is not tolerant of warming of the soil in the summer (Correll 1978), suggesting that it would be negatively impacted by warmer summer temperatures. Temperature increase could cause vegetation zones to climb 350 ft. in elevation for every degree Fahrenheit of warming (U.S. Environmental Protection Agency 1997), and is likely to result in net drying due to increased evapotranspiration (Reiners 2003). This type of change will probably degrade habitat quality and availability and may extirpate *M. brachypoda* locally. Because of the disjunct nature of its populations, and the fact that these populations will be unable to retreat to more suitable conditions, this threat is pertinent to all occurrences of *M. brachypoda* in Colorado.

Pollution

Atmospheric nitrogen deposition has become one of the most important agents of vegetation change in densely populated regions (Köchy and Wilson 2001). Nitrogen loading and vegetation change have been observed to be greatest near large metropolitan areas (Schwartz and Brigham 2003). Measurable impacts from nitrogen pollution might be expected in all locations where *Malaxis brachypoda* has been documented in Region 2. Nitrogen enrichment experiments show universally that nitrogen is limited (Gross et al. 2000). This is likely to cause a few species to increase in abundance while many others decline (Schwartz and Brigham 2003). Acid deposition, which has increased markedly in Colorado through the 20th century, may have already caused changes to the soil chemistry that threaten the viability of *M. brachypoda*. High elevation watersheds of the Front Range have already reached an advanced stage of nitrogen saturation (Burns 2002).

Conservation Status of <u>Malaxis brachypoda</u> in Region 2

Terrestrial orchids are among the most vulnerable of all plant species, and little is known about how they reproduce in nature (Rasmussen 1995). Habitat destruction in the form of deforestation has led to global decline of many orchid species (Koopowitz 2001).

Malaxis brachypoda is vulnerable to extirpation due to its narrow ecological amplitude, the uncommon nature of its habitat, and its tendency to occur in small, scattered, and isolated populations. It is vulnerable to any direct impacts to its habitat, especially those that alter hydrology or canopy cover. It is also vulnerable to indirect human impacts including climate change. *Malaxis brachypoda* requires constant water availability, shade, and cool soil temperatures, and it does not tolerate water table fluctuations. As an obligate outcrosser, *M. brachypoda* depends on an unknown pollen vector for fertilization. The small populations in Region 2 and elsewhere mean that this species is particularly vulnerable to demographic and environmental stochasticity.

The lack of recent observations of this species in Colorado and the small size of documented occurrences suggest that this species is declining or is possibly extirpated in Region 2. However, *Malaxis brachypoda* is extremely difficult to detect; it is found in densely vegetated habitats, and it is very small and cryptically colored. Of *M. brachypoda* in California, Coleman (1999) wrote, “the ability of the plant to hide from searchers for 42 years indicates that it is safe from casual observation.” There is evidence of its decline in other portions of its range as well. Most occurrences in Region 2 are isolated from each other, making the recolonization of extirpated sites unlikely without human intervention. Stochastic processes and normal environmental variation could easily result in extirpation of Region 2 occurrences, regardless of current protections.

In Region 2, *Malaxis brachypoda* is a relict species that is disjunct from other populations by 750 miles or more. Although the species' survival does not depend on the populations in Colorado, these populations are of great interest to science. The distribution of relictual and disjunct boreal and alpine species provides insight into the Quaternary natural history of North America. Peripheral populations may also be important as genetic reserves, since outlying populations are exposed to different selective pressures and therefore are often genetically different from those within the heart of a species' range (Lesica and Allendorf 1995).

Management of Malaxis brachypoda in Region 2

Implications and potential conservation elements

Malaxis brachypoda is Colorado's rarest orchid. Existing data for *M. brachypoda* in Region 2 portray a species that is on the brink of local extinction due to demographic stochasticity and possibly human impacts to its habitat. The failure to find any occurrence of this species since 1990 despite surveys by experts suggests that it may already be extirpated in Region 2. The greatest threat to *M. brachypoda* is the effect of small population size, but it is possible that other populations await discovery in Region 2. The challenges of detecting this species are so great that other occurrences, if they are present in Region 2, could easily remain undetected.

There are many possible reasons why *Malaxis brachypoda* is so rare in Region 2. With so little knowledge of the autecology of this species or its population trend, any discussion of this topic is necessarily speculative. Many locations in Region 2 have apparently suitable but unoccupied habitat for *M. brachypoda*. This may result from its distribution during early post-glacial times. The species' ability to disperse to suitable habitats may be limited, confining it to a small number of sites. It is also possible that *M. brachypoda* responds to habitat variables in ways that we do not understand. It may have been more widespread historically, but its tendency to occur in small populations in Region 2 led to demographic instability and local extirpation. If *M. brachypoda* uses a metapopulation strategy, it is possible that there is insufficient suitable habitat available in Region 2 to support this strategy. *Malaxis brachypoda* is so rare in Region 2 and so inconspicuous that it is fortunate that any occurrences have been found here. The extent to which the abundance of this species has been diminished in Region 2 by human activities is unknown.

Even if other occurrences are found, habitats that can support *Malaxis brachypoda* are threatened throughout Region 2. *Malaxis brachypoda* is disjunct, and there is only a minute chance of natural reintroduction given the current distribution of occurrences and potential habitat. This species is in need of conservation action, especially the protection of land and hydrologic resources that support occurrences and potential habitat.

Conservation elements for *Malaxis brachypoda* are derived from observations made mostly outside Region 2, but there have been few quantitative studies of this species. Human-induced habitat loss and disturbance, decreased canopy cover, increased soil temperature, competition, hydrologic changes, and impacts to its pollinators are all factors that would likely contribute to a decline of this species. Hydrologic integrity of its habitat appears to be very important for its survival, but many factors threaten this throughout its range, and some are affecting occurrences and habitats in Region 2. Impoundment, ditching, roads, and trails all may be affecting critical hydrologic attributes within Region 2 occurrences.

Range-wide, 13.5 percent of the element occurrence records of *Malaxis brachypoda* in the United States are in national forests. The conservation and management of a significant fraction of the known occurrences of *M. brachypoda* therefore rest in the hands of the USFS. Of the 423 element occurrences known, only 12 are in protected sites (Schultz 2003).

Further research on the ecology and distribution of *Malaxis brachypoda* will help to develop effective approaches to management and conservation. Until a more complete picture of the distribution and ecology of this species is obtained, priorities lie with conserving known occurrences.

Tools and practices

Species and habitat inventory

Inventories targeting *Malaxis brachypoda* are needed. Many locations on National Forest System land contain suitable habitat for *M. brachypoda*, and surveys are needed to search more of these sites, especially on the Pike National Forest (Jennings personal communication

2005). The Pike National Forest is interested in trying to relocate the occurrences of this species at Green Mountain Falls and Wellington Lake (Tapia personal communication 2005). At Green Mountain Falls, well-vegetated, perennial, northeast-flowing streams draining Pikes Peak are good places to search for *M. brachypoda*. The Lost Creek Wilderness adjacent to Wellington Lake appears to have suitable habitat for *M. brachypoda* (Olson personal communication 2005). The Distribution and abundance section has a more detailed discussion of potential survey areas in Region 2.

Finding *Malaxis brachypoda* in the field is a challenge even for orchid experts. It is very small and difficult to detect (Coleman 1990). Case (1987) wrote that "The entire plant, small, shiny green, and hidden in moss or among bog vegetation, may be easily overlooked by even the diligent orchid searcher." Describing the rediscovery of *M. brachypoda* in the San Bernardino Mountains of California, Coleman (1990) wrote, "The orchids were in short sedges and grasses right at the feet of the corn lilies. To find the plants it is necessary to get down on your hands and knees and spread the grasses. I had searched this area on a previous trip but missed the plants because I was looking in the more open areas away from the corn lilies." Hogan (personal communication 2005) also noted that field crews must search for *M. brachypoda* on hands and knees, and that there is no hope of finding this species in its vegetative state. Brackley (1985) and Reddoch and Reddoch (1997) suggest that the light brown capsules of *M. brachypoda* are easier to see than the tiny, greenish flowers. The capsules are also larger than the flowers (Schultz 2003). The previous year's inflorescence and capsules may be present while *M. brachypoda* is flowering (Catling and Magrath 2002).

Recent advances in mark and recapture methods may be useful for censusing *Malaxis brachypoda* populations. These methods have been applied successfully to plants and are useful for censusing populations that may exhibit prolonged dormancy or may be difficult to find in concealing vegetation (Alexander et al. 1997).

The effort to rediscover *Malaxis brachypoda* in California was a cooperative effort between the California Natural Diversity Database, California Native Plant Society, and state and federal agencies (Coleman 1990, Coleman 1999). Similar collaborative efforts have been employed in Region 2 and would increase the potential scope and personnel available for an intensive search for this species.

Aerial photography, topographic maps, soil maps, and geology maps can be used to limit surveys of large areas, and these tools could be highly effective for identifying survey areas for *Malaxis brachypoda*. These tools are most effective for species for which there is a basic understanding of its habitat requirements, and from which distribution patterns and potential search areas can be deduced.

Searches for *Malaxis brachypoda* could be aided by the use of deductive and inductive species distribution modeling techniques. Goerzen et al. (2003) used deductive techniques to model the distribution of orchid species in southeastern Manitoba. They generated a predictive model by intersecting soil and cover type data known to characterize the most suitable orchid habitats. Using inductive techniques such as Classification and Regression Tree (CART; Breiman et al. 1984) and envelope models could also help to refine survey areas. However, these techniques may be problematic for many orchid species, including *M. brachypoda*, because these plants are very sensitive to microscale habitat attributes that are often inadequately represented in digital datasets.

Population and demographic monitoring

Data from demographic studies of *Malaxis brachypoda* would provide insight into the nature of dormancy and vital rates in this species, and permit the use of modeling in which critical life history stages, minimum viable population size, and the probability of long-term persistence could be determined. For species like *M. brachypoda* where the proportion of dormant plants may vary among years, it is difficult to monitor population trends accurately (Lesica and Steele 1994). Prolonged dormancy complicates monitoring studies and requires consideration in sampling design. It has been suggested that *M. brachypoda* populations persist as a shifting mosaic on the landscape in response to suitable germination sites (Schultz 2003). If this is true, then it may compound the difficulty of monitoring and tracking this species, and complicate the interpretation of results.

Standard demographic and population monitoring methods employing the use of randomly arrayed systematic sampling units (quadrats) are reviewed in Lesica and Steele (1997) and Elzinga et al. (1998). In these designs, data are recorded for each marked plant; the data include a measure of size (for *Malaxis brachypoda*, this could be a measurement of the area of the leaf and/or height of the inflorescence), life history stage, fecundity (e.g., the number of fruits), and mortality. Recruitment within each quadrat can be quantified by counting seedlings. Quantifying reproductive success will be challenging in *M. brachypoda* because plants may persist mycotrophically underground for a number of years before reaching their adult heterotrophic stage.

Although data gleaned from demographic monitoring of *Malaxis brachypoda* in Colorado would be valuable (if extant populations were found), the potential for negative impacts of this research (mostly from trampling of plants and habitat) are so great that this type of monitoring is not recommended for Colorado occurrences. Demographic research on this species would be more appropriate in portions of its range where it is less imperiled. At this time, appropriate monitoring of *M. brachypoda* in Colorado is limited to periodic checks for presence or absence at known sites.

Beneficial management actions

Conferring protected status on land supporting *Malaxis brachypoda* occurrences would help to mitigate the threat of residential development. Of the three occurrences that have been seen within the last 20 years, Wellington Lake is the least protected. Jennings (1989) wrote "the Wellington Lake population deserves some protection. However, the site is small and the orchids occupy less than 10 square feet. The proximity of the road, logging, and an unused ditch break the site into very small management units."

Schultz (2003) stated that "the viability of *Malaxis brachypoda* depends on assuring that tracts of land with suitable habitat continue to exist." While there is still value in protecting individual occurrences, the long-term viability of orchid populations will be realized by protecting entire ecosystems (Reddoch and Reddoch 1997).

Although *Malaxis brachypoda* is not currently known from National Forest System land in Region 2, it is very likely that populations of this species await discovery on federal land. One known occurrence is very close to the Pike National Forest, and an historic occurrence probably was documented on lands now within the Pike National Forest. Retaining USFS sensitive species status will be beneficial to this species.

Recreational impacts can be mitigated through a variety of actions. Minimizing impacts to hydrology from trails by installing bridges or boardwalks is likely to benefit the species. The City of Boulder Open Space and Mountain Parks Department has wisely tried not to draw attention to the occurrences on Green Mountain (Hogan personal communication 2005), and they are re-routing the trail away from the *Malaxis* occurrence at Greenman Springs (Wanner personal communication 2006).

Buffering known occurrences and *Malaxis brachypoda* habitat when conducting fuels reduction projects and other activities on National Forest System land will mitigate threats resulting from canopy removal. Maintaining the hydrologic integrity of known occurrences and suitable habitat will also benefit *M. brachypoda*.

Raising the awareness of USFS personnel will help to protect *Malaxis brachypoda*. To prevent inadvertent impacts to known populations, all USFS personnel involved in planning and on-the-ground management activities taking place near known occurrences or within suitable habitat should be provided with location data and information to assist with field identification.

No experimental data exist to describe the response of this species to most management actions. If *Malaxis brachypoda* still exists in Colorado, a monitoring program is needed to address its management needs, trend, and habitat condition.

Seed banking and restoration methods

No seeds or genetic material of *Malaxis brachypoda* are currently in storage at the National Center for Genetic Resource Preservation (Miller personal communication 2004). It is not among the National Collection of Endangered Plants maintained by the Center for Plant Conservation (Center for Plant Conservation 2004). An understanding of the species' germination, life history, and seasonal phenology in natural habitats is essential for the success of culture methods, propagation, and conservation (Rasmussen 1995). *Malaxis brachypoda* habitats like those in which it occurs in Region 2 are not restorable within a typical management timeframe.

No methods have been developed specifically for propagating *Malaxis brachypoda*. However, methods for propagating other orchid species would probably apply to *M. brachypoda*. Case (1962) references the May 1960 Orchid Society Bulletin for methods of pot culture of the lily-leaved twayblade, and notes that similar methods can be used for the entire group. Correll (1978) states that *M. brachypoda* can be grown in northern gardens under circumneutral, more or less calcareous conditions. Case (1962) notes that for growing *M. brachypoda* "a sheltered spot near a log or rock in sandy, acid soil will suffice." Germinating terrestrial orchids was extremely difficult until recently (Koopowitz 2001). Easy and reliable methods of germinating terrestrial orchids have now been developed either aseptically or using symbiotic mycorrhizae (Wodrich 1997).

Information Needs and Research Priorities for Region 2

In order for the viability of *Malaxis brachypoda* to be adequately addressed, better information is needed regarding its distribution and abundance in Region 2. Therefore, inventory and monitoring are the two highest research priorities for this species. Revisits of all known occurrences are needed to obtain abundance data. Suitable habitats along the Colorado Front Range and the Black Hills of South Dakota and Wyoming need to be searched. Habitat characteristics and associated species need to be defined to refine the search image for this species. Obtaining information regarding the soil chemistry of *M. brachypoda* habitat throughout its range will help to clarify this species' needs and potential distribution.

Very little is understood about the life cycle, ecology, or population biology of *Malaxis brachypoda*. Schultz (2003) listed two categories of information needs: basic life history (e.g., germination, establishment, growth requirements, life span, pollinator identity) and ecology and habitat (e.g., soil and substrate chemistry, nutrient requirements, light and moisture requirements, distribution of mycorrhizal fungi). Some information regarding life history and autecology may be inferred (cautiously) from other orchid species, including *M. paludosa*, and this is discussed in this assessment where relevant. However, research is needed specifically on *M. brachypoda* to mitigate threats and to support management and conservation efforts for this species in Region 2.

Demographic monitoring of occurrences is needed to assess the population trend of *Malaxis brachypoda* locally and regionally. Knowledge of the vital rates of *M. brachypoda* (i.e., recruitment, survival, and fecundity) is needed to investigate (and mitigate if necessary) potential bottlenecks in its life history and to develop practical management protocols. With these data, a stochastic projection matrix model could be constructed to assess viability.

The pollen vector or vectors for *Malaxis brachypoda* in Region 2 are unknown, and there have been no attempts to note any aspect of this species' pollination ecology in Region 2. Knowledge of the pollination ecology of *M. brachypoda* is critical for developing conservation plans for this species. Methods used to observe pollinators of *M. paludosa* that would also apply to *M. brachypoda* are discussed in Reeves and Reeves (1984). Methods for investigating pollination ecology are discussed more broadly by Kearns and Inouye (1993).

Definitions

Anamorph – an asexually reproducing phase of a fungus (Wikipedia Contributors 2006).

Auriculate – with earlike lobes at the base of a leaf, encircling the stem (Harris and Harris 1999)

Autogamy – self-pollination in the absence of animal pollinators, followed by seed development, implying self-fertilization (Catling 1983).

Axenic – not contaminated by or associated with any other living organisms; usually used in reference to pure cultures of microorganisms that are completely free of the presence of other organisms (Houghton Mifflin Company 2003).

Column – the united filaments and style in the Orchidaceae (Harris and Harris 1999).

Conduplicate – folded together lengthwise with the upper surface within, as the leaves of many grasses (Harris and Harris 1999).

Conservation Status Rank – the Global (G) Conservation Status (Rank) of a species or ecological community is based on the rangewide status of that species or community. The rank is regularly reviewed and updated by experts, and takes into account such factors as number and quality/condition of occurrences, population size, range of distribution, population trends, protection status, and fragility. A subnational (S) rank is determined based on the same criteria applied within a subnation (state or province). The definitions of these ranks, which are not to be interpreted as legal designations, are as follows:

- **GX** **Presumed Extinct**: Not located despite intensive searches and virtually no likelihood of rediscovery
- **GH** **Possibly Extinct**: Missing; known only from historical occurrences but still some hope of rediscovery
- **G1** **Critically Imperiled**: At high risk of extinction due to extreme rarity (often 5 or fewer occurrences), very steep declines, or other factors.
- **G2** **Imperiled**: At high risk of extinction due to very restricted range, very few populations (often 20 or fewer), steep declines, or other factors.
- **G3** **Vulnerable**: At moderate risk of extinction due to a restricted range, relatively few populations (often 80 or fewer), recent and widespread declines, or other factors.
- **G4** **Apparently Secure**: Uncommon but not rare; some cause for long-term concern due to declines or other factors.
- **G5** **Secure**: Common; widespread and abundant.

CSR (competitive/stress-tolerant/ruderal) model – a model developed by J.P. Grime in 1977 in which plants are characterized as competitive, stress-tolerant, or ruderal, based on their allocation of resources; competitive species allocate resources primarily to growth, stress-tolerant species allocate resources primarily to maintenance, and ruderal species allocate resources primarily to reproduction; a suite of other adaptive patterns also characterize species under this model; some species show characteristics of more than one strategy (Barbour et al. 1987).

Febrifuge – a medication that reduces fever (Houghton Mifflin Company 2003).

Labellum – synonymous with Lip (see below).

Lip – the upper (but by twisting of the pedicel appearing to be lower) petal in Orchidaceae (Harrington and Durrell 1957).

Marly – composed of fine-grained sediments rich in calcium carbonate and organic matter (Fertig and Jones 1992).

Pseudobulb – a false bulb; the thickened or bulblike stem of many orchids (Luer 1975)

Resupinate – upside down due to twisting of the pedicel, as the flowers of some orchids (Harris and Harris 1999).

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