# *Cypripedium parviflorum* Salisbury var. *pubescens* (Willd.) Knight

## Large Yellow Lady's-slipper

Conservation Assessment

For USDA Forest Service Region 9

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# SUMMARY

Large yellow lady's-slipper (*Cypripedium parviflorum* var. *pubescens*) is an herbaceous perennial in the orchid family (Orchidaceae) that is distributed throughout much of North America. Although this taxon is globally secure and is common in many parts of its range, it is threatened in one state, and is ranked S1 (critically imperiled) in six states, S2 (imperiled) in three states and four provinces, and S3 (vulnerable) in seven states and five provinces. Most populations are small, and they are vulnerable to a number of threats, including habitat loss, alteration, and fragmentation; herbivory by livestock and grazing wild animals; destruction by insects and disease; competition from non-native invasive species; and collection and cultivation. The importance of each of these threats varies geographically.

This orchid grows in a variety of habitats range-wide, including dry to mesic deciduous woods; moist, seepy, swampy, or seasonally wet deciduous or coniferous forests that are usually rich or calcareous; thickets; meadows or prairies; edges of bogs or fens; and occasionally even tundra or roadside ditches. Plants reproduce both vegetatively and sexually, and are out-crossers that depend on insects for pollination. Anthers produce copious amounts of pollen, but the flowers offer no nectar reward, are infrequently pollinated, and produce fewer fruits than flowers. When fruits are produced, they contain approximately 7000 seeds; however, percent seed set is low, and propagation is presumed largely vegetative. Seeds lack any stored reserves and are dependent on mycorrhizal fungi for germination and establishment. Seedling mortality of large yellow lady's-slippers is high, and it can take several years for a mature plant to develop from seed. Individual plants are long-lived, clonal, and typically consist of 1-20 stems per clump.

*Cypripedium parviflorum* var. *pubescens* is one taxon within a larger complex of lady's-slippers that have long been a source of systematic and nomenclatural confusion Most states do not track this species, and of those that do, many are unable to accurately distinguish records for var. *pubescens* from varieties *parviflorum* and *makasin*. The great morphological plasticity exhibited by plants in different environments and unusually high levels of genetic variation within populations have contributed to the confusion. This confusion, in turn, hampers conservation efforts.

While this report encompasses information about the systematics, biology, habitat/ecology, threats, distribution, status and current conservation measures across this species' range, it is written for the Eastern Region (Region 9) of the USDA Forest Service, and includes as much detailed information as was available from the 20 states, 15 National Forests, and one Tallgrass Prairie within Region 9 as was available.

# ACKNOWLEDGMENTS

The USDA Forest Service provided funding for the development of this conservation assessment. Many other agencies and individuals provided input or support.

The bulk of the text of this document is based on the literature review completed by Lisa St. Hilaire in 2003, as part of the species viability evaluations done during Forest Plan revision on the Finger Lakes National Forest. Her review incorporates that of Kai-Ewe Allen, who completed a literature review of the same species for the same purpose on the Green Mountain National Forest in 2002. Lisa's work was exhaustive, and included dozens of literature citations and personal communications, all of which are included in the reference sections at the end of this document, in addition to a reference to her literature review, itself. While in some places, Lisa's text is retained verbatim, and is indicated as such, most of her text is reworded just enough to tell the story of large yellow lady's-slippers in the format of a conservation assessment rather than a literature review. The author expresses heartfelt thanks to Lisa for her extensive research on this taxon.

Employees of state Natural Heritage Programs in Connecticut, Indiana, Iowa, Maine, Massachusetts, Minnesota, Missouri, New Hampshire, New York, Ohio, Pennsylvania, Vermont, West Virginia, and Wisconsin provided names of contacts, contributed element occurrence records, and provided information specific to the populations in their states.

Botanists and ecologists from National Forests within Region 9 of the USDA Forest Service provided information regarding status, habitat, threats, and conservation measures on their Forests.

## INTRODUCTION

*Cypripedium parviflorum* Salisbury var. *pubescence* (Willd.) Knight (Orchidaceae), large yellow lady's-slipper, is a perennial that grows in a variety of habitats range-wide, including dry to mesic deciduous woods; moist, seepy, swampy, or seasonally wet deciduous or coniferous forests that are usually rich or calcareous; thickets; meadows or prairies; edges of bogs or fens; and occasionally even tundra or roadside ditches. These plants reproduce both vegetatively, by means of rhizomes that send up new shoots, and sexually, through the production of flowers and fruits. Large yellow lady's-slippers are out-crossers; they depend on insects for pollination and are easily pollinated by lots of small insects. Although anthers produce copious amounts of pollen, the flowers offer no nectar reward, are infrequently pollinated, and produce fewer fruits than flowers. When fruits (capsules) are produced, they contain approximately 7000 seeds; however, percent seed set is low, and propagation is presumed largely vegetative. Seeds lack any stored reserves and are dependent on mycorrhizal fungi for germination and establishment, but if the soil/substrate conditions are not right, the fungus can become a pathogen and destroy the seed. Seedling mortality of large yellow lady's-slippers is high, and it can take several years for a mature plant to develop from seed. Individual plants, or genets, are long-lived, clonal, and typically consist of 1-20 ramets (shoots) per clump (genet).

Large yellow lady's-slippers are distributed throughout most of North America, with the exception of Arkansas, California, Hawaii, Louisiana, Nevada, and Oklahoma in the United States and the province of Nunavut in Canada. Authorities disagree about their presence in the Northwest Territories in Canada and Alabama, Alaska, Delaware, Florida, Idaho, Maryland, Navajo Nation, Nebraska, North Dakota, Oregon, South Carolina, South Dakota, Texas, or Wyoming in the United States. They are thought to be distinct from the European entity, *Cypripedium calceolus*, but they are one taxon within a larger complex of lady's-slippers that have long been a source of systematic and nomenclatural confusion. This confusion has contributed to disagreements about the extent of their distribution and can impede conservation efforts. Two factors contributing to the confusion are the great morphological plasticity exhibited by plants in different environments, and unusually high levels of genetic variation within populations.

Large yellow lady's-slippers' global rank is G5T4T5. In North America they are listed T (threatened) in New Hampshire, are ranked S1 (critically imperiled) in six states, S2 (imperiled) in three states and four provinces, and S3 (vulnerable) in seven states and five provinces. Although they are common in many parts of their range, most populations are small, and they are vulnerable to a number of threats, including habitat loss, alteration, and fragmentation; herbivory by livestock and grazing wild animals; destruction by insects and disease; competition from non-native invasive species; collection and cultivation. The importance of each of these threats varies geographically.

This report summarizes assesses and summarizes what is currently known about large yellow lady's-slippers. It describes the plant, its taxonomic relationships, history,

and synonymy; its biology, habitat, and ecology; and its threats, distribution, status, and current conservation measures. Because this report is written for the Eastern Region (Region 9) of the USDA Forest Service, it includes as much detailed information as was available from the 20 states, 15 National Forests, and Midewin Tallgrass Prairie within this region. (The Eastern Region covers Connecticut, Delaware, Illinois, Indiana, Iowa, Maine, Maryland, Massachusetts, Michigan, Minnesota, Missouri, New Hampshire, New Jersey, New York, Ohio, Pennsylvania, Rhode Island, Vermont, West Virginia, and Wisconsin.)

## DESCRIPTION

Large yellow lady's-slipper is a flowering herbaceous perennial, with an erect stem ranging in height from about 30 to 60 cm. Its leaves are alternate, entire, broad, prominently parallel-veined, and sheathing at the base. Stems are usually single-flowered, although double flowers occasionally occur. The flower consists of a yellow inflated pouch (labellum), accompanied by two straw-colored, linear, often helically twisted petals, and three sepals, the lower two more or less fused. Flowers are perfect. Each flower has two stamens, one on each side of a staminode that partially closes the aperture of the labellum. Ovaries are inferior, and develop into elongate capsules after fertilization. The labellum edge, veins, and staminode are often dotted with minute reddish –purple spots. Within the yellow lady's-slipper complex, variety *pubescens* is generally recognized as having a larger labellum than varieties *makasin* and *parviflorum*, and light straw-colored petals, compared to purple in the other two. This description is a composite based on Flora of North America Editorial Committee (1993+), Gleason and Cronquist (1991), Sheviak (New York State Museum, personal communication), and Deller (1994).

Stem and foliage of yellow lady's slippers, perhaps just the large-flowered variety, are finely hairy, and these hairs can cause skin irritation in some people (Morris and Eames 1929, Correll 1950, Luer 1975, Brackley 1985, Chapman 1997, Reddoch and Reddoch 1997, Ladd 2001). The skin irritation is attributed to an allergen called cypripedin, the potency of which increases with development of the plant, with a maximum effect during seed capsule formation (MacDougal 1895 in Kull 1999).

The *Cypripedium* genus, along with three other genera, are thought to belong to the most primitive group of orchids, isolated from the rest of the orchid family, and referred to as the Cypripedieae; no intermediary forms between Cypripedieae and the rest of the orchid family are known (Correll 1950). The primitive habit, *which Cypripedium* has with some modifications, is relatively slender rhizomes, fleshy roots (but not storage roots), elongate stems, spirally arranged, non-articulated plicate leaves, and a terminal inflorescence (Dressler 1981).

The number of chromosomes in somatic cells of large yellow lady's-slippers is $2n=20$ (Brackley 1985). Chromosome size in the subfamily Cypripedioideae is relatively large (Dressler 1981). The large yellow lady's-slipper phenotype is highly variable and

influenced by the environment in which it grows (Correll 1950, Luer 1975, Chapman 1997). Environmental conditions in early years may strongly influence morphology and physiology in later years (Sheviak, New York State Museum, personal communication in Deller 1994). The result is that vigorous immature or depauperate mature individuals of large yellow lady's-slippers may have small flowers (Sheviak 1974). Botanists typically report that small flowered plants transplanted into a garden will subsequently grow larger and bear large flowers (Sheviak 1995). The reverse is also apparently true - Knight (1905) notes an example in which large yellow lady's-slipper plants growing in rich soil in low shady woods were transplanted into less rich soil in a sunny garden, and were subsequently much smaller and bore smaller flowers, thus resembling the typical var. *parviflorum*.

Plants of more open, exposed sites tend to be smaller and have narrower leaves than those of shady, sheltered sites (Sheviak 1995). Larger clumps may be found in sunnier sites, especially in limestone soils (Sheviak 1995). Northern plants in limestone soils typically exhibit great morphological plasticity; depending on the intensity of selection pressure, populations may be composed of varying percentages of "woodland-form" and "open-form" plants (Sheviak 1995). This variability may be partially fixed by a plant's genotype, and partially the result environmental influence on the phenotype (Sheviak 1995). For a list of morphological characters that may distinguish var. pubescens from the other two North American varieties of yellow lady's slippers, see Appendix 1.

## TAXONOMIC RELATIONSHIPS, HISTORY, AND SYNONYMY

The yellow lady's-slipper complex in North America has long been a source of systematic and nomenclatural confusion; this confusion can impede conservation efforts for these taxa (Deller 1994, Case et al. 1998 in St. Hilaire 2003). In a literature review of large yellow lady's-slippers for the Finger Lakes National Forest, St. Hilaire (2003) provides a thorough history of the taxonomic relationships, history, and synonymy of this complex; what follows is a paraphrase of her review, although in places, as indicated, her text is used verbatim.

While some botanists consider the European *C. calceolus* to be a circumboreal species and describe the North American plants to be *C. calceolus* var. *pubescens* (Correll 1950, Fernald 1950, Luer 1975, Gleason and Cronquist 1991, Homoya 1993, MOBOT 2002), others (Baldwin 1884, Gibson 1905, Knight 1906, Fernald 1950, Atwood 1984, Brackley 1985, Sheviak 1994, 1995) consider the North American taxon distinct, but disagree regarding its classification.

North American yellow lady's-slippers differ from the Eurasian *Cypripedium calceolus* by their yellow, conduplicate staminodia that are broadest near the middle or the base, compared to white staminodia that are broadest near the apex in the Eurasian plants (Keenan 1988, Sheviak 1994, 1995, Haines 2001). Cladistic analysis also suggests that the North American yellow lady's slippers are not close to the European plants

(Freudenstein 2001). In 1791, Salisbury separated North American yellow lady's slippers from the Eurasian *C. calceolus* and called the North American plants *C. parviflorum* (Case et al. 1998).

In 1802, Willdenow separated North American plants into two species, *C. parviflorum* and *C. pubescens* (Case et al. 1998). In 1929, Morris and Eames treated yellow lady's slippers as a single species, *C. parviflorum*, of highly variable habitat, and included in it the small-flowered variety *parviflorum*, the large-flowered *C. parviflorum* var. *pubescens*, and the flat-petalled *C. parviflorum* Salisb. var. *planipetalum* Fernald from the Gulf of St. Lawrence. Fernald (1926, 1928) suggested that several species, including *C. parviflorum* var. *planipetalum*, demonstrate a geographic phenomenon in which the Newfoundland variant of a circumpolar series is morphologically closer to the European than the eastern North American species, or it bridges the gap between them. Atwood (1984) also recognized the flat-petalled form as a separate entity, calling it *C. pubescens* Willd. var. *planipetalum* (Fernald) Atwood. This variety is now considered an extreme expression of var. *pubescens* rather than a separate variety (Sheviak 1994). Sheviak (1992, 1995) includes in *Cypripedium parviflorum* var. *pubescens* not only this Newfoundland variety, but also *C. flavescens* DC with its laterally compressed lip, and *C. veganum* Cockerel from high elevations in New Mexico. All are now considered to represent expressions of var. *pubescens* rather than distinct taxa. One hypothesis for the variation seen in North American yellow lady's-slippers is that North America has a variable population of orchids undergoing active speciation (Luer 1975).

An additional taxon, *Cypripedium kentuckiense*, is a recent species segregate of the *C. parviflorum* complex; it was previously considered an unusual form of *C. parviflorum* var. *pubescens* (Case et al. 1998), but isozyme analyses and morphological differences support its recognition as a distinct species, separate from *C. parviflorum* var. *pubescens* (Case et al. 1998).

Sheviak (1994), whose interpretation of the North American complex is widely accepted, lists three varieties of *C. parviflorum*: *C. parviflorum* var. *parviflorum*, the small-flowered southern variety; var. *makasin*, the small-flowered northern variety of cedar bogs (formerly known as *C. calceolus* var. *parviflorum)*; and the large-flowered var. *pubescens*, the most widely distributed and variable variety. This differs slightly from Atwood's 1984 recognition of *Cypripedium parviflorum* Salisbury, *C. pubescens* var. *pubescens* Willd., *C. pubescens* Willd. var. *planipetalum* (Fernald) Atwood, and *C. kentuckiense* C. F. Reed. Sheviak (1992, 1993, 1994, 1995) includes *C. montanum*, *C. candidum* Muhl. ex Willd., and *C. kentuckiense* Reed as part of the larger *Cypripedium calceolus* complex.

Of the three varieties recognized by Sheviak, all occur in at least some states within Region 9. *Cypripedium parviflorum* var. *pubescens* is listed as Regional Forester Sensitive on the Green Mountain National Forest in Vermont, Shawnee National Forest in Illinois and the Hoosier National Forest in Indiana, and is present within the proclamation boundary, but not determined to be at risk, on the Midewin National Forest

in Illinois, the Wayne National Forest in Ohio, the Chequamegon/Nicolet National Forest in Wisconsin, and the Superior and Chippewa National Forests in Minnesota; it is also documented to occur in an additional 14 out of a total of 20 states within this Region. In New York State, although it has not been documented from the Finger Lakes National Forest, it is expected to occur there, since it is present in the Cayuga Lake Basin[1]. *Cypripedium parviflorum* var. *parviflorum* is listed as Regional Forester Sensitive on the Green Mountain National Forest in Vermont (although this is slated to change to "not present" as a result of information gathered during recent Species Viability Evaluations)[2], present on the Chippewa National Forest in Minnesota, and not present for any other Region 9 Forest, although it is documented to occur in another ten states within the Region. *Cypripedium parviflorum* var. *makasin* is not currently on the Regional Forester Sensitive Species (RFSS) list for Region 9, although this is slated to change as a result of information gathered during recent Species Viability Evaluations: the Green Mountain National Forest in Vermont expects to list this taxon as Regional Forester Sensitive, which will initiate risk evaluations for any other National Forest in Region 9 that has documented occurrences of this species within its proclamation boundary. It is present in 14 states in the Region.

Results from statistical analyses disagree about the ability to separate the three varieties of *Cypripedium parviflorum* based on morphological characters. Wallace and Case (1997) suggest that varieties *parviflorum* and *makasin* are not very distinguishable, but are distinct from var. *pubescens*. Deller (1994) separated three varieties in Vermont by using a suite of morphological characteristics (see Appendix A). Isozyme data indicate that var. *makasin* has high levels of genetic variability and large levels of among-population variation, and that varieties *pubescens* and *parviflorum* are indistinguishable (Wallace and Case 1997), but support treating varieties *parviflorum*, *pubescens*, and *planipetalum* as infraspecific taxa of the same species (Case 1993 in Deller 1994). Freudenstein (2001) suggests that, while *Cypripedium pubescens* and *C. parviflorum* do not form distinct genetic groups and should be maintained at the varietal level, they do show some geographic patterning, which could reflect recent gene flow. One hypothesis is that *Cypripedium parviflorum* and *C. pubescens* (=*C. parviflorum* var. *parviflorum* and *C. parviflorum* var. *pubescens*) diverged during the Pleistocene glaciation, and post-glacial migration produced an overlapping range of the two varieties (Ilitis 1965 in Brackley 1985).

Adding to the nomenclatural confusion is that there have likely been misidentifications in herbarium specimens and the literature. Sorrie (1987), in a review of specimens from Harvard University's New England Botanical Collection (NEBC) and Oakes Ames Orchid Herbarium (AMES), notes that many records of small-flowered yellow lady's slippers from seepage slopes and swampy woods probably refer to var.

[1] *Cypripedium parviflorum* var. *pubescens* will be tracked as a species of viability concern for the FLNF during Forest Plan Revision, and the results of this process will determine whether or not it will be listed as Regional Forester Sensitive.

[2] Variety *pubescens* is documented to occur on the GMNF, and variety *parviflorum* is reported from just outside the Forest's proclamation boundary in southern Vermont, but needs verification.

*pubescens* rather than var. *parviflorum* as is indicated in literature and on specimens. He noted specifically that nine of the 34 specimens of var. *parviflorum* at NEBC and AMES are actually var. *pubescens*, and another eight are unclear as to which variety they are. Also, there seems to be confusion with synonymy, e.g., *Cypripedium hirsutum* Mill (Gibson 1905) versus *Cypripedium hirsutum* Britton & Brown, Illus. Flora, but not Miller, 1768 (House 1905). Schweinfurth (1925) indicates *C. hirsutum* "of recent authors, probably not Mill." as a synonym for *C. reginae*, the showy lady's slipper; Wherry (1920) also indicates *C. hirsutum* as a synonym for *C. reginae*.

There are also many hybrids in this complex of taxa. St. Hilaire (2003) gives a thorough description of these: "The favored name for the hybrid swarm formed from yellow and white lady's slippers is *C*. x *andrewsii* (Sheviak 1974, Keenan 1988). Notomorphs, hybrids between varieties of species and backcrosses are *C*. x *andrewsii* nm. *favillianum* (J. T. Curtis) Boivin, (*C. parviflorum* var. *pubescens* x *C. candidum*), *C*. x *andrewsii* nm. *andrewsii* A. M. Fuller (*C. parviflorum* var. *parviflorum* x *C. candidum*), and *C. andrewsii* nm. *landonii* (Garay) Boivin (*C. parviflorum* var. *parviflorum* x *C*. x *andrewsii* nm. *favillianum* or *C. candidum* and *C*. x *andrewsii* nm. *favillianum*) (Keenan 1988, Sheviak 1992). Atwood (1984) indicates these hybrids as *C*. x *favillianum* Curtis, and those between *C. parviflorum* var. *parviflorum* and *C. candidum* as *C*. x *andrewsii* Fuller, rather than indicating them as notomorphs. In the northwest, *C. parviflorum* var. *pubescens* hybridizes with *C. montanum* to produce *C*. x *columbianum* Sheviak (Keenan 1988, Sheviak 1992). These hybrids are likely to occur wherever parents occur in adjacent populations, though close contact of the parents is not a prerequisite for hybridization (Sheviak 1974). Gene flow is bi-directional between *Cypripedium pubescens* (=*C. parviflorum* var. *pubescens*) and *C. candidum* where the two species are sympatric (Klier et al. 1991). Hybrid populations generally consist of individuals that are later-generation backcrosses or recombinants (=notomorphs), and there are few "pure" parents or first generation hybrids (Klier et al. 1991). Horticultural hybrids include "Otto" (*Cypripedium pubescens* x *C. calceolus*) W. Frosch 1996, "Favillianum" (*C. pubescens* x *C. candidum*), "Ulli" (*C. pubescens* x *C. cordigerum*), "Aki" (*C. pubescens* x. *C. macranthos*), "Genesis" (*C. pubescens* x *C. reginae*), and "Patrick Pinkepank" (*C. pubescens* x *C. tibeticum*) (CypHaven 2002)."

St. Hilaire (2003) provides a thorough list synonymy for large yellow lady's slippers from Luer (1975, who calls this taxon *C. calceolus* L. var. *pubescens* (Willd.) Correll, Bot. Mus. Leafl. 7: 14. 1938.

- *Calceolus hirsutus* (Miller) Nieuwland, Am. Midl. Nat. 3: 118. 1913
- *Cypripedium assurgens* Rafinesque, Herb. Raf. 76. 1833
- *Cypripedium aureum* Rafinesque, Herb. Raf. 76. 1833
- *Cypripedium bulbosum* Miller according to Farwell, Rep. Mich. Acad. Sci. 15: 170. 1913
- *Cypripedium bulbosum* Mill., Gard. Dict. ed. 8, no. 2, 1768, Not Linneus 1753 (House 1905)

- *Cypripedium bulbosum* Miller var. *flavescens* (de Candolle) Farwell, Rep. Mich. Acad. Sci. 15: 170. 1913
- *Cypripedium calceolus* Linnaeus, Sp. Pl. 2: 951, in part. 1753
- *Cypripedium calceolus* Walt., Fl. Car. 222. 1788. Michx. Fl. Bor.-Am. 2: 161, 1803, Not Linneus 1753 (House 1905)
- *Cypripedium calceolus* L. var. *pubescens* (Willd.) Correll, Rhodora 48:4, 1946 (Cameron 1976, MOBOT 2002).
- *Cypripedium flavescens* A. P. De Candolle, Liliacées I: 20. 1802
- *Cypripedium furcatum* Rafinesque, Herb. Raf. 76. 1833
- *Cypripedium hirsutum* Miller according to Morong, Mem. Torrey Club 5: 121. 1894
- *Cypripedium hirsutum* Britton & Brown, Illus. Flora, but not Miller, 1768 (House 1905)
- *Cypripedium luteum* Ait; Raf., Med. Fl. 140, 1828 (House 1905)
- *Cypripedium luteum* Aiton var. *angustifolium* Rafinesque, Med. Fl. I: 142. 1828
- *Cypripedium luteum* Aiton var. *biflorum* Rafinesque, Med. Fl. I: 142. 1828
- *Cypripedium luteum* Aiton var. *concolor* Rafinesque, Med. Fl. I: 142. 1828
- *Cypripedium luteum* Aiton var. *glabrum* (Willdenow) Rafinesque, Med. Fl. I: 142. 1828
- *Cypripedium luteum* Aiton var. *maculatum* Rafinesque, Med. Fl. I: 142. 1828
- *Cypripedium luteum* Aiton var. *pubescens* (Willdenow) Rafinesque, Med. Fl. I: 142. 1828
- *Cypripedium makasin* Farwell, Rep. Mich. Acad. Sci. 20: 1918
- *Cypripedium parviflorum* Sims, Bot. Mag. 23 pl 911. 1806, not Salisbury
- *Cypripedium parviflorum* Salisb. var. *planipetalum* Fernald (Sheviak 1994)
- *Cypripedium parviflorum* Salisbury var. *pubescens* (Willdenow) Knight, Rhodora 8: 93. 1906
- *Cypripedium pubescens* Willdenow, Hort. Berol. I: pl. 13. 1804
- *Cypripedium pubescens* Willdenow var. *makasin* Farwell, Rep. Mich. Acad. Sci. 20: 198. 1918
- *Cypripedium pubescens* Willd. var. *planipetalum* (Fernald) Atwood (Sheviak 1994)
- *Cypripedium undatum* Rafinesque, Herb. Raf. 76. 1833
- *Cypripedium veganum* cockerell & Barker, Proc. Biol. Soc. Wash. 4: 178. 1901

In addition, MOBOT (2002) lists five infraspecific taxa:

- *Cypripedium parviflorum* fo. *albolabium* Magrath & J.L. Norman, *Sida* 13: 372, 1989 (MOBOT 2002)
- *C. parviflorum* var. *makasin* (Farw.) Sheviak, *American Orchid Society Bulletin* 62: 403, 1993
- *C. parviflorum* var. *parviflorum* Salisbury, *Transactions of the Linnean Society of London* 1: 77, 1791
- *C. parviflorum* var. *planipetalum* Fernald, *Rhodora* 28: 1680169, 1926
- *C. parviflorum* var. *pubescens* (Willd.) O.W. Knight, *Rhodora* 8: 93, 1906.

Paralleling the complexity of its taxonomic history, this species' has been known by several common names. These include yellow lady's-slipper and downy lady's slipper

(Baldwin 1884, House 1923); large yellow lady's-slipper (Brown 1997); yellow moccasin, golden slipper, water stealer, Noah's Ark, and Whip-poor-will shoe (Morris and Eames 1929); downy yellow lady's-slipper (Brackley 1985); large yellow moccasin flower (Haines and Vining 1998); yellows, yellow Indian shoe, Venus' cup, Venus' shoe, and ducks (Correll 1950); American valerian and nerve-root (Grieve 1971); and male nervine, yellows, monkeyflower, umbil-root, and yellow umbil (Sievers 1930).

## SPECIES BIOLOGY

### *Lifespan*

Large yellow lady's-slippers are perennial, long-lived plants (SVE Monocot Panel 2003) that can persist for decades in a stable habitat (Reddoch and Reddoch 1997); individual plants may reach 100 years of age (Marilyn Light, University of Ottawa, personal communication, October 2001). The average time from seed germination to flowering is 12 years (Curtis 1943), and a plant will bloom for about 6 years (SVE Monocot Panel 2003).

### *Reproduction*

#### *Phenology*

Large yellow lady's slippers reproduce both sexually and vegetatively (Curtis 1943, Brackley 1985, Tremblay 1994, Light and MacConaill 1998, NH NHI 1998). Across central and northeastern United States and adjacent Canada, flowers open between mid or late spring to early summer (Gibson 1905, Fernald 1950, Brown 1997, Gleason and Cronquist 1991, Homoya 1993, Chapman 1997, Ladd 2001); bloom time for specific localities within this range is often shorter. In New England and adjacent New York, flowering occurs May to June (Brackley 1985, Magee and Ahles 1999). Within the Cayuga Lake Basin in New York State (in the region of the FLNF), flowering occurs from May 25 to June (Wiegand and Eames 1926). (Brackley 1985, Chapman 1997, Magee and Ahles 1999), May 10-July 1 in Maine and the Ottawa District of Canada (Cameron 1976, Reddoch and Reddoch 1997).

Flowering time in large yellow lady's-slippers may be influenced by both habitat and genetics. Sheviak (1974) notes that there is much apparently genetically fixed variation in flowering phenology. Knight (1906) reports that plants that typically flowered late June to July in a cold bog flowered late May to early June when transplanted into very rich soil in a sunny location.

#### *Flowers and fruits*

Annual fluctuation in flower production is normal (Curtis 1954). In Wisconsin, average flower production recorded in three habitats over 20 years was: 79% in bogs, with about 11% variation; 58% in oak woods, and 52% in prairie with about 34% variation (Curtis 1954).

Lady's-slippers, in general, tend to produce many flowers, but very few fruits (Brackley 1985). Hypothesized causes include orchid flowers not attracting pollinators (Gill 1989 in Kull 1998), a lack of locally available pollinators (Correll 1950, Bingham 1939 in Brackley 1985, Kull 1998 and references therein), late frosts that prevent capsules from ripening (Case 1964 in Brackley 1985), and herbivory (Tremblay 1994). In the closely related Eurasian species, *C. calceolus*, some clones always have more fruits than others, and this could be because clones attract pollinators differently due to their different exposures, especially light conditions (Kull 1998).

In a Canadian study, fruit set in large yellow lady's-slippers was 32% in 1990 and 9% in 1991, and herbivory further reduced the number of capsules maturing to dehiscence (Tremblay 1994). In this study, just over half of the mature capsules suffered insect damage in 1990, and only 14.2% of the flowers produced capsules to maturity without damage; in 1991 only 10% of the capsules were damaged. Typical damage was by insects that burrow into one end of the capsule and exit through the other, leaving most of the capsule tissue intact and consuming only a portion of the seeds (Tremblay 1994). Capsules are also susceptible to drought if water stress occurs during critical stages of seed development (Light and MacConaill 1998). Interestingly, even after a capsule dries and dehisces, moisture can cause it to reseal (SVE Monocot Panel 2003). While capsule production in *Cypripedium* may be infrequent, the yield of viable seeds is "usually adequate" (Luer 1975: 38).

*Pollination*

Large yellow lady's-slippers are out-crossers (Tremblay 1994); like most *Cypripedium* species, they depend on insect pollination for sexual reproduction (van der Pijl and Dodson 1966 and Stoutamire 1967 in Bornbusch et al. 1994), and are easily pollinated by lots of small insects (SVE Monocot Panel 2003). Bees in the genus *Andrena* are often found in the flowers of *Cypripedium* species (Luer 1975). While some authors suggest that only bees of the families Andrenidae, Megachilidae, and Halictidae pollinate the yellow lady's slipper complex in North America (Stoutamire 1967 and Newhouse 1976 in Atwood 1984), others report that bees in the genus *Ceratina*, family Anthophoridae, have been observed pollinating them (Robertson 1928 and Stoutamire 1967 in Brackley 1985). Despite the number of potential pollinators and occasionally high pollen rates, large yellow lady's slippers are infrequently pollinated and may not commonly receive multi-paternal pollen deposits (Light, University of Ottawa, personal communication in Tremblay 1994).

Flower color, fragrance, and the presence of a landing platform are what apparently attract bees, which are the primary pollinators (Brackley 1985). Some botanists describe the flowers as scentless (Clute 1898), others describe them as fragrant (Morris and Eames 1929, Atwood 1984, Sheviak 1995), and some describe them as having a heavy oily odor (Baldwin 1884). The flowers offer no nectar reward (Correll 1950, Luer 1975, Dressler 1981, Brackley 1985); Darwin (1884 in Correll 1950:18) hypothesized that bees visit the flowers to obtain pollen for making "bee bread", but they

may also be attracted to viscid droplets of fluid that adhere to hairs at the base of the lip (Luer 1975).

The shape of the flower and presence of downward-pointing hairs trap a visiting insect, which must then exit via two small openings near the base of the labellum (Gibson 1905, Luer 1975, Dressler 1981, Brackley 1985). In so doing, it brushes against the column, loses any pollen it was carrying, passes the anther, and dislodges a new pollen mass that adheres to its back (Brackley 1985). Several crescent-shaped translucent spots at the back of the labellum allow light to shine through and guide the insect to the escape holes (Baldwin 1884, Gibson 1905). Earlier authors (Baldwin 1884, Gibson 1905) note Darwin's work (undated) in determining this pollination mechanism, and Baldwin (1884) also acknowledges Professor Trelease of the University of Wisconsin, who first noted the translucent spots on the back of the labellum that aid imprisoned bees (*Halicta*, *Augochlora*) in their effort to escape the flower of some *Cypripedium* species. Size of a visiting insect affects its ability to escape (Brackley 1985) - some bees can lift themselves back out through the entrance (Nilsson 1979 in Brackley 1985), but larger bees can become trapped in the flower and die (Arthur 1962 in Brackley 1985).

A single large yellow lady's slipper anther contains approximately 100,000 pollen grains (Light and MacConaill 1998). Light and MacConaill (1998) and Dressler (1981) describe pollen grains in the subfamily Cypripedioideae as monads (single grains), in contrast to most other orchids in which pollen grains remain in tetrads or adhere into larger masses, called pollinia, which are transferred in whole or in part by a pollinator. However, Luer (1975) apparently disagrees, and states that *Cypripedium* pollinia are somewhat granular and sticky, and pull apart easily. Only a portion of large yellow lady's-slipper pollen is transferred during a pollinator visit (Light and MacConaill 1998). Pollen germination between and within genets of large yellow lady's-slippers is variable, but since anthers produce such copious amounts of pollen and full capsules contain approximately 7000 seeds, even 1 to 10% pollen germination would be adequate to stimulate fruit development (Light and MacConaill 1998).

In a Canadian study of large yellow lady's-slippers, pollen traveled 0.95 – 23.3 m, with a mean distance of 5.2 ± 0.9 m, suggesting that pollen flow is limited to individuals within demes (Tremblay 1994). However, pollen was never deposited on a stigma from the same flower or other flowers within the same clone (Tremblay 1994). Fertilization occurs when ovary growth has almost ceased; *Cypripedium* ovaries have two phases for growth in diameter, and one phase for growth in length, and (Duncan and Curtis 1942).

Flowers generally remain receptive to pollinators for seven to ten days or more (Curtis 1954). In one Canadian study, flowers within one genet of large yellow lady's-slippers opened over a four-day period, and individual flowers remained fresh for up to two weeks (Light and MacConaill 1998). In the same study, the maximum age at which pollinated flowers set fruit varied between genets from two to ten days and was not correlated to genet size or the day any flower opened, and the proportion of seeds with full embryos increased with increasing flower age at pollination.

*Seeds*

In a Canadian pollination experiment of large yellow lady's-slippers, four test groups were established to compare seed set across pollination types. Three of the groups were hand-pollinated, and of these, one group received pollen from many parents, another received pollen from one parent, and a third was self-pollinated; a fourth group was naturally pollinated. All test groups had a consistent seed set (Tremblay 1994). Over 99% of seeds had embryos, and seeds from naturally pollinated flowers germinated as frequently as those from hand-pollinated flowers; however, naturally pollinated flowers had significantly larger embryos than hand pollinated flowers. Some research suggests that multi-parental pollinations may occur more frequently when pollinator visits are more frequent (Tremblay 1994).

Percent seed set in large yellow lady's-slippers is small, and propagation is presumed largely vegetative (Brackley 1985, NH NHI 1998). In an Estonian study of the closely related *Cypripedium calceolus*, two populations showed abundant recruitment from seed, in contrast to most populations in the study; these two were at sites with significantly higher bryophyte coverage and lower herb coverage than other sites (Kull 1998), perhaps highlighting the importance of the regeneration niche/germination microsites (*sensu* Grubb 1977) to reproduction by seed. Calvo (1993 in Kull 1998) stated that availability of appropriate microsites for germination and establishment of orchid seeds is limited, but that the observed low levels of fruit production are sufficient to saturate available sites.

A ripe *Cypripedium* capsule can contain as many as 54,180 seeds (Stoutamire 1964); large yellow-lady's-slipper capsules contain about 7000 (Light and MacConaill 1998). Orchid seeds are minute, dust-like, very buoyant, and believed to be wind-dispersed (Curtis 1954, Stoutamire 1964, Sheviak 1990); however, experimental efforts have failed to confirm this (Sheviak in SVE Monocot Panel 2003). In the Ottawa District of Canada, seed dispersal occurs in early to mid October (Reddoch and Reddoch 1997); similar data for other parts of this species' range were not found. *Cypripedium* seeds can still be viable after 8 years in storage (Curtis 1943).

Seeds lack any stored reserves and are dependent on mycorrhizal fungi for germination and establishment (Stoutamire 1964, Sheviak 1990). With the aid of external food supplied by these fungi (Burges 1939 in Curtis 1943), seeds increase almost 2000-fold in size in two years (Curtis 1943).

***Plant Development and Growth***

*Germination*

Within the hand-pollinated treatments in the Canadian experiment described previously (Tremblay 1994), seeds from capsules produced as a result of pollination by many parents germinated more frequently than those from capsules produced as a result

of pollination by one parent, and the latter germinated more frequently than those from self-pollination. The lower germination rate in seeds produced by self-pollination suggests that large yellow lady's-slippers contain recessive alleles that become expressed when self-pollination occurs (Tremblay 1994). Seedling weights among treatments showed no significant differences after five months growth (Tremblay 1994).

Mature seeds of large yellow lady's-slippers are reportedly unpredictable in germination response (Ballard 1990 and De Pauw and Remphrey 1993 in Light and MacConaill 1998). In a Canadian study, different ages of seeds germinated variably, with post-anthesis interval the most reliable predictor (Light and MacConaill 1998). Mature seeds required a three-month chilling treatment to induce germination, but prematurely harvested seeds (7-8 weeks post-pollination) germinated asymbiotically without chilling in less than one month (Light and MacConaill 1998). Weber (1997) also found that seed germination rates for large yellow lady's slippers decreased substantially with seed maturation, and that mature seeds might require two winter seasons to germinate. Seeds of the related Eurasian species, *C. calceolus*, germinate most successfully when collected 40 days after pollination (Wagner & Hansel 1994 in Kull 1999). In a laboratory experiment, high phosphorus content of the media also suppressed seed germination (Sheviak 1983 in Kull 1999). In cultivation, specific parents consistently give superior progeny, and can be quickly screened for pollen germination ability (Light, University of Ottawa, personal communication). Both seed production and germination rate appear to be maternally mediated traits (Light and MacConaill 1998).

*Mycorrhizal associations*

The most important factors for successful seed germination in the field are a constant supply of available water (Curtis 1943) and appropriate mycorrhizal fungi (Stoutamire 1964, Sheviak 1990, SVE Monocot Panel 2003). Bernard assigned mycorrhizal fungi associated with orchids to the genus *Rhizoctonia* DeC, and *Rhizoctonia repens* Burgeff has been isolated from small yellow lady's-slippers (*C. parviflorum* var. *parviflorum*) in Wisconsin (Curtis 1939); it is uncertain whether the same mycorrhizal fungi are associated with var. *pubescens*. Also isolated from the living roots of yellow lady's-slippers (variety not indicated) is the hypomycete *Phialocephala victorinii* sp. nov. (Vujanovic et al 2000).

Mycorrhizae are made of both orchid and fungal tissues (Stoutamire 1964). The fungal filaments (hyphae) invade an orchid seed and supply an external source of carbon (Stoutamire 1964); however, if the soil/substrate conditions are not appropriate, the fungus can become a pathogen and destroy the seed (VT Ladyslipper 2002). The growing orchid seed, called the protocorm, dissolves the fungal filaments, and the fungus then attempts to reinvade it. This back and forth process continues until the protocorm produces a small dormant eye bud and root system, at which point it is considered a seedling (VT Ladyslipper 2002). The following spring a *Cypripedium* seedling produces its first green leaf and purportedly utilizes photosynthesis as a primary energy source (VT Ladyslipper 2002). However, there is disagreement regarding the point at which young

orchid seedlings can utilize photosynthesis rather than external soluble carbohydrates; even after visible chlorophyll has developed, seedlings may not be able to photo-assimilate, and in some cases may die (Rasmussen and Whigham 2002). In nature, the myco-heterotrophic phase can last three to seven years, and it may be an additional five to ten years before the plant reaches flowering size (VT Ladyslipper 2002). In the related Eurasian *C. calceolus*, the extent of mycotrophy decreases as plants produce more and larger leaves (Kull 1999), and the percentage of cells infected by hyphae increased from 12.4% to 24.4% when soil pH decreased from 6.0 to 5.1 (Sizova & Vahramejeva 1983 in Kull 1999).

Seedling mortality of large yellow lady's-slippers is very high (Curtis 1943). In one study, sampling in suitable habitats where *Cypripedium* species occurred yielded as many as 42 seedlings (including protocorms) per 100 cubic centimeters, but seedlings of large yellow lady's-slippers were quite rare and difficult to find in large numbers (Curtis 1943). The closely related Eurasian *C. calceolus* is sensitive to drought, and young seedlings require constant, moderate moisture (Corkhill 1996 in Kull 1999).

*Plant growth*

After germination of a large yellow lady's slipper seed, a corm with root and stem primordia develops during the first year (Curtis 1943). The corm enlarges during the second year, and one or two roots, a scale leaf, and an organized stem tip develop. The first green aerial leaf is produced during the third year, and additional growth is characterized by yearly production of aerial shoots of increasing size (Curtis 1943).

Pink lady's-slippers (*Cypripedium acaule*), and presumably also large yellow lady's-slippers, form two new roots per year just below the scale leaves of the rhizome (Curtis 1943). Old roots continue growing until they reach about 20 cm and remain functional for a long time; roots on one specimen were reportedly at least nineteen years old. Most adult terrestrial orchids have few thick, unbranched roots, due to a highly developed cortex (Rasmussen and Whigham 2002). The resulting small surface area is not favorable to water and nutrient uptake, but does provide a large volume of potentially mycotrophic tissue (Rasmussen and Whigham 2002). Roots in this genus are fibrous, have a characteristic acrid odor (Brackley 1985), and have been the source for a drug used to treat nerve disorders (Hocking 1955 in Brackley 1985). Root hairs are present, but seldom abundant (Rosso 1966 in Kull 1999).

Spring growth of orchids arises from over-wintered buds produced during the previous growing season (Sheviak 1990). The appearance of the over-wintering structures of large yellow lady's-slippers is one or more grayish green, broadly conical shoots that appear in late September beside the current year's stem, and are 0 to 2 cm above the ground; alternatively, they may be pale green and remain below ground until spring (Reddoch and Reddoch 1997). If a late frost destroys this growth, the orchid cannot replace the lost tissues until the following year; even if dormant buds are present, they will not initiate growth. Even if roots remain, new buds form, or dormant buds enlarge, the plant may still die (Sheviak 1990). Nonetheless, *Cypripedium* is more resilient to shoot loss than other orchids (Sheviak 1990). *Cypripedium* plants that lose

their growth before midsummer will commonly appear the next year, but will not bloom, and may require two or more subsequent vegetative seasons before they do (Case 1987, Whitlow 1983 in Sheviak 1990).

In years when no aboveground parts of large yellow lady's-slippers are visible, the rhizome (underground stem) may continue to function normally and may send up shoots the following year (Curtis 1954). Flower buds begin to develop in late summer of the year preceding anthesis and are enclosed within a lateral rhizome bud that elongates to produce a leafy crown after a period of low winter temperatures (Curtis 1954). Lack of a flower at the end of the crown reflects unfavorable conditions during initiation, over-wintering, or elongation (Curtis 1954).

Stems develop each year from subterranean rhizomes (Luer 1975, Brackley 1985). Kull(1999) reports that in the closely related Eurasian species, *C. calceolus*, a creeping rhizome may be 0.4 to 0.9 cm in diameter and up to 10 cm deep. Curtis (1943) reports that corms of *Cypripedium* species, in general, develop at an average depth of 3 centimeters beneath the soil surface and are most numerous in places with relatively constant soil moisture. Since both corms and rhizomes are underground stems, presumably these two authors are referring to the same structure; however, it is uncertain which, if either, of these parameters would most closely approximate the North American large yellow lady's-slippers.

A rhizome typically produces two apical buds per year, and the following year's shoot develops from the larger of these two buds. This larger bud alternates from left to right on the rhizome each year, producing a zigzag growth pattern. The smaller bud tends to be dormant, although it may begin growth either in the year of formation or the year after. A new rhizome segment starts to grow at the end of flowering (Kull 1999).

Large yellow lady's slippers form clonal patches (Great Plains Floral Association 1986 in NatureServe 2001). These and other members of the same genus can produce branches from the rhizome and form clumps consisting of multiple stems (Curtis 1954). Stems may occur singly or in clumps of up to about 20; one was observed with 75 flowering stems in 1969, but declined to about 30 flowering stems in 1973 (Reddoch and Reddoch 1997). Although they are capable of developing enormous clumps, large clumps eventually become susceptible to attack by fungi (SVE Monocot Panel 2003). In the Eurasian species, clones rarely become larger than 70 cm in diameter, and rhizome death rate increases as a clone increases in size and becomes increasingly dense (Kull 1999). This species also occurs in colonies; colony sizes in the Ottawa District of Canada are from 1 to 835 flowering and non-flowering plants, with 125 typical (Reddoch and Reddoch 1997).

***Dormancy***

In one study, large proportions (19-67%) of a population of the related small yellow lady's slipper (presumed to be var. *makasin*) became dormant each year (Shefferson et al. 2001). Dormant periods of up to four years were observed, but rarely

lasted longer than a year, and the probability of regrowth after two years was greatly diminished (Shefferson et al. 2001). Dormancy was correlated with spring frost days, precipitation effects, and mean spring temperature, suggesting that environmental conditions may regulate genet dormancy in this taxon (Sherrerson et al. 2001). Dormancy in the Eurasian *C. calceolus* can apparently last up to10 years, but with an increasingly small chance of resprouting over time (Kull 1995 in Shefferson et al. 2001). It is uncertain which, if either, of these related taxa is most similar to the North American large yellow lady's slippers, with regard to dormancy.

***Genetics***

Although yellow lady's-slippers (all varieties) are similar to other *Cypripedium* species in life history characteristics, they have unusually high levels of genetic variation (Bornbusch et al. 1994 and references therein). One hypothesis is that natural disturbances, such as landslides, forest fires, etc., over a geological time scale back to the Pleistocene glacial epoch may have contributed sufficient genes of natural hybrids to yellow lady's-slippers to account for the high level of variation within it today (Sheviak 1992). Genetic bottlenecks are uncommon in the yellow lady's-slipper complex of North America, but significant bottlenecks may have occurred on two occasions, giving rise to two new taxa, *C. kentuckiense* and *C. candidum* (Case et al. 1998).

***Relations with other species***

In addition to mycorrhizal associations described in a previous section, large yellow lady's slippers are ecologically interwoven with a number of other species, sometimes much to the detriment of the orchids. These include a weevil that feeds on orchid flowers, and spider mites that damage plants in both gardens and natural habitats.

A weevil, purportedly the small black weevil, *Stethobaris ovata* (in the order Coleoptera), can be a pest on large yellow lady's-slippers (Light, University of Ottawa, personal communication). The first generation of weevils emerges in spring and feeds on orchid flowers, including *Cypripedium*, and non-orchids, such as Canada mayflower (*Maianthemum canadense*). Females oviposit in flower stalks and ovaries. The second generation hatches in late July to mid-August and feeds on flowers of the helleborine orchid (*Epipactis helleborine*), and oviposits in stems and fruits of helleborine and large yellow lady's-slippers (Light, University of Ottawa, personal communication). In a 2000 study, weevils had affected seventy-five percent of large yellow lady's-slipper fruits examined (Light, University of Ottawa, personal communication).

Sheviak (SVE Monocot Panel 2003) hypothesizes that large yellow lady's slippers have largely disappeared because of this weevil, which may be non-native, and that it is especially a problem in heavier shade. However, questions remain regarding the identity of the weevil, which is difficult to identify to genus (Sheviak, New York State Biological Survey and personal communication). Because a photograph of a *Cypripedium* plant from Poland has what appears to be the same weevil on it, and because the weevil is not in synch with its host (in years with a cold, late spring, the weevil emerges before the

plants and destroys them from the top), it is hypothesized that this may be an introduced species (Sheviak in SVE Monocot Panel 2003). Sheviak (SVE Monocot Panel 2003) has observed the weevil destroy whole stems of large yellow lady's-slippers, but not the capsules.

Large yellow lady's-slippers also suffer from spider mite damage in both gardens and natural habitats (Case 1987). Developing leaves that are damaged by late frost are more susceptible to deterioration later in the season, and the injured leaves often have more numerous spider mites (Case 1987). Insects associated with the related Eurasian *C. calceolus* include Dipteran species that accidentally fly into a flower and get trapped (mostly families Culicidae, Empididae, and Syrphidae), larger beetles and bumblebees that destroy flowers while visiting them, and caterpillars that destroy the perianth (Kull 1999); whether these same problems plague the North American species is uncertain.

Other herbivores that feed upon yellow lady's-slippers include deer, which eat the flowers, but not the whole plant (SVE Monocot Panel 2003), voles that can bite through shoots at ground level and can be serious pests, especially in small populations of the related Eurasian *C. calceolus* (Kull 1999), and slugs and snails that cut off the plant at ground level, preventing blooming the following year in the North American species (Native Son's Nursery 2002). In Wisconsin, the parasitic fungus *Ascochyta cypripedii* was found on living leaves of *Cypripedium candidum*, a member of the same complex as large yellow lady's-slippers, but there are no other reports of this fungus on other *Cypripedium* species (Greene 1952). A rust *(Puccinia cypripedii* Arth. & Holw.) can also infect yellow lady's-slippers, resulting in devitalization of the plant (Stevenson 1926 in Correll 1950).

## HABITAT/ECOLOGY

### *General habitat types*

*Region-wide*

Across its range, large yellow lady's-slippers occur in a wide variety of habitats. Morris and Eames (1929) describe its habitat as rich woods, and the New Hampshire Natural Heritage Inventory (1998) describes it as rich, usually swampy or seasonally wet, limy deciduous woods (both descriptions presumed to apply range-wide). Chapman (1997) lists its habitat (also presumed range-wide) as moist deciduous and coniferous forest, thickets, meadows, prairies, sometimes tundra, and occasionally fens; often in calcareous soils. Across central and northeastern United States and adjacent Canada, Fernald (1950) describes its habitat as dry to moist mesophytic, usually rich, woodlands; this is consistent with Magee and Ahles (1999) for New England and adjacent New York. Brown (1997) includes edges of bogs and fens for New England, New York, and adjacent Pennsylvania and New Jersey. Northern prairies, and in the Great Lakes Region, even roadside ditches, frequently support populations of large yellow lady's-slippers (Sheviak 1990).

*States and National Forests*

In Maine, Cameron (1976) describes its habitat as rich, well drained to moist woods, cedar swamps and alder thickets, and Haines and Vining (1998) describe its Maine habitat as mesic woods. Haines (2001) includes edges of bogs and fens. The New Hampshire Natural Heritage Inventory (1998) lists it as a species of nutrient-rich (intermediate to basic) northern and southern forests, including mesic forests, dry forests, thin woods, forested swamps, bogs, fens, and swamps. It occurs most frequently in dry to moist, generally rich, forests or woodlands, along the edges of spring run-off streams (Brackley 1985, NH NHI 1998), or in circumneutral/calcareous forests and woodlands, including rich mesic forests, seepage forests, and seepage swamps (NH NHI 1998). In Vermont, large yellow lady's-slipper habitat includes rich northern hardwoods forests and lowland softwood and hardwood swamps (Deller 1994); its known locations on the Green Mountain National Forest fit within these habitat types (personal observation).

In New York State maple-basswood forests are preferred, and hemlock northern hardwoods and successional northern hardwoods are utilized (SVE Monocot Panel 2003). The maple-basswood rich mesic forest (as described by Edinger et al. 2002) roughly corresponds with forest type 82 -sugar maple/basswood - on the Finger Lakes National Forest; there are five stands with this forest type on the National Forest (Deller 2000). House (1923) lists its New York State habitat as rich woods and thickets, and McVaugh (1935) describes its habitat in the Hudson Valley, within Columbia County, New York, as rich mesic forests and low or moist woods. In Schenectady County, large yellow lady's-slippers occur along the rims of bowl-shaped secondary ravines associated with the Mohawk River (Sheviak, New York State Museum, personal communication). It does not occur in other areas of these ravines, even though conditions appear to be the identical; it may have specialized habitat requirements that are not readily discernable (Sheviak, New York State Museum, personal communication). Within New York State, the natural communities with which large yellow lady's slippers are associated range in rank from S2S3 through S5 (Reschke 1990, Edinger et al. 2002), with the most suitable habitats (rich mesophytic forest, maple-basswood rich mesic forest) being less common. To the south in Pennsylvania, it occurs in moist, rich, rocky woods and slopes (Rhoads and Klein 1993). On the Wayne National Forest in Ohio, this species generally occurs in mesic woods (E. Larson, Wayne National Forest, personal communication).

In Indiana, large yellow lady's slippers occur most commonly in mesic and dry-mesic upland forests on east and west-facing slopes; generally, south-facing slopes are too dry, while north-facing slopes are too shady (Homoya 1993). However, they are also found in hill prairies and wetlands with organic and sandy soils saturated with ground water, and, in these habitats, can grow in full sunlight on treeless gravel slopes (Homoya 1993). They tend not to occur in sites with dense shade, such as forests without any disturbance history, but if present would occur as only a few non-vigorous individuals (Homoya 1993). In Wisconsin, Curtis (1954) lists large yellow lady's-slippers as abundant in three habitats: wet prairie, oak savanna and forest, and conifer bog forest.

Typical habitat in Missouri, including the Mark Twain National Forest, is lower north and east-facing slopes of dry-mesic chert forests with a preponderance of oaks (D. Moore, Mark Twain National Forest, personal communication). In Michigan, Case (1987) describes it as "tolerant of many habitats – rocky woodland, hillsides, low areas along small streams, bogs, wooded and open swamps, lake shores and fens, especially those of the Great Lakes, usually in sub-acid to neutral soils…rare in areas where bottomland alluvium predominates…seems to thrive in limestone areas where large colonies develop – often in roadside meadows and clearings." Within the Ignace District of the Hiawatha National Forest in Michigan, it generally occurs in highly calcareous conditions, in habitats such as cedar glades, cedar swamps, and road edges (J. Schultz, Hiawatha National Forest, personal communication).

*Associated Species*

Baldwin (1884) indicates that in New England, large yellow lady's-slippers have a preference for maples, beeches, and particularly butternuts. If this is so, then there may be a link between butternut decline and a decline in large yellow lady's-slippers (SVE Monocot Panel 2003). He also describes knolls with ferns, cohosh, and trilliums as likely places to find this species[3].

Associated species at New Hampshire sites include *Acer saccharum, Fraxinus americana, Betula alleghaniensis, Carex lacustris, Solidago uliginosa, Geum rivale, Adiantum pedatum, Osmunda cinnamomea,* and *Botrychium virginianum* (NH NHI 1998). On the Green Mountain National Forest in Vermont, ground cover and shrubs are sparse where this orchid grows (D. Burbank personal communication in Allen 2002).

In Indiana, large yellow lady's-slippers regularly occur under a canopy of white, red, black, or chinquapin oak, tulip tree, sugar maple, American basswood, hop hornbeam, bigtooth aspen, and sassafrass. (Homoya 1993). Associated understory species include *Adiantum pedatum, Arisaema triphyllum, Aster macrophyllus, Botrychium virginicum, Brachyelytrum erectum, Carex Careyana, C. hirtifolia, C. jamesii, C. laxiculmis, C. pensylvanica, Caulophyllum thalictroides, Desmodium nudiflorum, Dryopteris marginalis, Euonymus obovatus, Fragaria virginiana, Geranium maculatum, Hamamelis virginiana, Hepatica acutiloba, Osmorhiza longistylis, Parthenocissus quinquefolia, Podophyllum peltatum, Polystichum acrostichoides, Smilacina racemosa, Solidago caesia, S. flexicaulis, Staphylea trifolia, Thaspian barbinode, Uvularia grandiflora,* and *Zizia aurea* (Homoya 1993).

In Pennsylvania, where large yellow lady's-slippers are usually in wooded sites, there tends to be lots of tulip poplar, spicebush and a diverse herbaceous flora (Chris

[3] Throughout this section, species names are reported as they occur in their source documents. This prevents misinterpretations that can occur when varied common names are used to denote the same entity in different places and at different times.

Firestone, Pennsylvania Department of Conservation and Natural Resources, personal communication).

Information regarding associated species in other parts of its range was not available for large yellow lady's-slipper.

### *Specific habitat features*

*Soils and hydrology*

USDA NRCS (2002) lists large yellow lady's-slipper as a facultative + species in the northeast, indicating it is equally likely to occur in wetlands or non-wetlands with an estimated probability 34% to 66%. The "+" indicates that it slightly more likely to be found in wetland situations. In Vermont, the most important habitat feature for this species seems to be water; it generally occurs in association with seepage, especially in limy areas (SVE Panel 2002 in Allen 2002). When found in palustrine habitats, these are minerotrophic. In New York State, it grows in rapid drainage situations, and never in slow drainage; even in fens, it is on hummocks rather than hollows (SVE Monocot Panel 2003). In Illinois, large yellow lady's-slippers can be found on sands, sandy loams, loams, and silt loams, but are notably absent from areas with poor drainage (Sheviak 1974). In Wisconsin, this species favors sites where sandstone cemented with lime overlies quartzite (Weber 1997). In Michigan, although it tolerates many habitats, it appears to thrive in limestone areas (Case 1987). In Ontario, Canada, large yellow lady's-slippers tend to occur in drier situations than var. *parviflorum*, especially in woodlands and on roadsides where limestone is near the surface (Whiting and Catling 1986).

Orchids generally exhibit rather specific, narrow pH tolerances (Sheviak 1974). However, large yellow lady's-slippers appear to do well in a variety of pH levels. The majority of authors indicate that this species does well in acid to sub-acid or neutral soils (Wherry 1920, Morris and Eames 1929, Correll 1950) with moderate moisture (Correll 1950); soils are sometimes calcareous (Chapman 1997). In one study, mature plants grew in soils ranging from pH 5.7 to pH 7.9, but seedlings were most abundant in moist soils between pH 6.9 and pH 7.2 (Curtis 1943). In Vermont, plants have been found on soils with a pH range of 5.0 to 8.0 (Wherry 1920), but are reportedly cultivated in neutral to slightly sub-acid (pH 6.0-7.5) soil/media (VT Ladyslipper 2002). In Indiana, large yellow lady's-slippers occur most frequently on neutral and calcareous soils with moderate moisture, though they also occur in mildly acidic soils (Homoya 1993). In New York, it would be very unusual to find large yellow lady's-slippers in soil with a pH below 5.0 (SVE Panel 2003). In Pennsylvania, this species may be on sites that are somewhat moist, with soils that are rocky and not overly rich (C. Firestone, Pennsylvania Department of Conservation and Natural Resources, personal communication). Wild plants in Rhode Island were in soils with pH 4.5, 5.0, 5.7, 6.1, and 6.4 - this last value at a site with limestone outcroppings - while garden plants were

reportedly grown in soils with pH 4.7 and 5.2 (Stuckey 1967). Data regarding soil pH in other parts of this species' range were not found.

*Elevation & Topography*

Although the entire range of elevation at which large yellow lady's-slippers occur throughout North America is unknown, data for more specific areas are available. Large yellow lady's-slippers usually occur below 1500 feet elevation in northern New England, although they have been observed as high as 2100 feet elevation (SVE Panel 2002 in Allen 2002). They have a preference, in New England, for sloping or hilly ground (Baldwin 1884). The related Eurasian species, *C. calceolus*, grows above 12,000 feet in the Himalayan Mountains, (3659 m, Correll 1950).

*Light and temperature*

In Illinois, ideal habitat for large yellow lady's-slippers is in a forest where the canopy has developed but is not yet closed; as the canopy closes, the plants weaken and few bloom, and the colony decreases to scattered individuals (Sheviak 1974). In New York, they grow in early as well as in later stage forests, seem to like sun flecks, and presumably could also become established in a mature forest (SVE Panel 2003). In Indiana, this species tends to occur on east or west slopes, since the canopy would be too heavy on north slopes and the soil too open and dry on south slopes (Homoya 1993 as reported by K. Larson, Hoosier National Forest, personal communication); one Indiana site is known from a trail edge, where some sunlight penetrates the canopy (K. Larson, Hoosier National Forest, personal communication. In cultivation, they require two to three hours of direct sun either early in the morning or late in the afternoon, and dappled shade/sun for the remainder of the day (VT Ladyslipper 2002). Light and temperature requirements for this species in other parts of its range were not found.

In contrast to the majority of native orchid species, yellow lady's slippers are amenable to transplanting (Light, University of Ottawa, personal communication), can be cultivated fairly easily, and are one of the easiest *Cypripedium* species to grow in woodland conditions (Morris and Eames 1929, Correll 1950, Brown 1997, Native Son's Nursery 2002, VT Ladyslipper 2002). The recommended optimal USDA zones are 3 to 7, although they may grow in zone 2 with extra winter mulch for protection and in zone 8 with extra shade (VT Ladyslipper 2002). Plants in cultivation require a minimum of a four-month winter cold dormancy period (VT Ladyslipper 2002).

***Landscape pattern***

In Vermont, large yellow lady's-slippers occur in patch-type natural communities of 1-50 acres, within larger complexes, and patch size is not perceived to be important (SVE Panel 2002 in Allen 2002). A common pattern in a mature forest would one to a half dozen widely scattered plants (SVE Panel 2003). A pattern that can occur in a more open site, especially in the northern plains, is massive populations (SVE Panel 2003). Distribution of patches may be related to periodic canopy opening or connectivity among

seed sources (SVE Panel 2003). Connectivity between seed sources is important for this species (SVE Panel 2003).

### *Other ecological influences*

Although large yellow lady's-slippers do occur in mature forests, larger populations are found in more open sites (SVE panel 2003). In Indiana, most populations of this species occur in areas with a history of disturbance, such as selective tree harvest, light grazing, fire, or a combination of these (Homoya 1993); however, it is unknown if the immediate effects of fire would be beneficial, detrimental, or neutral. Wind-throw is another natural disturbance that could open up the canopy and might benefit this species.

Natural disturbances, such as landslides and forest fires, that have occurred over a geological time scale back to the Pleistocene glacial epoch may have contributed sufficient gene flow to the yellow lady's slipper complex to account for the great variation within it today (Sheviak 1992).

## THREATS TO LARGE YELLOW LADY'S-SLIPPERS

### *Introduction*

Despite the abundance of populations of large yellow lady's-slippers across much of their range, they are vulnerable to a number of threats, including habitat loss, alteration, and fragmentation; herbivory by livestock and grazing wild animals; destruction by insects and disease; competition from non-native invasive species; collection and cultivation. The importance of each of these threats varies geographically. Since this taxon is not tracked in most states where it occurs, numbers of populations lost per region and numbers of individuals lost per population are unknown. Likewise, it is difficult to compare the quantitative effects of the different threats that this taxon faces.

### *Habitat loss, alteration, or fragmentation*

Habitat loss, alteration, or fragmentation can have both direct and indirect impacts on an uncommon plant species such as large yellow lady's-slippers. Direct impacts involve destruction of either individual plants or entire populations. Indirect impacts involve changes that render a habitat no longer suitable or fragmentation that results in lack of a seed source for recruitment into a suitable habitat (SVE Panel 2003). Cumulative results of these kinds of direct and indirect impacts can include not only reduction in range or abundance, but also reduced genetic variation at the level of the meta-population, which, in turn, can compromise a species' ability to survive environmental change. However, for this species, habitat loss, plant collection, and demographic stochastic events are believed to be more significant threats than lack of genetic variation (Bornbusch et al. 1994).

NatureServe (2001) describes large yellow lady's-slippers as vulnerable to habitat loss, including human encroachment on habitat (Case et al. 1998). They may also be

relatively intolerant of habitat degradation, which may, in turn, relegate them to diminishing portions of the natural landscape (Swink and Wilhelm 1994 in NatureServe 2001); the landscape, in turn, is subject to pollution, hydrologic changes, harvesting of resources, over-abundance of some animal populations, invasion by non-native species, and fragmentation (NatureServe 2001).

Human activities that alter habitats include road and right-of-way maintenance, such as herbicide use, mowing, ditch cleaning, and removal of woody vegetation, which are listed as threats to large yellow lady's-slippers in Idaho and Manitoba (Michael Mancuso, personal communication, and Elizabeth Punter, personal communication, both in NatureServe 2003). In Manitoba, human activities associated with forest management and agriculture are also listed as threats (Elizabeth Punter, personal communication in NatureServe 2003). On the Hiawatha National Forest in Michigan, road construction and maintenance may pose a threat to this species (J. Schultz, Hiawatha National Forest, personal communication).

Habitat alteration can also occur as a result of non-human activities, such as beaver-induced flooding, and is ranked fourth in importance to large yellow lady's-slippers in northern New England (SVE Panel 2002 in Allen 2002). Habitat alteration and loss are ranked third in importance to this species over the next 20 years in New York State (SVE Panel 2003). Widespread land conversion, such as clearing and establishing pine plantations, poses a threat in Mississippi (Ronald Wieland, personal communication in NatureServe 2003).

Succession is another form of habitat alteration that may pose a threat to this taxon. Although large yellow lady's-slippers do occur in mature forests, they are more likely to occur in sites at earlier successional stages with broken canopies (SVE Panel 2003). As their habitat matures and the canopy closes, plants weaken and few bloom (Sheviak 1974), their populations tend to decline in number, and plants become more scattered (Sheviak 1974, SVE Panel 2003). In the Midwest, large yellow lady's-slippers sometimes colonize successional, open woodlands that develop on old fields and pastures (Sheviak 1990). In Indiana, most populations of large yellow lady's-slippers are found in areas with a history of disturbance, such as selective tree harvest and/or light grazing and/or fire (Homoya 1993); the short-term effect of fire on this species is unknown. The relationship between large yellow lady's-slippers and succession appears to vary somewhat, geographically; roadside ditches in the Great Lakes region and northern prairies frequently support this species (Sheviak 1990).

Large yellow lady's-slipper plants do appear to respond to canopy opening, which can occur naturally in late successional woods, and it is possible that wind-throw might provide adequate canopy openings (SVE Panel 2003). While selective thinning may also be beneficial, the effects of heavy machinery or trees being dragged over the plants pose an additional threat; an opening might also allow dense growth of early successional and/or non-native invasive species (SVE Panel 2003). This has been documented to occur with the related Eurasian species, *C. calceolus*, whose populations decline

following clear-cutting, apparently as a result of competition with tall herbs and grasses (Sjöberg & Ericson 1992 in Kull 1999).

***Herbivory***

In New York, browsing by deer and cattle poses some threat to large yellow lady's-slippers, but follows weevils, non-native invasive plants species, and habitat loss and alteration in importance (SVE Panel 2003). In New England, herbivory by deer and moose are the second most significant threat, following habitat loss (SVE Panel 2002 in Allen 2002). In Wyoming grazing by livestock in the Bighorn Range is an issue (Walt Fertig, personal communication in NatureServe 2003). In New Mexico, individuals in one population were found with tops removed, but it was not clear whether this was due to grazing or collection (Sara Gottlieb, personal communication in NatureServe 2003). In Georgia, wild pigs rooting in the soil are known to damage large yellow lady's-slippers (Tom Patrick, personal communication in NatureServe 2003). In Pennsylvania, where deer are over-populated, browse poses a big threat to this species (C. Firestone, Pennsylvania Department of Conservation and Natural Resources, personal communication). Deer are thought to eat only the flowers, and not the whole plant (SVE Panel 2003). They are also probably the biggest threat on the Hiawatha National Forest in Michigan (J. Schultz, Hiawatha National Forest, personal communication). Cattle can have devastating effects not only the plants, but on the soil in which the plants are growing (SVE Panel 2003). There are also slugs and snails that cut off the plant at ground level, preventing it from blooming the following year (Native Son's Nursery 2002).

***Insects and disease***

As described in the section on life history, a weevil, hypothesized to be the small black weevil, *Stethobaris ovata*, can be a pest on large yellow lady's-slippers (Light, University of Ottawa, personal communication). In New York State, these weevils may pose the most significant threat to large yellow lady's slippers (SVE Panel 2003). Spider mites can damage plants in both gardens and natural habitats (Case 1987), and a rust *(Puccinia cypripedii* Arth. & Holw.) can infect them, resulting in devitalization of the plant (Stevenson 1926 in Correll 1950).

***Non-native invasive species***

Many native plant species are susceptible to competition by non-native invasive plant species. In New York State, competition from non-native invasive species, such as garlic mustard (*Alliaria petiolata*) and barberry (*Berberis*), is the second most significant threat to large yellow lady's-slippers (SVE Panel 2003). In Illinois, bush honeysuckle (*Lonicera spp.*) and garlic mustard (*Alliaria petiolata*) pose a threat to this taxon (Bill McClain, personal communication in NatureServe 2001). Non-native invasive species are also cited as causing problems for large yellow lady's-slippers in Idaho (Michael Mancuso, personal communication, in NatureServe 2001).

Another potential threat also comes from non-native invasive earthworms. Current studies show that exotic earthworms can significantly affect both nutrient cycling and plants communities in the understory of northern hardwood forests (Holdsworth et al. 2003); there is speculation that large yellow lady's-slippers could be affected by this problem in the Midwest (R. Newman, Chippewa National Forest, personal communication).

***Trampling***

In Wyoming, large yellow lady's-slippers are threatened by trampling from off-road vehicles and hikers (Walt Fertig, personal communication, in NatureServe 2003). While this specific threat is not mentioned for this species in other places, it is expected that it could occur any place where these plants occur near trails or roads. In Indiana, when these plants occur along a trail, horse trampling may be a threat (K. Larson, Hoosier National Forest, personal communication).

***Collection***

Threats to natural *Cypripedium* populations include centuries of exploitation (Case et al. 1998). Plants in this genus in general and large yellow lady's-slippers in particular are collected for both horticultural and herbal or medicinal use. Yellow lady's slippers (variety not indicated) were once used as a sedative (Clapp 1852 in Homoya 1993), and roots collected in autumn can be used as a gentle nervous stimulant and antispasmodic (Henkel 1907 in Correll 1950, Sievers 1930, Grieve 1971, Felter and Lloyd 2002). The active ingredient in these plants is cypripedin (Grieve 1971, Felter and Lloyd 2002). Since *C. parviflorum* var. *parviflorum* is reportedly the usual source for dried roots (Frontier Co-op 2000 in NatureServe 2001 and Homoya 1993), it is uncertain whether var. *pubescens* (large yellow lady's-slipper) is equally at risk. In 1988, an industry resolution was passed to discontinue sales of wild-collected lady's-slipper root, and many responsible herb companies complied, but some did not (Frontier Co-op 2000 in NatureServe 2001), and some still pay for rhizomes dug in the wild (Klein, personal communication in NatureServe 2001). However, one estimate of the amount of *Cypripedium* sold for medicinal/herbal use is about ten pounds of dry root per year, suggesting that the resulting loss of plants may be insignificant, and that collection for horticulture may pose a much greater threat (McGuffin, personal communication in NatureServe 2001).

Collection of large yellow lady's slippers may be one of the most important factors affecting the decline of large yellow lady's-slippers in New England (SVE Panel 2002 in Allen 2002), New York (SVE Panel 2003), Iowa (Niemann 1986), Missouri (T. Smith, personal communication in NatureServe 2003), Indiana (M. Homoya, personal communication in NatureServe 2003), and Manitoba (E. Punter, personal communication in NatureServe 2003). In Kentucky, anecdotal information suggests that all species of lady's-slippers are being collected (D. White, personal communication, in NatureServe 2003). On the Mark Twain National Forest in Missouri, collection by orchid enthusiasts and for herbal use may be a threat to this species (D. Moore, Mark Twain National Forest,

personal communication). On the Shawnee National Forest in Illinois, some previously known populations have not been found recently, and it is suspected that they have been dug up by people (E. Shimp, Shawnee National Forest, personal communication). On the Wayne National Forest in Ohio, collection may be the biggest threat to this species, because of its showy appearance (E. Larson, Wayne National Forest, personal communication). Poaching is also a problem on the Hiawatha National Forest in Michigan (J. Schultz, Hiawatha National Forest, personal communication). In Minnesota, some botanists do not report sightings of large yellow lady's-slippers, because they fear the plants will be collected (J. Greenlee, Superior National Forest, personal communication). While numbers of plants or populations lost are unknown, Case et al. (1998) report that collection of *Cypripedium* species in the wild ranges from levels of hobbyists to large-scale illegal poaching and trade. The result is that a number of populations have declined over the years (Weber and Wittmann 1996 in NatureServe 2001).

NatureServe (2001) provides a more detailed description of this problem in the state of Georgia, where large yellow lady-slippers are often dug for horticultural or medicinal purposes. Because they are both uncommon and commercially exploited there, they are protected as a "Special Concern Plant". When sold by permit, they are required to have transport tags, a copy of which is to be filed with the Georgia Natural Heritage Program. Records indicate that, between 1993 and 1999, 0-43 plants per year were sold by permit (as garden plants) in Georgia. However, while permits are required for collection, there is no estimate on numbers taken without a permit, and little enforcement is carried out with regard to protected plants (Georgia Natural Heritage Program in NatureServe 2001); no misdemeanors have been filed against anyone for removing yellow lady's-slippers in the past few years (Tom Patrick, personal communication in NatureServe 2001). It is believed that some illegitimate nurseries still obtain plants dug from the wild without either a permit or landowner permission.

One reason that wild orchids are targets for harvesting may be that large yellow lady's-slippers are challenging to grow from seed (NatureServe 2001), partially because of difficulty in developing germination techniques (Case 1998 and references therein). However, there is disagreement regarding whether plants collected from the wild are readily transplanted. While some authors and horticulturalists state that large yellow lady's slippers are generally amenable to transplanting and subsequent cultivation in the garden, especially when compared to other orchids (Light, University of Ottawa, personal communication; Morris and Eames 1929; Correll 1950; Brown 1997; and Native Son's Nursery 2002), others state that these transplants commonly fail (Deborah White, personal communication in NatureServe 2001). Another factor influencing collection from the wild is that quantities and prices of commercially propagated plants render cultivation for the dried herb market unfeasible, with the result that dried lady's-slipper roots available on the market are likely to be either roots from wild plants or roots from plants dug from the wild and then replanted in order to be called cultivated (Frontier Co-op 2000 and Homoya, personal communication in NatureServe 2001). However, some collection from the wild may be more benign; for example, Native Son's Nursery (2002),

a licensed Tennessee endangered plant dealer now going out of business, sells blooming size plants salvaged from road construction projects.

Laboratory propagated *Cypripedium parviflorum* var. *pubescens* plants (from seed, grown *in vitro*) are available from The Vermont Ladyslipper Company (VT Ladyslipper 2002). This company actively encourages people to start new colonies in appropriate natural habitats using their cultivated plants in the belief that this will reverse the decline in numbers of this species. One problem that may arise from this is the potential for changing the genetics of wild populations; it is uncertain if planting cultivated plants from other areas could cause genetic damage to local populations (SVE Panel 2003). An additional problem is that, in states where it is tracked, Heritage Programs may not know if a population is natural or planted, and thus cannot accurately assess the conservation needs of these plants in the wild (SVE Panel 2003).

## DISTRIBUTION AND STATUS

Because of taxonomic problems, there is confusion over the S ranks for this species. Those in the table are from NatureServe (2005), with footnotes indicating states and territories for which additional status information is available from other sources. In addition to taxonomic confusion, other factors that can sometimes make it difficult to determine population size for this species include its clonal nature (Great Plains Floral Association 1986 in NatureServe 2001) and its potential to exhibit dormancy (Shefferson et al. 2001), both of which can obscure the number of individuals at a site.

### *General Status and Distribution*

Large yellow lady's-slippers' global rank is G5T4T5 (NatureServe 2005). According to NatureServe (2001), they are distributed throughout North America, and are absent only from the Northwest Territories and Nunavut in Canada, and Arkansas, California, Hawaii, Louisiana, Nevada, Oklahoma, and Oregon in the United States (NatureServe 2005); reports that they are present in Texas and absent in Florida are both questionable (NatureServe 2005). Flora of North America (2001) includes Northwest Territories and Oregon in their distribution, but do not include Alabama, Alaska, Delaware, Idaho, Maryland, Navajo Nation, Nebraska, North Dakota, South Carolina, South Dakota, Texas, or Wyoming. Differences in descriptions of distribution most likely reflect taxonomic confusion within this complex of species.

*Cypripedium parviflorum* var. *pubescens* is listed as Division Indeterminate by the New England Plant Conservation Program, which means it is under review for inclusion in one of the *Flora Conservanda* divisions (divisions indicate degree of rarity in New England), but that issues of taxonomy, nomenclature, or status in the wild are not clearly understood (Brumback and Mehrhoff et al. 1996).

**Table 1. Occurrence and status of *Cypripedium parviflorum* var. *pubescens* in the United States and Canada based on information from NatureServe and State Natural Heritage Programs, with ranking from other sources as footnotes[4].**

| RANKED AS SX, S1, S2 or LISTED as T or E by State | RANKED AS S3-S5 | RANKED as SU or SNR |
|---|---|---|
| **SX within Region 9:**<br>None<br>**S1 within Region 9:**<br>Delaware[5], Rhode Island[6]<br>**S2 within Region 9**:<br>New Hampshire (T): 8 extant & 10 historical[7] | **S3 within Region 9:**<br>Illinois (S3?), Indiana[8], New Jersey (S3S4), Vermont[9]<br>**S4 within Region 9:**<br>Pennsylvania, West Virginia,<br>**S5 within Region 9:**<br>None | **SU within Region 9:**<br>Connecticut[10]<br>**SNR within Region 9:**<br>Iowa, Maine[11], Maryland[4], Massachusetts[12], Michigan, Minnesota, Missouri,<br>New York[13]: 6+ extant & 48+ historical[14], Ohio, Virginia, Wisconsin |
| **SX outside Region 9:**<br>District of Columbia<br>**S1 outside Region 9**:<br>Arizona[15], Idaho[4], Navajo Nation[4], Wyoming[4] (S1S2)<br>**S2 outside Region 9:**<br>Mississippi[16], New Mexico (S2?)[17] | **S3 outside Region 9:**<br>Alabama[4], Georgia[18], N. Carolina,<br>**S4 outside Region 9:**<br>Kentucky<br>**S5 outside Region 9:**<br>None | **SU outside Region 9:**<br>None<br>**SNR outside Region 9:**<br>Alaska[4], Colorado, Kansas, Montana, Nebraska[4], N. Dakota[4], S. Carolina[4], S. Dakota[4], Tennessee, Texas[4], Utah, Virginia, Washington |
| **SX in Canada:**<br>None<br>**S1 in Canada:**<br>None<br>**S2 in Canada:**<br>Nova Scotia, Prince Edward Island[4] (S2S3), Saskatchewan | **S3 in Canada:**<br>Alberta, British Columbia (S3S4), New Brunswick, Newfoundland Island (S3S4), Quebec<br>**S4 in Canada:**<br>None<br>**S5 in Canada:**<br>Manitoba (S5?), Ontario | **SU in Canada:**<br>None<br>**SNR in Canada:**<br>Labrador, Yukon Territory[4] |

[4] Flora of North America (2001) also includes Oregon and Northwest Territories in its distribution for this species, which NatureServe (2005) does not.
[5] Flora of North America (2001) does not list this state or territory in its distribution for this species.
[6] Brumback and Mehrhoff et al. (1996) indicate this is S1, T, with 4 occurrences in RI; Endangered (USDA NRCS 2002); 1 of 5 counties (Baldwin 1884)
[7] NH NHI (1998)
[8] It used to be on the Indiana Watch List (R. Hellmich, Indiana Department of Natural Resources, personal communication), but is not any longer (K. Larson, Hoosier National Forest, personal communication).
[9] Brumback and Mehrhoff et al. (1996) indicate this is S3 in VT, considered common and not tracked; 9 of 13 counties (Baldwin 1884)
[10] Brumback and Mehrhoff et al. (1996) indicate this is SU in CN; Connecticut Botanical Society (2002) indicates SC; 5 of 8 counties (Baldwin 1884)
[11] Brumback and Mehrhoff et al. (1996) indicate this is S3? in ME, considered common and not tracked; 5 of 16 counties (Baldwin 1884); 13 of 16 counties (Campbell et al. 1995)
[12] Brumback and Mehrhoff et al. (1996) indicate this is S3 in MA and on the Watch List; 7 of 14 counties (Baldwin 1884)
[13] Exploitatively vulnerable (NYS DEC 1989; USDA NRCS 2002)
[14] Number of occurrence in New York State is from Weldy et al. (2002); "+" indicates there is not enough detail to indicate exactly how many sites are known.
[15] Highly Safeguarded (USDA NRCS 2002)
[16] MI DWFP (2002) indicates S2S3
[17] Endangered (USDA NRCS 2002)
[18] Unusual (USDA NRCS 2002)

***Status of Region 9 Occurrences — Current and Historical***

Within Region 9 of the USDA Forest Service, *Cypripedium parviflorum* var. *pubescens* is on the Regional Forester's Sensitive Species (RFSS) list, indicating that there is a viability concern for this taxon on each Forest for which it is listed as sensitive (USDA Forest Service 2002). The Forests listing it as sensitive are the Shawnee, Hoosier, and Green Mountain National Forests. It is listed as a "Species of Viability Concern" for the Finger Lakes National Forest (SVE Monocot Panel 2003), meaning that it is being tracked through the process of forest plan revision, after which it may or may not move to the RFSS list; it has never been reported from the Forest. However, within the Cayuga Lake Basin, which encompasses the National Forest, it is described as scarce (Wesley 1999). Information regarding number of occurrences on National Forests is available only for the Green Mountain National Forest in Vermont, where there are five known occurrences (Allen 2002), and the Hoosier National Forest in Indiana, where there are also five known occurrences (K. Larson, Hoosier National Forest, personal communication); in Indiana, it is more common in the northern part of the state, than in the southern part where the National Forest is (K. Larson, Hoosier National Forest, personal communication).

Viability outcomes were determined by expert panels during the process of forest plan revision on the White Mountain, Green Mountain(SVE Panel 2002 in Allen 2002), and Finger Lakes National Forests (SVE Panel 2003 in St. Hilaire 2003). The current viability on the Green Mountain National Forest in Vermont it is believed to be a B and the taxon is likely to remain stable at B. On the Finger Lakes National Forest in New York, the current and expected outcome is D, because of limitations in metapopulation dynamics; this assumes that the species is actually present, which was considered likely by the panel. Future surveys may validate or invalidate this assumption. On the White Mountain National Forest in New Hampshire, the current and expected outcomes are uncertain, since occurrence records are uncertain and most New Hampshire records are historical (SVE Panel 2002 in Allen 2002). Outcome B indicates that habitat across the species' historical range is reduced in quality or quantity. Local demes may be extirpated and metapopulation interactions are adversely altered, but the species generally retains the geographic extent typical of the historical distribution. Outcome D indicates that habitat across the species' historical range is much reduced in quality or quantity. A majority of the historical populations have been extirpated and metapopulation interactions are essentially precluded. The geographic extent of the species is significantly reduced.

Large yellow lady's-slippers are found throughout Missouri, and are especially prominent in the Ozarks, which encompass the Mark Twain National Forest (D. Moore, Mark Twain National Forest, personal communication). David Moore, botanist with the Mark Twain National Forest, reports that, if a population is defined as a noticeable group of plants separated by at least a quarter of a mile, there are probably thousands of populations on the National Forest, with some populations up to half an acre in size. Since it is a fairly common plant in Missouri, its occurrences are not tracked. It is also

not tracked on the Hiawatha National Forest, since it is relatively common on the St. Ignace district (Mackinac County) and not uncommon on the other districts (J. Schultz, Hiawatha National Forest, personal communication). On the Wayne National Forest in Ohio, it used to be tracked informally because it was a state-listed species in that state; this is no longer true (E. Larson, Wayne National Forest, personal communication).

Within Region 9, this species is ranked by NatureServe (2005) as S1 in Delaware and Rhode Island; S2 (T) in New Hampshire; S3 in Illinois, Indiana, New Jersey, and Vermont; S4 in Pennsylvania and West Virginia; SU in Connecticut; and SNR in Iowa, Maine, Maryland, Massachusetts, Michigan, Minnesota, Missouri, New York, Ohio, and Wisconsin. Additional status and distribution information is listed below for states from which it was available.

For the two states within Region 9 that rank this species S1, there is no further status and distribution information. In New Hampshire, the only state in Region 9 that ranks it S2, there are eight extant and ten historical occurrences (NH NHI 1998). The extant occurrences are in four out of ten counties (NH NHI 1998, Baldwin 1884); it is historic in the same four counties plus one additional (NH NHI 1998). Element occurrences are listed later in this section.

For states within Region 9 that rank this species S3, limited information is available. In Indiana, it used to be on the Watch List, but no element occurrence records are maintained for it (R. Hellmich, Indiana Department of Natural Resources, personal communication), and it is no longer on that list (K. Larson, Hoosier National Forest, personal communication). In Vermont, 40+ occurrences are extant, the number of historic is unknown, and element occurrences are not formally tracked (VNNHP 2001). However, the Vermont Nongame and Natural Heritage Program does maintain a logbook of known occurrences, and these are listed later in this section.

Information is available for both states within Region 9 that rank this species S4. In West Virginia, large yellow lady's-slippers are scattered across the state, and reported from 25 out of 55 counties, but are not tracked beyond this (B. Sargent, West Virginia Department of Natural Resources, personal communication). In Pennsylvania, large yellow lady's-slippers (reported as *Cypripedium calceolus* var. *pubescens*) are one of three species listed as "Pennsylvania Vulnerable", because of their potential for collection; however, this confers no protection – it's simply a means of "keeping an eye on it" (Kierston Carlson, The Nature Conservancy, Pennsylvania Chapter, personal communication). Populations range in size from one plant with two to three stems to under a hundred; density may be about 50 plants throughout a couple of acres (C. Firestone, Pennsylvania Department of Conservation and Natural Resources, personal communication). While protection of this species is not allowed on state land, officials are concerned enough that they're collecting habitat and location information.

In Connecticut, the one state within Region 9 that ranks this species SU, records are maintained for *Cypripedium parviflorum*, but these are not separated by variety, and it

is uncertain which of the records might be var. *pubescens* (K. Zyko, Connecticut Natural Diversity Database, personal communication). There are sixty two records, of which 50 are considered historic, and it is listed as a species of State Special Concern (K. Zyko, Connecticut Natural Diversity Database, person communication). Because it is uncertain which of these 62 records pertain to *Cypripedium parviflorum* var. *pubescens*, the element occurrences are not listed here.

Within Region 9, of the states that rank this species SNR, additional information is available only for Massachusetts, Michigan, New York, and Ohio. In Massachusetts, Paul Somers (Massachusetts Division of Fisheries and Wildlife, personal communication) reports that, although this taxon is not officially listed under the state Endangered Species Act, it is listed (as *C. pubescens*) on an unofficial Watch List of additional rare plants of conservation interest in the state. He adds that, with the help of volunteers, they are beginning to develop a database based on herbarium records and on field forms completed by Heritage staff, volunteers for the New England Plant Conservation Program, and others. The eight records listed in the section on element occurrences are based on field forms, and are mainly from sites in the Berkshire Mountains; Somers expects these records are "a very limited representation of what exists currently or historically for this species" in Massachusetts. In Michigan, Case (1987) shows large yellow lady's-slippers in 62 of 84 counties. In New York, *C. calceolus*, no variety (=*Cypripedium parviflorum* both varieties) is listed as exploitatively vulnerable, meaning that it is legally protected and is likely to become threatened in the near future throughout all or a significant portion of its range within New York if causal factors continue unchecked (NYS DEC 1989). Weldy et al. (2002) indicate 6+ extant occurrences, and 48+ historic occurrences in New York State; of these, there are no known extant and 11+ historic occurrences in the Finger Lakes Highlands region of the state, within which lies the Finger Lakes National Forest. In Ohio, large yellow lady's-slippers were de-listed as "state rare" a few years ago, and are no longer tracked (G. Schneider, Ohio Department of Natural Resources, personal communication).

The majority of the states in Region 9 where this species is present do not track it (N. Conrad, New York Natural Heritage Program; T. Smith, Missouri Department of Conservation; K. Cieminski, Minnesota Natural Heritage and Nongame Research Program; K. Dohrmann, Iowa Department of Natural Resources; B. Sargent, West Virginia Department of Natural Resources; G. Schneider, Ohio Department of Natural Resources; R. Hellmich, Indiana Department of Natural Resources; and E. Pinkham, Maine Natural Areas Program; all personal communication).

Below is a detailed description of each Element Occurrence (EO) of large yellow lady's-slippers, in narrative form. Immediately following these narratives in Table 2 is a summary of information on each of these occurrences. The Tables list the state, county, town, and site ownership, followed by the first and last observation dates, site description, element occurrence rank, population size, comments, and threats; current occurrences are in bold. Element Occurrence Records provided by State Natural Heritage Programs are

the source for all information in this section. Appendix II provides an explanation of conservation ranks given to populations.

**Massachusetts Element Occurrences**
(Reported as *Cypripedium parviflorum* var. *pubescens*)

**MA.1 (New Marlboro)** – This population was visited in 1989 and consists of 19 plants. No further population, habitat, or land ownership information is available.

**MA.2 (Lanesboro)** – In 1990, five plants (four vegetative, and one with fruit) were found in open woods at the crest of a steep slope. No further population, habitat, or land ownership information is available.

**MA.3 (West Stockbridge)** – Four plants, including one mature, were found in 1991 at the edge of an upland swamp; however, the survey was "very limited" and there may be more plants. No further population, habitat, or land ownership information is available.

**MA.4 (West Stockbridge)** – This population consists of eight plants, three of which had mature flower bracts when they were observed in August of 1999. They are growing on a south-facing slope in talus of Ordovician Calcite formation under an overstory dominated by *Acer saccharum*, but near the base of a large red oak (*Quercus rubra*). Competition from invasive plants is a threat, as is a log landing that is proposed for the area below the site. No further population, habitat, or land ownership information is available.

**MA.5 (Holyoke)** – Two plants were reported at the edge of a vernal pool in 1989. No further population, habitat, or land ownership information is available.

**MA.6 (Hingham)** – Six to ten plants were reported near a pond in the woods in 1986. No further population, habitat, or land ownership information is available.

**MA.7 (Holyoke)** – Two plants were reported in 1983 on a state reservation. No further population, habitat, or land ownership information is available.

**MA.8 (Glendale)** – In 2000, three clumps with a total 15 stalks of good vigor were reported in a wetland with a combination of hardwood swamp and forested fen characteristics. Of the 15 stalks, 12 were flowering. This population is threatened by buckthorn and honeysuckle (invasive exotic species), which the landowner plans to girdle; browsing by deer is also a threat.

**New Hampshire Element Occurrences**
(Reported as *Cypripedium pubescens* – large yellow lady's-slipper)

**NH.001 (Lancaster) –** One of the best populations in the state, this one was first observed in 1913, and visited in 1970, 1988, 1990, 1994, and 1999. While given an A conservation rank, the population trend is uncertain. In 1989, 75 vigorous blossoms were

reported, in 1994, a total of 671 ramets were reported from six separate colonies, and in 1999, 50-100 ramets were observed, 50% in flower; it is unclear whether all six populations were monitor each time, or only in 1994, since the EOR notes that the entire area was not searched in 1999. A composite description of the habitat from three different visits indicates that this site, at 1600' elevation and with at least part of it on a steep slope, is either a dry-mesic to mesic transitional hardwood forest, or moist woodland, on loamy to very gravelly or stony loam. Associated trees are *Fagus grandifolia*, *Quercus rubra*, *Acer saccharum*, *Picea* sp., *Ostrya virginiana*, *Fraxinus americana*, and *Populus grandidentata*; associated understory species include *Clintonia* sp., *Aquilegia* sp., *Polygonatum* sp., *Antennaria* sp., *Aralia* sp., *Caulophyllum thalictroides*, *Aster acuminatus* and A. *macrophyllus*, *Pteridium aquilinum*, *Polystichum acrostichoides*, *Dryopteris marginalis*, *Solidago caesia* and *S. flexicaulis*, *Carex platyphylla*, *Oryzopsis asperifolia*, *Rhus radicans*. In 1999, four stems were found with flowers either eaten or picked, suggesting that either herbivory, collection, or both may be a problem. The population is near a road in a park in that is heavily trafficked in good weather, suggesting that impacts from recreation may be a problem. Land ownership is not reported.

**NH.002 (Hanover)** – This historical population, known from specimens at HNH, VT, and NHA, was first observed in 1876, and was observed again in 1897. Elevation is 900'; no other habitat, population, or land ownership data is available.

**NH.003 (New Durham)** – This historical population, known from specimens at NHS and NEBC, was first observed in 1936 and last observed in 1967. The habitat is described only as deciduous woods by a stream near an outlet (presumed into a lake), at 700'. No population or land ownership information is available.

**NH.004 (Dummer) –** This historical population, known from specimens at NEBC, was observed only once, in 1948. Elevation is 1780'; no population, habitat, or land ownership information is available.

**NH.005 (Barrington)** – First observed in 1941, this population was visited again in 1983 and 1999. Population data exist only for 1999, at which time there were eight plants, three of which were flowering. A composite habitat description from the two most recent visits suggests that the plants occur at 320' elevation, on gentle terrain near a road, at the upstream end of a rocky, vegetated mound, on a tiny island in the stream, within a rich mesic forest. Associated trees are *Acer saccharum*, *Tilia americana*, and *Fraxinus americana*; associated understory species include *Polystichum acrostichoides*, *Trillium erectum*, *Veratrum viride*, *Athyrium thelypterioides*, *Carex plantaginea*, and *Thelypteris phegopteris*. The population was not given a conservation rank. Notes from 1999 indicate the recent housing has been developed within 80 feet of the population, and that while this poses no direct threat, changes in light may affect the population. A recommendation is give to preserve the existing forest canopy and the water quality of the stream.

**NH.006 (Tamworth)** – This historical population, known from a specimen in a private collection, was first observed in 1946, and has not been observed since. The plants were in a spruce swamp near a lake, at 680' elevation; no additional habitat or population information is available. The site is now part of a preserve.

**NH.007 (Lancaster)** – This historical population, known from a specimen at NEBC, was first observed in 1920, and has not been observed since. The plants were in rich woods at 1120' elevation. No additional habitat, population, or land ownership information is available.

**NH.008 (Success)** – This historical population, known from specimens at NEBC and HNH, was first observed in 1925, and has not been observed since. The plants were in rich, boggy woods at 2920' elevation. No additional habitat, population, or land ownership information is available.

**NH.009 (Sugar Hill)** – Discovered in 1984, this population of 11-50 flowering has a C conservation rank, and is scattered in woods; additional habitat information is confusing, but it appears that these woods are at the moist lower-slope NNE of an acidic level fen, with partial to filtered light, and associated with *Cypripedium acaule*. No landownership information is available, and the population is described as unprotected but nice.

**NH.010 (Lebanon)** – This historical population, known from a specimen at HNH, was in wet places in low woods at 600' elevation. No other habitat, observation date, population, or landownership information is available.

**NH.011 (Hookset)** – This historical population, known from a specimen at NHA, was first observed in 1902, and has not been observed since then. Site elevation of is 355'; no other habitat, population, or land ownership information is available.

**NH.012 (Wolfeboro)** – This historical population, known from specimens at NEBC and NHA, was observed just once, in 1936. Habitat is wet woods at 550'; population and land ownership information is unavailable.

**NH.013 (Tamworth) –** This historical population, known from a specimen at NEBC, was observed in 1888 and has not been observed since then. Elevation is 600'; no other information is available about the habitat, population size, or land ownership.

**NH.014 (Brookfield)** – This population was first observed in 1985; no visit has occurred since then. In 1985, there were 30 stems in four to six groups; plants were in flower and exceptionally vigorous, but the conservation rank was C. The natural community is a circumneutral seepage swamp at 540' elevation, flat hydric, and with associated species that include *Solidago uliginosa*, *Carex lacustris*, and *Geum rivale*.

**NH.015 (Lyme) –** This population, first observed in 1987, was visited again in 1990 and 2000. In 1987, the population consisted of 5-10 plants, some mature. In 1990, it had a

total of 142 genets in two areas – one with two clumps with 37and 38 flowers, respectively, and the other with five clumps with 19, 12, 7, 2, and 4 plants, respectively (reason for inconsistency in the data not known). In 2000, the population consisted of 127 stems occurring in 11 clumps, within which 52 stems had flowered, and three fruit capsules were visible. A composite description of the habitat from the three visits suggests it is a wet-mesic NNE seepage forest with alternating seepy and drier patches, with a "typically lush" herbaceous layer and limited shrub layer, including several fern glade openings in which the lady's slippers occur most frequently. Associated dominant tree species are *Acer saccharum* and *Fraxinus americana*; ferns dominate the herbaceous layer, which includes *Adiantum pedatum*, *Athyrium thelypteroides*, *Athyrium filix-femina* var. *angustum*, and *Cystopteris bulbifera*, and *Sanicula trifoliata*. There is definite history of logging in the area, which still has old skid roads throughout; timber management and invasive alien species have apparently caused some degradation; *Tussilago farfara*, although not dense at the time of the most recent site visit, is listed as a potential future problem. In 1990, a recommendation was made that the site be registered to prevent further logging. The conservation rank for this population is B.

**NH.016 (Lyman)** – Observed just once in 1990, this population has a conservation rank of B, and consists of 32 genets, many of which appeared mature and had flowers. Spider webs and herbivory were evident; these in combination with number of plants are thought to degrade the quality of the population somewhat. The habitat consists of a large peatland basin dominated by *Thuja occidentalis*, *Picea rubens*, *Abies balsamea*, and other plants representative of calcareous influence. The site was previously logged, but it is uncertain whether logging is perceived as a threat to the population.

**NH.017 (Landaff)** –This population, first observed in 1992, was observed again in 1993, and not found after searching in 1999. In 1993, it had 68 ramets within 15-20 genets, of normal vigor, with evidence of sexual reproduction. It was described in 1993 as a "healthy population with some room for expansion, good numbers, off the beaten path", given a conservation rank of A, and described as having "excellent quality, viability, and defensibility." In 1993, the habitat was described as a hardwood seepage swamp influenced by nutrient-rich ground water and perhaps surface run-off, at 1800' elevation. In 1999, the approximate area where the population was mapped was described as an open area dominated by *Rubus* sp., between the rich mesic forest and calcareous seepage swamp. It is uncertain whether the population has been extirpated because of logging, or simply was not located; the surrounding area is reported to have had much logging activity, with some tracks running through and along the edges of the swamp.

**NH.019 (Moultonborough)** – This population was first observed in 1996, and visited again in 1999. It consists of two patches, one with 54 plants, of which 25 had flowered but senesced, the other with three plants, two flowering; the latter had apparently declined from 28+ plants in 1996, of which 14 had bloomed. The conservation rank is B. Plants occur along a streamside, in a natural community described as a semi-rich mesic forest on an upper south-south-west facing slope, with filtered light, in an overflow channel. Associated species include *Hamamelis virginiana, Fagus grandifolia, Uvularia*

*sessilifolia*, *Sanicula gregaria*, *Aralia nudicaulis*, *Solidago flexicaulis*, *Viburnum acerifolium*, *Acer saccharum*, *Trillium erectum*, and *Amphicarpaea bracteata*. The site is in an area unlikely to be developed, and although hiking is listed as a possible threat, it is also noted that hikers do not seem to leave the trail in this section. Landownership is not mentioned, but the site is apparently along a public trail.

**Vermont Element Occurrences**

While Vermont does not track large yellow lady's slippers with Element Occurrence Records, the Vermont Nongame and Natural Heritage Program does maintain a logbook of known occurrences that lists the county, town, and location, and sometimes mentions the habitat type. Large yellow lady's-slippers, listed as *Cypripedium calceolus* var. *pubescens* in this logbook, are documented to occur in 40 locations; all entries are between 1983 and 1997. Landownership and population information are not available.

In Addison County, large yellow lady's-slippers are documented from Addison (1), from a large swamp that includes the towns of Whiting, Leicester, Brandon, and Sudbury and is partly in Rutland County (1), and also from the towns of Bridport (1), Ferrisburg (1), Weybridge (1), Cornwall (1), Monkton (1), Salisbury (1), Goshen (1), and Leicester (1). In Bennington County, they are reported from Manchester (2) and Dorset (1). In Caledonia County, the plants are documented from Peacham (2) and Sutton (1). One of the Peacham sites is known by the author to contain only var. *makasin*, and so it is likely that this particular entry in the logbook does not pertain to var. *pubescens*. In Chittenden County, large yellow lady's-slippers are documented from Colchester (3), Burlington (1), Essex (1), Hinesburg (1), and South Burlington (1). In Franklin County, Highgate (1) is the only town from which they are reported. In Rutland County, large yellow lady's-slippers are recorded from Mt. Tabor (1), Benson (1), West Haven (2), Fair Haven (1) and Sudbury (1). In Lamoille County, they are known only from Eden (1). In Orange County, they are reported only from Stafford (1). In Orleans County, they are reported from Derby (1), Albany (1), Troy (1), and Craftsbury (1). In Washington County, they are reported from Marshfield (1) and Woodbury (2). In Windsor County, they are known only from Ludlow (1). Habitats mentioned are along road, ledges, woods and cobbles, limy cobbles and wetland, talus slope, near brook, woods, swamps, and cedar swamps.

**Table 2. Element Occurrence Records for Large Yellow Lady's-slippers in Region 9. Shaded occurrences are considered extant.**

| State | EO # | County | Town | Site Ownership | First Obs. | Last Obs. | Description | EO Rank | Population Size (date) | Comments | Threats |
|---|---|---|---|---|---|---|---|---|---|---|---|
| MA | 1 | Berkshire | New Marlboro | Unknown | 1989 | 1989 | | ? | 19 (1989) | | |
| MA | 2 | Berkshire | Lanesboro | Unknown | 1990 | 1990 | In open woods at the crest of a steep slope | ? | 5; 4 vegetative, 1 w/ fruit (1990) | | |
| MA | 3 | Berkshire | West Stockbridge | Unknown | 1991 | 1991 | At the edge of an upland swamp | ? | 4; 1 mature; survey not complete – may be more plants(1991) | | |
| MA | 4 | Berkshire | West Stockbridge | Unknown | 1999 | 1999 | On S-facing slope in talus of Ordovician Calcite formation under overstory dominated by *Acer saccharum*, but near base of large *Quercus rubra* | ? | 8; 3 w/ flower bracts(1999) | | Competition from invasive plants is a threat, as is log landing proposed for area below site |
| MA | 5 | Hampton | Holyoke | Unknown | 1989 | 1989 | At edge of vernal pool | ? | 2 (1989) | | |
| MA | 6 | Plymouth | Hingham | Unknown | 1986 | 1986 | Near pond in woods | ? | 6-10 (1986) | | |
| MA | 7 | Hampton | Holyoke | State reservation | 1983 | 1983 | | ? | 2 (1983) | | |
| MA | 8 | Berkshire | Glendale | Unknown | 2000 | 2000 | In wetland w/ a combination of hardwood swamp & forested fen characteristics | ? | 3 clumps; total of 15 stalks w/ 12 flowering (2000) | Plants of good vigor | Threatened by buckthorn and honeysuckle (invasive exotic species), which landowner plans to girdle; browsing by deer is also a threat |

| | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| NH | 001 | Coos | Lancaster | Unknown | 1913 | 2003 | 1600' elevation, at least part on a steep slope; either dry-mesic to mesic transitional hardwood forest, or moist woodland, on loamy to very gravelly or stony loam; associated trees are *Fagus grandifolia, Quercus rubra, Acer saccharum, Picea* sp., *Ostrya virginiana, Fraxinus americana*, & *Populus grandidentata*; associated understory species include *Clintonia,, Aquilegia, Polygonatum, Antennaria, Aralia, Caulophyllum thalictroides, Aster acuminatus* & A. *macrophyllus, Pteridium aquilinum, Polystichum acrostichoides, Dryopteris marginalis, Solidago caesia* & *S. flexicaulis, Carex platyphylla, Oryzopsis asperifolia, Rhus radicans* | A | 75 vigorous blossoms(1989); 671 ramets from 6 separate colonies (1994); 50-100 ramets w/ 50% in flower; (1999); unclear whether all 6 populations monitored each time, or only in 1994, since EOR notes entire area not searched in 1999;<br>1 clump lost due to theft (2003). | One of the best populations in the state, but population trend is uncertain | In 1999, 4 stems found w/ flowers either eaten or picked, suggesting that either herbivory, collection, or both may be a problem; population is near a road in a park that is heavily trafficked in good weather, suggesting impacts from recreation may be a problem. |
| NH | 002 | Grafton | Hanover | Unknown | 1876 | 1897 | Elevation 900' | H | | Known from specimens at HNH, VT, and NHA | |
| NH | 003 | Strafford | New Durham | Unknown | 1936 | 1967 | Deciduous woods by stream near outlet (presumed into lake); 700' | H | | Known from specimens at NHS and NEBC | |
| NH | 004 | Coos | Dummer | Unknown | 1948 | 1948 | Elevation 1780' | H | | Known from specimens at NEBC | |

| | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| NH | 005 | Strafford | Barrington | Unknown | 1941 | 1999 | 320' elevation, on gentle terrain near road, at upstream end of rocky, vegetated mound, on tiny island in stream w/in rich mesic forest; associated trees are *Acer saccharum*, *Tilia americana*, & *Fraxinus americana*; associated understory species include *Polystichum acrostichoides*, *Trillium erectum*, *Veratrum viride*, *Athyrium thelypteroides*, *Carex plantaginea*, & *Thelypteris phegopteris* | | 8 plants; 3 flowering (1999) | A recommendation is to preserve the existing forest canopy & water quality of the stream | Recent housing has been developed w/in 80' of population, & while this poses no direct threat, changes in light may affect population |
| NH | 006 | Carroll | Tamworth | Site is now part of a preserve | 1946 | 1946 | In a spruce swamp near a lake at 680' elevation | H | | Known from a specimen in a private collection | |
| NH | 007 | Coos | Lancaster | Unknown | 1920 | 1920 | In rich woods at 1120' elevation | H | | Known from a specimen at NEBC | |
| NH | 008 | Coos | Success | Unknown | 1925 | 1925 | In rich, boggy woods at 2920' elevation | H | | Known from specimens at NEBC & HNH | |
| NH | 009 | Grafton | Sugar Hill | Unknown | 1984 | 1984 | Scattered in woods that are at moist lower-slope NNE of an acidic level fen, w/ partial to filtered light, & associated w/ *Cypripedium acaule*. | C | 11-50 flowering stems (1984) | Unprotected but nice | |
| NH | 010 | Grafton | Lebanon | Unknown | ? | ? | In wet places in low woods at 600' elevation | H | | Known from a specimen at HNH | |
| NH | 011 | Merrimack | Hookset | Unknown | 1902 | 1902 | 355'elevation | H | | Known from a specimen at NHA | |
| NH | 012 | Carroll | Wolfeboro | Unknown | 1936 | 1936 | Wet woods at 550' elevation | H | | Known from specimens at NEBC & NHA | |
| NH | 013 | Carroll | Tamworth | Unknown | 1888 | 1888 | 600' elevation | H | | Known from a specimen at NEBC | |

| | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| NH | 014 | Carroll | Brookfield | Unknown | 1985 | 1985 | In a circumneutral seepage swamp at 540' elevation, flat & hydric; associated species include *Solidago uliginosa*, *Carex lacustris*, & *Geum rivale*. | C | 30 stems in 4-6 groups; plants were in flower & exceptionally vigorous (1985) | | |
| NH | 015 | Grafton | Lyme | Unknown | 1987 | 2000 | In a wet-mesic NNE seepage forest w/ alternating seepy & drier patches, w/ a "typically lush" herbaceous layer & limited shrub layer, including several fern glade openings in which the lady's slippers occur most frequently; associated dominant tree species are *Acer saccharum* & *Fraxinus americana*; ferns dominate the herbaceous layer, which includes *Adiantum pedatum*, *Athyrium thelypteroides*, *Athyrium filix-femina* var. *angustum*, Cystopteris *bulbifera*, & *Sanicula trifoliata*. | B | 5-10 plants, some mature (1987);<br>142 genets in 2 areas – 1 w/ 2 clumps w/ 37 & 38 flowers, respectively, & the other w/ 5 clumps w/ 19, 12, 7, 2, & 4 plants, respectively (1990);<br>127 stems occurring in 11 clumps, w/in which 52 had flowered, & 3 fruit capsules were visible (2000) | In 1990, a recommendation was made that the site be registered to prevent further logging. | History of logging in the area, which still has old skid roads throughout; timber management & invasive alien species have apparently caused some degradation; *Tussilago farfara*, although not dense at the time of the most recent site visit, is listed as a potential future problem |

| | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| NH | 016 | Grafton | Lyman | Unknown | 1990 | 1990 | In a large peat land basin dominated by *Thuja occidentalis*, *Picea rubens*, *Abies balsamea*, & other plants representative of calcareous influence | B | 32 genets, many of which appeared mature & had flowers | | Site previously logged; uncertain whether logging is perceived as threat to population; spider webs & herbivory evident; these in combination w/ # of plants are thought to degrade quality of population somewhat |
| NH | 017 | Grafton | Landaff | Unknown | 1992 | 1993 | Described in 1993 as in a hardwood seepage swamp influenced by nutrient-rich ground water & perhaps surface run-off, 1800' elevation; in 1999, the approximate area where population was mapped was described as an open area dominated by *Rubus* sp., between the rich mesic forest & calcareous seepage swamp | A | 68 ramets w/in 15-20 genets, of normal vigor, w/ evidence of sexual reproduction (1993); not found in 1999 | Described in 1993 as a healthy population w/ some room for expansion, good numbers, off the beaten path; excellent quality, viability, & defensibility; not found in 1999 | Uncertain whether the population has been extirpated because of logging, or simply was not located; surrounding area is reported to have had much logging activity, w/ some tracks running through & along the edges of swamp |
| NH | 019 | Carroll | Moulton-borough | Apparently along a public trail | 1996 | 2001 | Along a streamside, in a semi-rich mesic forest on an upper S-SW facing slope, w/ filtered light, in an overflow channel; associated species include *Hamamelis virginiana*, *Fagus grandifolia*, *Uvularia sessilifolia*, *Sanicula gregaria*, *Aralia nudicaulis*, *Solidago flexicaulis*, *Viburnum acerifolium*, *Acer saccharum*, *Trillium erectum*, & *Amphicarpa bracteata* | B | 2 patches, 1 w/ 54 plants, of which 25 had flowered but senesced, the other w/ 3 plants, 2 flowering; the latter had apparently declined from 28+ plants in 1996, of which 14 had bloomed (1999) | Site is in an area unlikely to be developed, & although hiking is listed as a possible threat, it is also noted that hikers do not seem to leave the trail in this section | |

## CURRENT CONSERVATION MEASURES IN REGION 9

### *Site Protection*

Because so few states formally track occurrences of large yellow lady's-slippers, limited information exists regarding whether the sites on which they occur are protected. Of the eight sites for which there are Element Occurrence Records in Massachusetts, land ownership is known for only one, which is a state reservation. Of the 18 Element Occurrence Records from New Hampshire, one is listed as apparently along a public trail, another is on land that is a state preserve, and ownership is not known for the remaining 16. Within Region 9 of the Forest Service, plants occur in a designated Special Area in one of five sites on Hoosier National Forest in Indiana (K. Larson, Hoosier National Forest, personal communication); on the Green Mountain National Forest in Vermont, one of five sites occurs in a location proposed as a Special Area during Forest Plan Revision in all but the "no action alternative" (D. Burbank, Green Mountain National Forest, personal communication). On all national forests, the USDA Forest Service Manual (FSM 2670.32) direction states that management activities that could affect known populations of sensitive species may be implemented only if the action does not result in loss of species viability on the forest or create significant trends toward federal listing. On the Mark Twain National Forest in Missouri, the Hiawatha National Forest in Michigan, and the Wayne National Forest in Ohio, since they are relatively common plants, there are no conservation measures in place to protect them (D. Moore, Mark Twain National Forest, J. Schultz, Hiawatha National Forest, and E. Larson, Wayne National Forest, all personal communication). Despite the lack of formal conservation measures, their occurrences sometimes receive protection: on the Wayne National Forest, during one trail-widening project, large yellow lady's-slippers growing along the trail were transplanted to another location; unfortunately, they are not known to transplant well, and it is not known whether or not this mitigation measure was successful (E. Larson, Wayne National Forest, personal communication).

### *Monitoring*

In Vermont, while large yellow lady's-slippers are considered common and not tracked, the Vermont Nongame and Natural Heritage Program maintains a logbook of known occurrences (Brumback and Mehrhoff et al. 1996).

On the Green Mountain National Forest in Vermont, standards and guidelines in the Land and Resource Management Plan, as amended, call for monitoring all populations of plants on the RFSS list every five years, unless the species' strategy dictates a different schedule (USDA Forest Service 2002).

Of the eight sites in Massachusetts and 18 sites in New Hampshire for which Element Occurrence Records exist, none have been visited more recently than five years ago, and most have not been visited in many years (see Element Occurrence table for

more details). Because this species is not tracked in most states where it occurs, it is not likely to be monitored very often. It is unknown whether any other states have any monitoring programs for this species.

***Watch Lists***

In Pennsylvania, large yellow lady's-slippers (reported as *Cypripedium calceolus* var. *pubescens*) are one of three species listed as "Pennsylvania Vulnerable", because of their potential for collection; however, this confers no protection – it's simply a means of "keeping an eye on it" (Kierston Carlson, The Nature Conservancy, Pennsylvania Chapter, personal communication). In Massachusetts, they are on a Watch List (Brumback and Mehrhoff et al. (1996) that serves an unofficial list of rare plants of conservation interest in the state (P. Somers, Massachusetts Division of Fisheries and Wildlife, personal communication). They used to be on a state Watch List in Indiana (R. Hellmich, Indiana Department of Natural Resources, personal communication), but have been removed (K. Larson, Hoosier National Forest, personal communication). In New York State, they are listed as exploitatively vulnerable, which is intended to protect them from collection (NYS DEC 1989). In Arizona, they are considered Highly Safeguarded (USDA NRCS 2002).

In addition to the status information listed in the section on status and distribution, all *Cypripedium* species are listed by the United Plant Savers at Risk Forum on their "At Risk" list. This list consists of "herbs which are broadly used in commerce and which, due to over-harvest, loss of habitat, or by the nature of their innate rareness or sensitivity are either at risk or have significantly declined in numbers within their current range" (United Plant Savers 2000 in NatureServe 2003); this listing does not confer any legal protection.

***Regulations on collection and sales***

The Convention on International Trade in Endangered Species (CITES) lists *Cypripedium parviflorum* var. *pubescens* as an Appendix II species. This means that export trade is allowed as long as trade is not detrimental to the survival of the species and the appropriate permits and certificates are obtained; import permits are not required (CITES 2002). In addition, in 1988, an industry resolution was passed to discontinue sales of wild-collected lady's-slipper root, and many responsible herb companies complied, but some did not (Frontier Co-op 2000 in NatureServe 2001), and some still pay for rhizomes dug in the wild (Klein, personal communication in NatureServe 2001).

In Pennsylvania, anyone buying this species must obtain a "Vulnerable Plant" license; if the plant is taken out of the country, USFW will report back (C. Firestone, Pennsylvania Department of Conservation and Natural Resources, personal communication).

In Georgia, where large yellow lady-slippers are often dug for horticultural or medicinal purposes, they are protected as a "Special Concern Plant". When sold by permit, they are required to have transport tags, a copy of which is to be filed with the Georgia Natural Heritage Program. Records indicate that, between 1993 and 1999, 0-43 plants per year were sold by permit (as garden plants) in Georgia. However, while permits are required for collection, there is no estimate on numbers taken without a permit, and little enforcement is carried out with regard to protected plants (Georgia Natural Heritage Program in NatureServe 2001); no misdemeanors have been filed against anyone for removing yellow lady's-slippers in the past few years (Tom Patrick, personal communication in NatureServe 2001). It is believed that some illegitimate nurseries still obtain plants dug from the wild without either a permit or landowner permission.

In Tennessee, a licensed endangered plant dealer, now going out of business, sells blooming size plants salvaged from road construction projects (Native Son's Nursery 2002).

***Seed Collection, Germination, and Reintroduction of populations***

Laboratory propagated *Cypripedium parviflorum* var. *pubescens* plants (from seed, grown *in vitro*) are available from The Vermont Ladyslipper Company (VT Ladyslipper 2002). This company actively encourages people to start new colonies in appropriate natural habitats using their cultivated plants in the belief that this will reverse the decline in numbers of this species. However, this practice also poses some potential threats to the species, which were discussed in the section on threats.

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**Appendix 1: Morphological Characters that Distinguish Varieties**

| **Quantitative morphological characters that most strongly distinguish varieties of yellow lady's-slippers in Vermont; varieties are best distinguished by using the following characters in combination, rather than separately (Deller 1994).** | | | |
|---|---|---|---|
| | **Variety** | | |
| **Character**<br>Mean +/- SD<br>(Range) | *pubescens* | *makasin* | *parviflorum* |
| Staminode length (cm) | 1.80 +/- 0.17<br>(1.4 – 2.2) | 1.29 +/- 0.15<br>(1.0 – 1.7) | 1.40 +/- 0.09<br>(1.2 – 1.6) |
| Aperture width (cm) | 1.07 +/-0.15<br>(0.7 - 2.0) | 0.75 +/- 0.08<br>(0.6 – 0.9) | 0.75 +/- 0.11<br>(0.5 – 0.9) |
| Bract length (cm) | 8.98 +/- 1.88<br>(3.7 - 16.5) | 4.99 +/- 2.05<br>(1.8 – 10.2) | 5.87 +/_1.95<br>(2.7 – 10.7) |
| Length of internode near flower (cm) | 7.27 +/- 1.73<br>(4.0 – 14.0) | 6.26 +/- 1.91<br>(4.0 – 11.0) | 5.92 +/- 1.24<br>(4.0 – 8.0) |
| Leaf width at widest point (cm) | 8.30 +/- 1.96<br>(4.5 – 18.2) | 4.26 +/- 1.22<br>(2.4 – 6.4) | 6.71 +/- 1.43<br>(4.7 – 10.0) |
| Location of widest part of leaf, measured from leaf base (cm) | 6.82 +/- 1.13<br>(4.8 – 10.0) | 4.88 +/- 1.19<br>(3.0 – 6.8) | 6.56 +/- 0.82<br>(5. – 9.0) |

## Appendix 2:

## An Explanation of Conservation Ranks Used by The Nature Conservancy and Natureserve

The conservation rank of an element known or assumed to exist within a jurisdiction is designated by a whole number from 1 to 5, preceded by a G (Global), N (National), or S (Subnational) as appropriate. The numbers have the following meaning:

1 = critically imperiled
2 = imperiled
3 = vulnerable to extirpation or extinction
4 = apparently secure
5 = demonstrably widespread, abundant, and secure.

G1, for example, indicates critical imperilment on a range-wide basis — that is, a great risk of extinction. S1 indicates critical imperilment within a particular state, province, or other subnational jurisdiction — i.e., a great risk of extirpation of the element from that subnation, regardless of its status elsewhere. Species known in an area only from historical records are ranked as either H (possibly extirpated/possibly extinct) or X (presumed extirpated/presumed extinct). Certain other codes, rank variants, and qualifiers are also allowed in order to add information about the element or indicate uncertainty.

Elements that are imperiled or vulnerable everywhere they occur will have a global rank of G1, G2, or G3 and equally high or higher national and subnational ranks (the lower the number, the "higher" the rank, and therefore the conservation priority). On the other hand, it is possible for an element to be rarer or more vulnerable in a given nation or subnation than it is range-wide. In that case, it might be ranked N1, N2, or N3, or S1, S2, or S3 even though its global rank is G4 or G5. The three levels of the ranking system give a more complete picture of the conservation status of a species or community than either a range-wide or local rank by itself. They also make it easier to set appropriate conservation priorities in different places and at different geographic levels. In an effort to balance global and local conservation concerns, global as well as national and subnational (provincial or state) ranks are used to select the elements that should receive priority for research and conservation in a jurisdiction.

Use of standard ranking criteria and definitions makes Natural Heritage ranks comparable across element groups; thus, G1 has the same basic meaning whether applied to a salamander, a moss, or a forest community. Standardization also makes ranks comparable across jurisdictions, which in turn allows scientists to use the national and subnational ranks assigned by local data centers to determine and refine or reaffirm global ranks.

Ranking is a qualitative process: it takes into account several factors, including total number, range, and condition of element occurrences, population size, range extent and area of occupancy, short- and long-term trends in the foregoing factors, threats, environmental specificity, and fragility. These factors function as guidelines rather than arithmetic rules, and the relative weight given to the factors may differ among taxa. In some states, the taxon may receive a rank of SR (where the element is reported but has not yet been reviewed locally) or SRF (where a false, erroneous report exists and persists in the literature). A rank of S? denotes an uncertain or inexact numeric rank for the taxon at the state level.

Within states, individual occurrences of a taxon are sometimes assigned element occurrence ranks. Element occurrence (EO) ranks, which are an average of four separate evaluations of quality (size and productivity), condition, viability, and defensibility, are included in site descriptions to provide a general indication of site quality. Ranks range from: A (excellent) to D (poor); a rank of E is provided for element occurrences that are extant, but for which information is inadequate to provide a qualitative score. An EO rank of H is provided for sites for which no observations have made for more than 20 years. An X rank is utilized for sites that known to be extirpated. Not all EO's have received such ranks in all states, and ranks are not necessarily consistent among states as yet.