New England Plant Conservation Program

Goodyera oblongifolia Raf
Giant Rattlesnake-plantain

Conservation and Research Plan for New England

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SUMMARY

Goodyera oblongifolia Raf. (giant rattlesnake-plantain), Orchidaceae, is one of four *Goodyera* species found in North America. It is globally secure (G5) and fairly common in western states and provinces of North America, but it is generally rare east of the Great Lakes. In New England, *G. oblongifolia* is found only in Maine, where it is ranked S2, Endangered. There are twenty-two records from Maine; six of these are historic and three are extirpated. There are thirteen extant occurrences; eight have extremely small populations and are not considered viable. Eight populations were discovered between 1999 and 2002, and there are likely at least a few more populations awaiting discovery through inventory of likely habitat. The New England Plant Conservation Program (NEPCoP) lists *G. oblongifolia* as a Division 2 species, indicating that it is a regionally rare taxon with fewer than 20 occurrences in New England.

Some information is available regarding the biology of *Goodyera oblongifolia*. *Goodyera oblongifolia* is pollinated by bumblebees, flowers in August in New England, and can be propagated asymbiotically in an *in vitro* culture. Information regarding potential herbivores, specific habitat and microhabitat requirements, and mycorrhizal symbiont identification is somewhat lacking. The range-wide habitat descriptions offered for *G. oblongifolia* are fairly non-specific, generally similar to "coniferous and mixed woods." In Maine, *G. oblongifolia* is typically found in mature northern white-cedar seepage forests, and at the bases of mature northern white-cedars in mixed stands. Disturbance due to logging activities is detrimental to this species and is a threat at most of the sites where it occurs.

The primary conservation objectives for *Goodyera oblongifolia* in New England are to determine the number of extant populations by survey of likely habitat, and to protect the species where found by information sharing with landowners, management agreements, and habitat management. An ideal conservation goal is to have at least eight extant and viable occurrences for *G. oblongifolia* by 2022. There are currently five extant, viable occurrences (those ranked C or better).

PREFACE

This document is an excerpt of a New England Plant Conservation Program (NEPCoP) Conservation and Research Plan. Full plans with complete and sensitive information are made available to conservation organizations, government agencies, and individuals with responsibility for rare plant conservation. This excerpt contains general information on the species biology, ecology, and distribution of rare plant species in New England.

The New England Plant Conservation Program (NEPCoP) of the New England Wild Flower Society is a voluntary association of private organizations and government agencies in each of the six states of New England, interested in working together to protect from extirpation, and promote the recovery of the endangered flora of the region.

In 1996, NEPCoP published "*Flora Conservanda*: New England." which listed the plants in need of conservation in the region. NEPCoP regional plant Conservation Plans recommend actions that should lead to the conservation of *Flora Conservanda* species. These recommendations derive from a voluntary collaboration of planning partners, and their implementation is contingent on the commitment of federal, state, local, and private conservation organizations.

NEPCoP Conservation Plans do not necessarily represent the official position or approval of all state task forces or NEPCoP member organizations; they do, however, represent a consensus of NEPCoP's Regional Advisory Council. NEPCoP Conservation Plans are subject to modification as dictated by new findings, changes in species status, and the accomplishment of conservation actions.

Completion of the NEPCoP Conservation and Research Plans was made possible by generous funding from an anonymous source, and data were provided by state Natural Heritage Programs. NEPCoP gratefully acknowledges the permission and cooperation of many private and public landowners who granted access to their land for plant monitoring and data collection.

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I. BACKGROUND

INTRODUCTION

Goodyera oblongifolia Raf., Giant Rattlesnake-plantain, is a member of the Orchid Family (Orchidaceae). *Goodyera oblongifolia* is fairly common in western states and provinces (Luer 1975) but is rare east of the Great Lakes area (Case 1964). The populations in the glaciated northeast are considered disjunct from the western populations (Kallunki 1976). From the Great Lakes area and eastward, *G. oblongifolia* is found in Wisconsin (S3), Michigan (S?), Ontario (S4), Quebec (SR), Newfoundland Island (SH), Nova Scotia (S2S3), New Brunswick (S2), and Maine (S2).

In New England, *Goodyera oblongifolia* is currently found only in Maine, where it is listed as an Endangered plant. The New England Plant Conservation Program (NEPCoP) lists *G. oblongifolia* as a Division 2 species, indicating that it is a regionally rare taxon with fewer than 20 occurrences in New England (Brumback and Mehrhoff et al. 1996). There are 22 records of *G. oblongifolia* in Maine. Six of these are historic and three are extirpated. Of the thirteen extant occurrences, eight are not considered viable due to extremely small population numbers. Eight populations were recorded between 1999 and 2002, and there are likely at least a few more populations awaiting discovery through inventory of likely habitat. *Goodyera oblongifolia* has been reported from New Hampshire, New York (Gibson 1905), and Vermont. The Vermont report is based on a misidentification of *G. tesselata* (Jenkins and Zika 1995). It is likely that other unconfirmed reports of *G. oblongifolia* are also based on mistaken identifications of *G. tesselata.* Prior to 1899, *G. tesselata* was typically misidentified as *G. oblongifolia* (Fernald 1899, Kallunki 1976).

Goodyera oblongifolia is a rhizomatous plant that forms colonies of rosettes (Case 1964, Luer 1975). It generally flowers in late summer and is pollinated by bumblebees (Ackerman 1975, Kallunki 1981), though only about 5% of Maine's plants flower. *Goodyera* species are relatively easy to propagate *in vitro* (Rasmussen 1995), and *G. oblongifolia* has been propagated by this method (Harvais 1974 in Rasmussen 1995, Arditti et al. 1981, 1982b).

The range-wide habitat descriptions offered for *Goodyera oblongifolia* are fairly general, as in "mixed conifer woods." In Maine, *G. oblongifolia* is typically found in mature northern white-cedar seepage forests, and at the bases of mature northern white-cedars in mixed stands (Andy Cutko, Maine Natural Areas Program, personal communication). Disturbance due to logging activities is detrimental to this species as indicated by the precipitous decline in populations at T12 R08 WELS following timber harvest (ME .003 and .009-.013). Timber harvest is a threat at most of the sites where it occurs.

This conservation plan is written in two sections. The first section summarizes available information on the ecology, taxonomy, distribution, and status of *Goodyera oblongifolia*. The second section presents conservation objectives and general conservation actions for *G. oblongifolia* in New England, specific conservation actions for each occurrence, and a prioritized implementation schedule for these conservation actions.

DESCRIPTION

There are about 25 species of *Goodyera* worldwide, with four species in North America (Luer 1975, Chapman 1977, Van der Cingel 2001). Four species of *Goodyera* are present in New England: *Goodyera oblongifolia*, *G. pubescens*, *G. repens* var. *ophioides*, and *G. tesselata* (Angelo and Boufford 2000). Creeping rhizomes and rosettes of evergreen leaves characterize the genus (Luer 1975, Brackley 1985). The genus *Goodyera* is closely related to the genus *Spiranthes*, and both have similarly-arranged flowers (Van der Cingel 2001). *Goodyera* flowers are characterized by a saccate nectary of the lip with a beak-shaped apex and sepals and petals connivant over the column (Luer 1975). Pollinia in *Goodyera* are granular, in contrast to other members of this tribe, the Cranichideae (Luer 1975).

The species description of *Goodyera oblongifolia* is compiled from the following sources: Fernald (1899), Morris and Eames (1929), Correll (1950), Case (1964), Luer (1975), Cameron (1976), Chapman (1977), and Gleason and Cronquist (1991). Characteristics mentioned in only one source are so indicated in the description.

Goodyera oblongifolia is terrestrial, with a robust, 20 - 45 (50) cm spike. The stem is stiff and densely glandular-hairy above and usually has a few (4 - 7) tiny bracts. Roots are fibrous and are produced from a short creeping rhizome. Leaves are in a basal rosette, 3 - 7 (up to 11) cm long by 1.5 - 4 cm wide, usually oblong to elliptic, sometimes ovate to ovate-lanceolate, rarely lanceolate. The basal rosette has three to seven leaves (Keenan 1998). The leaves are uniformly nine-veined and taper at both ends, and the leaf margins are fluted or wavy (Cameron 1976). The leaf tip is obtuse to acute, and leaf petioles are fairly wide (Correll 1950). The leaves are dark green to pale bluish-green, and are typically marked with white only along the broad midrib. The white marking varies from very narrow to broad and slightly branched. The blade area may or may not be reticulated (white markings in a net-like pattern).

The inflorescence is a sparsely to densely flowered raceme with 12 - 24 (up to 30) flowers. Flowers are loosely spiraled to one-sided, from their tendency to turn toward the light. The flower spike tapers at the apex and is 6 - 14 cm long by 1 - 2.5 cm in diameter, and occupies one-quarter to one-third of the stem. Floral bracts are ovate to ovate-lanceolate to elliptic-lanceolate, 6 - 13 mm long by 2 - 3 mm wide. Cameron (1976) notes that floral bracts are broadly triangular with an acute tip and are short and inconspicuous. In flowering plants, the upper leaves are smaller than the lower leaves and intergrade with bracts (Kallunki 1976). The flowers are white and are often tinged or streaked with green, especially on the upper or outer parts. They are large for the genus,

8 mm tall by 7 - 8 mm wide by 7 - 10 mm long, and are more or less pear-shaped when viewed from the side. The ovaries are subsessile, stout, pedicellate, and about 5 - 10 mm long by 3 mm wide. The dorsal sepal is triangular-lanceolate, to elliptic-lanceolate, blunt, recurved at the apex, concave below, greenish, and 6 - 10 mm long by 3 - 4 mm wide. The lateral sepals are free, ovate-lanceolate, oblique, concave, and rather abruptly tapering to the recurved acuminate apex. The lateral sepals are whitish with green centers and are 5 - 8 mm long by 3 - 4 mm wide. Petals are connivant with the dorsal sepal and form a hood over the column and lip. Petals are spatulate, oblique and tapering, narrowly cuneate below the middle, dilated at the middle, then tapering to the subobtuse apex. Petals are 6 - 10 mm long by 3 - 4 mm wide mid-petal, erose-ciliate above the middle (Correll 1950), white with a green mid-vein, or green-streaked on the line of contact with the upper sepal (Morris and Eames 1929). The lip is white and deeply concave or bulbous-saccate. The lip is prolonged into a long beak and has inrolled and boatlike margins. The saccate portion is up to 4.5 mm wide, and has three or four unequal rows of tubercules on its inner surface (Correll 1950). The beak is 2 - 3 mm long, sulcate, with a somewhat recurved, lingulate apex. The total length of the lip is 5 - 8 mm or longer, averaging 6 mm. The column is short with a pointed rostellum and is 4 - 5.5 mm long by 2.5 mm wide. The slender beak of the column is as long or longer (2.3 - 3.6 mm in length) than the body of the stigma. The stigma is prolonged in a narrow beak of two converging mandibles twice as long as stigmatic disc (Morris and Eames 1929). The anther is ovate to long-acuminate (Fernald 1899). The capsule is obovoid-ellipsoid and is about 10 mm long by 5 mm wide. In Maine, only about 5% or so of large populations of *Goodyera oblongifolia* flower, and flowering is not generally seen in the small populations (Cutko, personal communication).

Rosettes are sturdy, tough, and are well-adapted to long, cold winters. Reticulation seems to occur more frequently in eastern plants of *Goodyera oblongifolia*, suggesting hybridization with other *Goodyera* species (Luer 1975). However, reticulation occasionally also occurs in plants of western areas, which are separated from other species by thousands of miles, prairies, and mountains (Luer 1975).

The following brief key for the four *Goodyera* species in North America and New England is from Luer (1975). Other authors provide more detailed keys of *Goodyera* species. Chapman (1977) cautions that characteristics of these species are to some degree variable, and that the best characters to identify *Goodyera oblongifolia* are the distinctive white stripe along the midvein of the leaf, the large pear-shaped flowers (versus the more spherical flowers of the other three species), and the blunt, tongue-shaped tip of the flower lip.

1a. Flower spike cylindrical, densely flowered.
    2a. Lip broadly globose with a short apex; rostellum blunt.....*G. pubescens*
    2b. Lip narrowly saccate with an elongated apex; rostellum elongated.....*G. tesselata*
1b. Flower spike one-sided or poorly spiraled, densely or loosely flowered.
    3a. Plant large, usually more than 20 cm. Tall; floral parts more than 5 mm long.
        4a. Leaves delicately reticulated, without a broad central stripe.....*G. tesselata*

4b. Leaves dark green or reticulated, with a broad whitish central stripe.....*G. oblongifolia*

3b. Plant small, usually less than 15 cm tall; floral parts less than 5 mm long.....*G. repens* var. *ophioides*

The following vegetative key is from Chapman (1977). His book also offers a key to *Goodyera* species based on floral characteristics. Kallunki (1976) also indicates separation of *Goodyera* species based on leaf reticulation pattern, but notes that it may be confusing in extreme forms.

1a. Leaves typically lacking a whitish stripe down the center.

2a. Reticulations wide, occasionally faint; leaves 2-8 cm long, usually pale green or pale bluish green.....*G. tesselata*

2b. Reticulations wide, occasionally faint or absent; leaves 1-3 (4) cm long, usually dark green or sometimes lighter.....*G. repens* var. *ophioides*

1b. Leaves with a whitish stripe down the center.

3a. Reticulations fine, completely interconnected; leaf 2.5-5 (9) cm long, bluish-green.....*G. pubescens*

3b. Reticulations sometimes absent, cross-bars often not interconnected; leaves 3-7 (11) cm long, dark green to pale bluish-green.....*G. oblongifolia*

Kallunki (1976) notes that there is considerable overlap in distinguishing characteristics in *Goodyera* species in northern Michigan, and, based on herbarium specimens, across North America. The means of scape height, leaf length, leaf width, galea length, sepal length, lip length, lip depth, rostellar beak length, and rostellar beak length:lip depth ratio are highest in *Goodyera oblongifolia*, and with the exception of lip depth, lowest in *G. repens* var. *ophioides* (Kallunki 1976). However, the range of all characteristics overlaps except rostellar beak length. *Goodyera tesselata* is intermediate between *G. oblongifolia* and *G. repens* var. *ophioides* in all characters except for number of flowers and lip depth (Kallunki 1976). The differences in the means of these characters between the three species are highly significant, but the most powerful discriminating characters are beak length, lip depth, galea length, and sepal length. In northern Michigan, the rostellar beak length/lip depth ratio alone is enough to identify an individual (Kallunki 1976).

Goodyera plants can be separated from *Spiranthes* based on the leaves. Leaves of *Goodyera* are elliptic, and pale to dark green with white marbling. Leaves of *Spiranthes* are oblong to broadly ovate, and entirely green (Brown 1997). Both genera will have more than two leaves present at flowering time in a basal rosette.

TAXONOMIC RELATIONSHIPS, HISTORY, AND SYNONYMY

Goodyera oblongifolia is a member of the family Orchidaceae, subfamily Orchidoideae, tribe Chranichideae, and subtribe Goodyerinae (Luer 1975). Van der Cingel (2001) puts it in the subfamily Spiranthoideae, but other classifications are the same as Luer's. The type locality for this species is the mountains of Oregon (Correll

1950, Luer 1975). Common names include Menzies' rattlesnake plantain, green-leaved rattlesnake orchid (Correll 1950), giant rattlesnake-plantain (NatureServe 2002), and western rattlesnake-plantain (Gleason and Cronquist 1991).

Goodyera nomenclature is from Haines and Vining (1998), with the exception of *Goodyera repens* var. *ophioides*. Haines and Vining treat this as *G. repens*, but most orchid specialists indicate the variety. Some of the orchid literature treats *G. tesselata* as *G.* x *tesselata.* This conservation plan refers to it as *G. tesselata* for simplicity.

Synonyms of Goodyera oblongifolia (Luer 1975 has the most complete list with original publication sources):

- *Epipactis decipiens* (Hooker) Ames, *Orchidaceae* 2: 261. 1908. Cameron (1976) lists *Grays Manual*, 1908 as a reference for this synonym.

- *Goodyera decipiens* (Hooker) Hubbard, in *Olmsted, Coville and Kelsey Standardized Plant Names* 328. 1923. MOBOT (2002) lists this synonym as *G. decipiens* (Hooker) Piper Hubbard. Cameron (1976) lists Fuller 1933 as reference for this synonym.

- *Goodyera Menziesii* Lindley, *Gen. Sp. Orchid*. 492. 1840.

- *Goodyera oblongifolia* Rafinesque var. *reticulata* Boivin, *Can. Field-Nat*. 65: 20. 1951 (Luer 1975 lists as a synonym, MOBOT 2002 considers an infraspecific taxon, see below).

- *Peramium decipiens* (Hooker) Piper, Contributions from the United States National Herbarium 11: 208, 1906. The basionym for this citation is *Spiranthes decipiens* Hooker, published in *Flora Boreali-Americana* 2: 203, 1839 (MOBOT 2002). Cameron (1976) lists Britton and Brown 1913 as reference for *Peramium decipiens*.

- *Peramium Menziesii* (Lindl.) Morong, *Mem. Torrey Club* 5: 124. 1894. Fernald (1899) lists as *Peramium Menziesii* Morong, published as above, and in Britt. and Brown, *Ill. Fl. i*. 475, in part.

- *Spiranthes decipiens* Hooker, *Fl. Bor.-Am*. 2: 203. 1839.

- *Orchiodes decipiens* (Hooker) Kuntze, *Rev. Gen*. 2: 675. 1891.

- *Orchiodes menziesii* (Lindley) Kuntze, *Rev. Gen*. 2: 675. 1891.

There are two homonyms or infraspecific names for *Goodyera oblongifolia* Raf. They are *G. oblongifolia* f. *reticulata* (Raf.) P.M. Br., *North American Native Orchid Journal* 1(1): 14, 1995, and *G. oblongifolia* var. *reticulata* B. Boivin, *The Canadian Field-Naturalist* 65: 20, 1951 (MOBOT 2002).

The genus name *Goodyera* was proposed by Robert Brown in 1813, in honor of John Goodyer (1592-1664), an early English botanist (Baldwin 1884, Luer 1975, Brackley 1985, originally published in *Aiton, Hort. Kew. Ed*. 2. 5: 197, 1813, Nom. Cons.). The specific epithet "*decipiens*" was by Hooker in 1839, in reference to the deceptive characteristics of this species, which could be easily confused with those of *Spiranthes* (Morris and Eames 1929, Luer 1975, Cameron 1976, Chapman 1997). The specific epithet "*Menziesii*" was by Lindley in 1840, in honor of the explorer and collector Menzies (Baldwin 1884, Luer 1975). In 1946, Fernald called attention to the correct earliest specific epithet, "*oblongifolia*" by Rafinesque in 1833 (Luer 1975).

The diploid chromosome number for *Goodyera oblongifolia* has been recorded as 22 (Angelo and Boufford 2000) and 30 (Kallunki 1976, Angelo and Boufford 2000, Hinds 2000). Löve and Simon (1968 in Kallunki 1976) recorded a diploid number of 28 in Colorado material.

Goodyera tesselata derives from a post-Pleistocene hybridization of *G. oblongifolia* and *G. repens* var. *ophioides* (Kallunki 1976, Van der Cingel 2001). This is supported by the fact that *G. tesselata* is distributed almost entirely within glaciated eastern North America, in the general area where both *G. oblongifolia* and *G. repens* occur (Kallunki 1976). There are only three collections of *G. tesselata* south of the glacial maximum, two from Camden County, New Jersey, and one from Montgomery County, Maryland (Kallunki 1976). *Goodyera tesselata* is an allotetraploid with a diploid number of 60 (Kallunki 1976, Angelo and Boufford 2000) and is intermediate in characteristics between *G. oblongifolia* and *G. repens* var. *ophioides* (Kallunki 1976). Prior to Fernald's 1899 paper where he noted that Loddiges originally described the species *G. tesselata* in 1824, it was usually misidentified, typically as *G. oblongifolia* (Fernald 1899, Kallunki 1976).

In the Great Lakes region, *Goodyera* species hybridize frequently, making identification difficult (Case 1964, Luer 1975). Luer (1975) states that wherever two or more species in this genus grow together, hybridization may be expected to occur. Kallunki (1981) has shown that mixed-species populations of *Goodyera oblongifolia*, *G. repens* var. *ophioides*, and *G. tesselata* are not completely isolated reproductively, and hybridization does occur in these populations. Morphologically intermediate triploids of *Goodyera* ($2n$ = about 45) have been found in northern Michigan (Kallunki 1976), and are a result of hybridization between diploid (*G. oblongifolia* or *G. repens* var. *ophioides*) and tetraploid (*G. tesselata*) parents. These triploid hybrids are assumed fertile, but are characterized by irregular meiosis and likely do not frequently or successfully backcross with diploid parents (Kallunki 1981). Hybridization in mixed-species populations of *Goodyera* occurs at low levels, and individual species maintain their unique identities (Kallunki 1981). Differences in habitat preference and less overlap in our area make hybridization less likely for New Hampshire (Brackley 1985), and presumably for northern New England.

All four *Goodyera* species in North America occur in Aroostook County, Maine, the only county in New England where *Goodyera oblongifolia* occurs (Angelo and

Boufford 2000). Aroostook is a large county, and Angelo and Boufford divide it into three parts, northwestern, northeastern, and southeastern. *Goodyera pubescens* is not recorded for northwestern Aroostook County, though the other three species are, and *G. oblongifolia* is not recorded from southeastern Aroostook County, though the remaining three species are. The other three *Goodyera* species are not rare in Maine, or the rest of New England, with the exception of *G. repens* (S1 in Massachusetts, not found in Rhode Island) and *G. tesselata* (S2 in Rhode Island).

SPECIES BIOLOGY

Goodyera species are long-lived perennials (Light 2000). Rosettes of evergreen leaves grow from creeping rhizomes and can last for several seasons. Each rhizome may have several rosettes, and it is common to find plants growing in groups and even large colonies (Case 1964, Chapman 1977). The rhizome has a few thick, fleshy, fibrous roots, at intervals, especially near the actively growing tip (Case 1964, Luer 1975). Each rosette takes one to three years to mature (Light 2000). A flowering stem emerges from the center of a mature rosette (Luer 1975, Light 2000). The rosette dies as the capsules ripen, meaning each rosette flowers only once (Ackerman 1975, Luer 1975, Light 2000). A *Goodyera oblongifolia* plant that flowers usually dies before the next flowering season, but other rosette growths from the same rhizome become independent prior to this (Ackerman 1975). Branches of the rhizome mature in succeeding years, leading to compact colonies (Luer 1975). In a northern California study of *G. oblongifolia*, the mean number of new rhizomatous growths was higher for flowering plants (average 1.74) than non-flowering plants (average 0.46) (Ackerman 1975). Vegetative propagation is the only form of asexual reproduction that occurs in *G. oblongifolia*, though parthenogenesis has been reported in related genera (Ackerman 1975). In Maine, over 95% of the *G. oblongifolia* plants found have been vegetative and not in flower (Cutko, personal communication).

Goodyera oblongifolia can multiply and spread rapidly, and it is quite abundant in some areas of the Lake Huron region (Correll 1950). Because *G. oblongifolia* is adapted to bumblebee pollination and has wind dispersed seeds, it has a great potential for range extension (Ackerman 1975).

Pollination

Goodyera oblongifolia is self-compatible, but it is infrequently self-pollinated, suggesting that autogamy does not occur (Ackerman 1975, Van der Cingel 2001). Van der Cingel (2001) reports *G. oblongifolia* as possibly parthenocarpic. Flowers of *Goodyera* species produce nectar and typically have spiral, mostly white flowers (Van der Cingel 2001). Fruit set within the genus is typically high (Van der Cingel 2001). Kallunki (1981) found that *G. oblongifolia* and *G. tesselata* have noticeable flower odors, which are stronger during the day than at night. *Goodyera oblongifolia* produced the most nectar of three *Goodyera* species examined in northern Michigan, averaging 0.549

ìl (range 0.0 to 3.08 ìl) upon initial examination (average 0.054 ìl for *G. repens* var. *ophioides*, and 0.366 ìl for *G. tesselata*, Kallunki 1981). This quantity of nectar likely encourages repeated pollinator visits (Ackerman 1975). In addition, because the plants are typically found in colonies, flowers are aggregated, which increases odor strength and visual stimulus for pollinators (Ackerman 1975). In visible light, the perianth of *G. repens* var. *ophioides* is a brighter white than the other two species, but under ultraviolet light, *G. oblongifolia* and *G. tesselata* are highly fluorescent while *G. repens* var. *ophioides* is not at all fluorescent (Kallunki 1981).

The bumblebees *Bombus occidentalis* and *B. vosnesenskii* were observed pollinating *Goodyera oblongifolia* in California's Sierra Nevada, though rarely on overcast days (Ackerman 1975). In northern Michigan, bumblebees (*Bombus vagans* F. Sm., which also occurs in New England) were the only insects of those observed on *G. oblongifolia* that visited the flowers systematically (Kallunki 1981). The bumblebees carried pollinia attached to their tongues (Kallunki 1981). In northern Michigan, halictid bees (Halictidae) and syrphid flies (Syrphidae) were also observed on flowers of all three *Goodyera* species, but they were never seen carrying pollinia (Kallunki 1981). One ant was seen on the lip of a *G. oblongifolia* flower at one of the study sites, but ant pollination is generally unlikely based on *G. oblongifolia* flower structure.

In *Goodyera*, as in *Spiranthes*, removal of pollen from a freshly open flower is from a small space presented between the rostellum and labellum (Luer 1975). Once the pollinia are removed, the lip descends minutely, but enough to allow deeper insect penetration and deposition of pollen on the now receptive stigma (Luer 1975).

The percent pollination of *Goodyera oblongifolia* was similar to the percent of flowers visited in a northern Michigan study, but varied between the four populations studied (Kallunki 1981). The percent of flowers pollinated in these *G. oblongifolia* populations (with percent visited in parentheses) were: 3 (3); 45 (49); 63 (63), and 66 (84).

Reproduction

Goodyera oblongifolia is slightly protandrous, meaning that young flowers are in the male stage (Ackerman 1975, Kallunki 1981). The position of the column in the young male flowers is parallel to the lip (Ackerman 1975). This allows removal of the pollinium, but inhibits insertion of another pollinium because the tube is too narrow for a bee proboscis bearing pollinia (Ackerman 1975). Older flowers are in the female stage. In these flowers, the column is slightly raised, enlarging the space between the column and the lip and allowing insertion of a pollinium and pollen deposition on the stigma (Ackerman 1975, Kallunki 1981). Luer (1975) indicates that the lip descends minutely after the pollinia are removed (versus the column raising), which allows subsequent deposition of pollinia on the now-receptive stigma. In an inflorescence with many flowers, bees usually visit flowers from bottom (older female flowers) to top (younger male flowers) (Darwin 1877 in Kallunki 1981, Ackerman 1975). This means that bees

remove the pollinia from upper, male stage flowers on one plant, then fly to another plant and deposit pollen on the lower, female stage flowers (Kallunki 1981). Because of the clonal population structure, outcrossing is not a guarantee, and the genetic effect is similar to autogamy (Ackerman 1975). However, outcrossing probably occurs occasionally (Ackerman 1975).

Flowers of *Goodyera oblongifolia*, *G. tesselata*, and *G. repens* var. *ophioides* are relatively similar, and because of their shared dependence on bumblebee pollinators, this may be an advantage in attracting pollinators in areas where the populations are relatively scarce (Kallunki 1981). In northern Michigan, insects visited other species of *Goodyera* before visiting *G. oblongifolia* (Kallunki 1981). Individual bumblebees may cross-pollinate *Goodyera* flowers in mixed-species populations (Kallunki 1981). Floral differences are greatest between *G. oblongifolia* and *G. repens* var. *ophioides* and may be effective isolating mechanisms (Kallunki 1981). However, when *G. tesselata* is present (with its intermediate floral characteristics), these differences are less effective.

Flowering times for *Goodyera oblongifolia* have been reported as follows: August (Fernald 1899, Gibson 1905, Chapman 1977, Brown 1997); late June to September in various parts of its range (Correll 1950); late July to August (Case 1964); mid July to mid-September (Morris and Eames 1929, Cameron 1976); August and September (Keenan 1998); and August to October (Ackerman 1975). In New England, *G. oblongifolia* typically flowers in August (Fernald 1899, Gibson 1905, Chapman 1977, Brown 1997). In northern California, each flower lasts about two weeks, and capsules mature in six to eight weeks (Ackerman 1975). This is a relatively short maturation period, and may have evolved as a response to environmental conditions (mortality would be higher if capsules had to overwinter) versus representing a primitive condition (Ackerman 1975).

Goodyera oblongifolia flowers later than *G. repens* var. *ophioides* and *G. tesselata* (Kallunki 1976, Barclay-Estrup et al. 1991). In northern Michigan (Kallunki 1976) and most of Ontario (Whiting and Catling 1986, Barclay-Estrup et al. 1991), the flowering sequence is *G. tesselata, G. repens* var. *ophioides*, and lastly *G. oblongifolia*, but in northwestern Ontario the flowering sequence is *G. repens* var. *ophioides*, *G. tesselata, G. oblongifolia* (Barclay-Estrup et al. 1991).

Orchid seeds are produced in large numbers and are dust-like (Case 1964), light and buoyant (Arditti 1967), highly mobile (Sheviak 1990), and can travel long distances by air (Case 1964, Summerhays 1951 in Arditti 1967) and water currents (Case 1964, Ames 1948 in Arditti 1967). Ants or birds can transport some orchid seeds (Anonymous 1915 b and 1923b in Arditti 1967). Rasmussen and Whigham (1998) state that orchid seeds are "so small practically nothing is known about their fate in the soil." Their small size minimizes the requirement for maternal investment (McKendrick et al. 2000a). It is possible that a seed bank of *Goodyera oblongifolia* could persist (Light 2000). *Goodyera oblongifolia* seeds are brown and approximately 0.3 to 0.9 mm by 0.11 to 0.16 mm in size (Arditti 1992). The embryo is also brown and is 0.2 by 0.08 mm in size (Arditti

1992). The pH preference for *in vitro* germination of *G. oblongifolia* is 5.0 to 5.2 (Gleason and Cronquist 1991, Arditti 1992).

In northern California, mean seed viability of *Goodyera oblongifolia* was 52.7% in hand-pollinated flowers (6132 seeds from 14 capsules) and 83.8% in naturally pollinated flowers (4874 seeds from 10 capsules) (Ackerman 1975). Seed viability of individual capsules ranged from 2.1 to 98.8% in hand-pollinated flowers and 62.7 to 96.6% in naturally pollinated flowers (Ackerman 1975). In northern Michigan, the percentage of viable seed produced in experimental self-pollination and cross-pollination with other *Goodyera* species was highly variable, ranging from 0 to 96% (Kallunki 1981). Average viability of *G. oblongifolia* was highest in experimental intraspecific cross-pollination (median=60%). A low frequency of polyembryonic seeds, with two fused embryos, was found in *G. oblongifolia* in northern California (Ackerman 1975). Polyembryony is not rare in orchids, and it also occurs in *G. tesselata* and *G. pubescens* (Leavitt 1901). Because of the low frequency of polyembryony, it was not considered significant to the reproductive biology of *G. oblongifolia* in northern California (Ackerman 1975).

Dormancy

Dormancy is common in terrestrial orchids (Hutchings 1987, Vitt 1991) and may or may not be a feature of *Goodyera oblongifolia*. This aspect of the orchid life cycle is not well understood and may be a response to herbivory (Vitt 1991), though herbivory has not been noted for any Maine *G. oblongifolia* occurrences (Cutko, personal communication). Dormancy is difficult to distinguish from mortality, especially in short-term studies (Menges 1991). The maximum dormancy period of most orchids, excluding *Isotria medeoloides*, which has a prolonged dormancy (Brumback and Fyler 1996), is usually less than three years, with longer periods of dormancy infrequent (Hutchings 1987, Mehrhoff 1989, Tamm 1991). Absence after a year does not indicate mortality, nor does presence of a new plant within three years indicate recruitment (Hutchings 1987). The tendency for orchids to remain dormant for years contributes to the apparent rarity of some species (Gawler 1983). *Goodyera* species do not have enlarged below-ground structures (Light 2000), and dormancy is not specifically indicated in the literature for *G. oblongifolia*.

Germination, Regeneration, and Mycorrhizal Associations

Fungi have long been noticed with orchid roots, but it was not until 1899 that it was realized that fungi play a role in germination (Arditti 1967). Mycorrhizal fungi initiate germination of orchid seed (Arditti et al. 1990, Clements 1988) and supply early developmental stages with an exogenous source of carbon (McKendrick et al. 2000a), though the seeds themselves do not carry endophytic fungi (Warcup 1981b in Clements 1988). Seeds that land in the general vicinity of the “correct” mycorrhizal fungus have a good chance of eventually being infected and germinating (Clements 1988). It has been

suggested that the distribution of adult orchids is based on the distribution of the fungi that initiate symbiotic germination, and that there are species-specific relationships between orchids and fungi (Clements 1988, McKendrick et al. 2000a). This may at least be true for the establishment phase, provided other factors are suitable, especially for long-lived orchids (Marilyn Light, University of Ottawa, personal communication). The fungus may provide an exudate with vitamins, hormones, specific sugars, amino acids, and/or other small molecules (Knudson 1925 in Clements 1988). This has not been supported by experimental evidence, which indicates that the physical presence of the live fungus is necessary for germination (Clements 1988, Arditti et al. 1990), suggesting the possibility that temperate orchids may require cellular contact, cell-surface signaling, an elicitor-type molecule, or a plasmid (Arditti et al. 1990).

Orchid species differ in germination strategy, and site and orchid/fungus specificity play a role in seedling establishment (Rasmussen and Whigham 1993). Orchid/fungus system specificity, known mostly for Australian species, can be extreme in temperate terrestrial orchids and may be a reason for non-germination (Arditti et al. 1990 and references therein). Not all fungi isolated from orchid roots can support germination (Smreciu and Currah 1989, Arditti et al. 1990 and references therein, Rasmussen and Whigham 1993 and references therein). For terrestrial Australian orchids, the less vigorous fungal isolate may best support germination, and the same may be true for other temperate terrestrial orchids (Clements 1981 and 1982 in Arditti et al. 1990), including *Goodyera oblongifolia*.

In the early 1920's, Knudson was the first to germinate orchid seed asymbiotically in the lab (Arditti 1967). *Goodyera* species are generally easy to germinate *in vitro* without the presence of a fungus (Rasmussen 1995). Arditti et al. (1982b) germinated *Goodyera oblongifolia* asymbiotically, using Curtis medium at half strength (see Appendix 3, Arditti et al. 1982a). Harvais (1974 in Rasmussen 1995) reports that *G. oblongifolia* will germinate on sucrose or glucose media but not on water agar. Seeds of *G. oblongifolia* germinate well in both dark and light, at a temperature of 25°C ± 2°C (Arditti et al. 1982b). Auxins, cytokinins, or Ethrel enhanced *G. oblongifolia* germination in the dark (Arditti et al. 1981). The addition of vitamins had an inconsistent effect on germination of *G. oblongifolia* (Arditti et al. 1981). Culture periods are long, and when the agar separates from the walls of the culture vessel, it needs to be irrigated with sterile distilled water under sterile conditions. Arditti et al. (1982b) found the germination percentage of *G. oblongifolia* to range from 10 to 90% in one sample, and >1% in the other. Different *G. oblongifolia* seed lots had different germination percentages (Arditti et al. 1981). Arditti et al. (1982b) caution that seeds collected from natural orchid populations may not always be viable, the viability of seeds may vary between capsules, and that germination of seeds of North American terrestrial temperate orchids is typically slow, seldom uniform, and often sparse and very unpredictable, in contrast with asymbiotic germination efforts with tropical orchids.

The time in months from the start of two cultures of *Goodyera oblongifolia* to the development of protocorms was 3.25 and 6.5 months, respectively; development of leaves 6 to 11 and 12.5 months; and development of roots 24.5 and 14.25 months (Arditti

et al. 1982b). This relatively late production of *G. oblongifolia* roots *in vitro* is also seen in the field (Rasmussen 1995). *Goodyera oblongifolia* seedlings may be potted in a greenhouse when they reach a height of 5 to 7.5 cm and roots are well developed (Arditti et al. 1982b).

In vitro studies of many orchid species, but not specifically *Goodyera oblongifolia*, have shown that vigorous mycelia may destroy orchid seeds (Arditti et al. 1990). Because mycorrhizal fungi are potential pathogens of other plants, it is necessary for the orchid to control the infecting hyphae (Clements 1988). Without such control, the invading fungus could destroy the orchid. The mechanism for such control has yet to be determined, but it has been suggested that it may be similar to the control mechanisms between legumes and *Rhizobium* bacteria that use mRNA (Clements 1988). Care should be taken in applying information from *in vitro* germination studies to an *in vivo* situation.

A California study sampled mycorrhizae from *Goodyera oblongifolia*, *Corallorhiza maculata, C. mertensiana*, and *Cephalanthera austinae* over a wide geographic range (Taylor and Bruns 1994). This study found that several fungal entities were associated with each orchid studied, and that a particular orchid species will associate with different fungi when grown in different habitats. Neighboring orchids of different species never shared the same mycorrhizal symbiont and there was no overlap in fungal symbionts of the four orchid species studied over the geographical range sampled. Their results show strong evidence for fungal specificity in orchid mycorrhizae because (1) neighboring orchids of different species never shared the same fungus, (2) four co-occurring orchid species had no common symbionts over a wide geographic range, and (3) fungi associated with an orchid were related to each other, but not to fungi from other orchids. The high degree of specificity and the absence of fungal overlap between orchid species indicate that a selection process is at work (Taylor and Bruns 1994). Though the authors of this study distinguished fungal symbionts, they did not identify them. Symbiont identification is critical to specificity studies, and this has been a difficulty in orchid studies (Taylor and Bruns 1994; June Wang, State University of New York, personal communication).

In a field germination experiment, Rasmussen and Whigham (1993) noted that *Goodyera pubescens* had a germination rate of 31.1% (± 4.7% [SE]) to 50.0% (± 8.7%). Mycorrhizal infection varied among seedlings; those without fungi did not grow much longer than the size of an imbibed embryo, and those with obvious infection were only found in sites where *G. pubescens* occurred naturally. Mortality was first observed at 36 weeks and averaged 42.9% ± 7.9% at 12 months (Rasmussen and Whigham 1993). Their methods (utilizing retrievable seed packets constructed of plastic photographic slide mounts and plankton netting) could be used to study field germination and seedling development of *G. oblongifolia*. Spring is the natural germination season for *G. oblongifolia* (Rasmussen 1995).

Mycorrhizal species widely reported from orchids include: *Rhizoctonia repens* Bernard “a ubiquitous orchid endophyte” (Currah et al. 1987, McKendrick et al. 2000a); *Leptodontidium orchidicola* Sigler and Currah “found in a wide range of terrestrial

orchids" (Currah et al. 1990); *Ceratorhiza* spp.; and *Epulorhiza* spp. (Zelmer 1994). *Goodyera oblongifolia* produced seedling mycorrhizae *in vitro* with the symbiont *Moniliopsis solani* (a rice pathogen) (Harvais 1974 in Rasmussen 1995). *Moniliopsis* is an anamorph (asexually reproductive) group within the genus *Rhizoctonia*, with the presumed teleomorphs (sexually reproductive) *Thanatephorus* and *Waitea* (Rasmussen 1995). Images of root cells of *G. oblongifolia* containing hyphal coils, likely of a mycorrhizal *Rhizoctonia*, can be found on-line, at www.mycorrhiza.ag.ufk.edu/kendrik22.htm and at www.mycorrhiza.ag.ufk.edu/kendrik23.htm. Van der Kinderen (1995) believes that knowledge of mycorrhizal associates is especially useful for cultivating endangered species, and that collected plant material could be used to start additional controlled cultures of protocorms or mycorrhizal fungi. Detailed knowledge of reproductive and competitive strategies used by terrestrial orchids is also vital to efficient conservation and management programs (Currah et al. 1990).

The expansion or decline of orchid populations may be greatly influenced by processes that determine germination and survival of seedlings, and to date, great spatial and temporal variability in seedling establishment appears to be the rule in terrestrial orchids (Rasmussen and Whigham 1998). Fungal switching during the lifetime of an orchid has not been documented, but it has been suggested that fungal symbionts that play an important role in orchid seedling development are replaced by others in adults (Zelmer et al. 1996 in Rasmussen and Whigham 1998). Light (personal communication) notes that there are a variety of fungal associates with orchid roots, many of which will not support germination, but may be useful for water and phosphate uptake.

For most orchids, the mycoheterotrophic juvenile phase is followed by an autotrophic adult phase, but associations with early fungal symbionts are retained (McKendrick et al. 2000a, 2000b). There is evidence that *Corallorhiza* species, which are mycoheterotrophic and achlorophyllous as adults, obtain carbon from surrounding photosynthetic plants via shared ectomycorrhizal fungi (Bruns et al. 2000). The proximal host is a fungus mutualistically associated with trees, the ultimate carbon source (Bruns et al. 2000). Campbell (1970 in Homoya 1993) showed a mycorrhizal connection between the rhizome of *Corallorhiza trifida* and the roots of *Thuja* and *Picea*. Nutrients were transferred from the tree to the orchid via the mycorrhizae. Hyphal transfer of carbon between plants interconnected by a common mycorrhizal mycelium may be especially important in supplementing carbon requirements of shaded understory plants (McKendrick et al. 2000b). This occurs between some autotrophic species; one study showed that shaded *Pseutotsuga menziesii* received about 6% of its carbon from unshaded *Betula papyrifera* (Simard et al. 1997 in McKendrick et al. 2000b). In Maine, *Goodyera oblongifolia* occurs in the shaded understory below trees such as *Thuja occidentalis*, *Picea rubens*, *Abies balsamea*, *Acer saccharum*, and *Betula alleghaniensis* (see site descriptions under Status of all New England occurrences). It is unknown if *G. oblongifolia* shares mycorrhizal connections with these tree species, but this is clearly an area for investigation.

Wild flower gardeners in the northwestern states have grown *Goodyera oblongifolia* with some success (Correll 1950), and it is offered for sale by several

northwestern nurseries (see Appendix 4). Vegetative propagation of *G. oblongifolia* is possible (Light 2000), and researchers have had some success germinating *G. oblongifolia* from seed (Arditti et al. 1982b, Rasmussen and Whigham 1993). Propagation notes, both from seed and vegetative means, are given at Gardenbed.com (2001). Seed should be surface-sown on compost and kept moist, and soil from established plants should be used to introduce the fungus, or the seeds should be sown at the base of an established plant (Huxley 1992 in Gardenbed.com 2001). Division is a method of vegetative propagation for *G. oblongifolia*, preferably done in spring (Cribb and Bailes 1989 in Gardenbed.com 2001). Each division should have two or three rhizome joints (Cribb and Bailes 1989 in Gardenbed.com 2001). To stimulate production of growth buds at the division point, cut halfway through the rhizome the season before division (Cribb and Bailes 1989 in Gardenbed.com 2001). It should be determined if nurseries selling *G. oblongifolia* are vegetatively propagating the species, or if they are wild-harvesting it. Light (2000) knows of no commercial scale seed propagation operation.

Goodyera oblongifolia is listed as an important potential medicine of the Stoltmann Wilderness in British Columbia, Canada (Diamond 2000). The moist inner leaves can be used as a poultice for cuts and sores, in a similar manner as *Aloe vera* (Diamond 2000). The First Nations peoples of British Columbia used *G. oblongifolia* as a medicine for childbirth (Pojar and MacKinnon 1994 in Diamond 2000). *Goodyera oblongifolia* is also used to produce a flower essence used to treat issues of aggressive and male-oriented tendencies in both men and women (Pegasus Orchid Essences 2002).

HABITAT/ECOLOGY

The habitat of *Goodyera oblongifolia* has been recorded as: coniferous and mixed woods (Angelo and Boufford 2000); dry woods (Fernald 1899); dry to damp areas in conifers, hardwoods, or mixed forests (Correll 1950, Luer 1975, Chapman 1977, Gleason and Cronquist 1991, Keenan 1998); dry coniferous woods (Morris and Eames 1929); second growth mixed hardwoods (Brown 1997); and damp old-growth arbor vitae and other coniferous or mixed woods of New Brunswick (Hinds 2000). The habitat of the recently discovered populations in Maine can be described as the drier areas of northern white-cedar seepage forests, where the cedar transitions to spruce-fir forest, and also in hardwood dominated forests at the base of northern white-cedar trees (Cutko, personal communication).

Goodyera oblongifolia does not seem to have a soil preference; it can be found in its range on both granite and limestone (Morris and Eames 1929). Correll (1950) indicates *G. oblongifolia* requires soil that is cool throughout the summer, and that it does best in subacid humus from the decay of conifer tree litter. In Maine, *G. oblongifolia* has been found growing in conifer litter, primarily litter from *Thuja occidentalis*, *Picea rubens*, and *P. mariana*, even in areas where hardwoods are also present (Cutko, personal communication). Regular precipitation is likely important to the persistence of species of *Goodyera* in any environment (Light 2000). In our region, *G. oblongifolia* is classified as

a Facultative Upland (FACU-) species, meaning that it usually occurs in non-wetlands (estimated probability 67 to 99%), though may occur in wetlands (estimated probability 1 to 33%, the minus sign indicating the upper percentages) (USDA, NRCS 2001). Nationally, it is classified as an Upland/Facultative Upland species, indicating that it is usually found in non-wetlands (probability 99% for upland, USDA, NRCS 2001).

In northern Maine, *Goodyera oblongifolia* is typically found in mature forests (Cutko, personal communication). Associated tree species include *Abies balsamea* (balsam fir), *Acer pensylvanicum* (striped maple), *Acer rubrum* (red maple), *Acer saccharum* (sugar maple), *Betula alleghaniensis* (yellow birch), *Fagus grandifolia* (American beech), *Picea rubens* (red spruce), *Pinus strobus* (eastern white pine), *Thuja occidentalis* (northern white-cedar), and *Tsuga canadensis* (eastern hemlock). Associated herbaceous species include *Actaea pachypoda* (white baneberry), *Aralia nudicaulis* (wild sarsaparilla), *Arisaema triphyllum* (Jack in the pulpit), *Botrychium virginianum* (rattlesnake fern), *Circaea alpina* (alpine enchanter's-nightshade), *Clintonia borealis* (bluebead-lily), *Cornus canadensis* (bunchberry), *Dryopteris carthusiana* (spinulose wood fern), *Epipactis helleborine* (helleborine), *Galium asprellum* (rough bedstraw), *Goodyera repens* var. *ophioides* (dwarf rattlesnake-plantain), *Goodyera tesselata* (checkered rattlesnake-plantain), *Gymnocarpium dryopteris* (oak fern), *Huperzia lucidula* (shining clubmoss), *Linnaea borealis* ssp. *longiflora* (twinflower), *Maianthemum racemosum* (false Solomon's seal), *Mitchella repens* (partridgeberry), *Mitella nuda* (naked miterwort), *Moneses uniflora* (one-flowered shinleaf), *Orthilia secunda* (one-sided pyrola), *Osmunda claytoniana* (interrupted fern), *Oxalis montana* (common wood-sorrel), *Petasites frigidus* var. *palmatus* (northern sweet-coltsfoot), *Phegopteris connectilis* (long beech fern), *Prenanthes alba* (rattlesnake root), *Pyrola elliptica* (shinleaf), *Trientalis borealis* (starflower), *Trillium undulatum* (painted trillium), and *Viola renifolia* (kidney-leaved violet). Associated bryophytes include *Hylocomium splendens* (stair-step moss) and *Rhytidiadelphus triquetris* (shaggy moss), though *G. oblongifolia* does not grow directly upon them (Cutko, personal communication). Scientific and common names for vascular species in this plan follow Haines and Vining (1998). Scientific names for bryophytes follow Allen (1999); bryophyte common names follow Glime (1993).

In the west, *Goodyera oblongifolia* typically grows in moss or rich humus on forest slopes in mountain regions. It commonly grows at high elevations, and can be found up to 915 m (3000 feet) in Montana, 1220 m (4500 feet) in Alberta, California, and Oregon, 1829 m (6000 feet) in British Columbia, 2287 m (7500 feet) in Washington and Wyoming, and 3049 m (10,000 feet) in Arizona, Colorado, New Mexico, and Utah (Correll 1950).

THREATS TO TAXON

The primary threat facing *Goodyera oblongifolia* is timber harvest and its associated threats of direct physical damage from machinery, and alteration of appropriate light and moisture regimes, soil conditions, and mycorrhizal associations.

Stochastic events are a threat to small populations. Potential threats to *Goodyera oblongifolia* include invasive exotic plants, collection, low genetic diversity, trampling, pollution, and climate change. Competition from other herbaceous plants does not seem to be a threat (Cutko, personal communication). Light (2000) considers *G. oblongifolia* and *G. repens* to be the least threatened of North American *Goodyera* species, with *G. pubescens* the most threatened, because the habitat where *G. pubescens* and *G. tesselata* grows is disappearing in northeast North America due to housing development. It is difficult to assess the severity of these threats due to a lack of historical data and biological information for *G. oblongifolia*.

- **Timber harvest** is or has been a threat at 12 of Maine's 13 extant occurrences. Logging is known to cause *Goodyera oblongifolia* to disappear from an area (MNAP rare plant fact sheet). The *G. oblongifolia* populations at T12 R08 WELS, Maine (ME .003 and associated sites) declined precipitously following heavy timber harvest in 1982. No plants were found here in 2002, suggesting that a decimated population such as this does not have the ability to recover (Cutko, personal communication). In addition, timber harvest would likely have a detrimental effect on mycorrhizal species, including those associated with *G. oblongifolia*. In western North America, tree cutting leads to foliage bleaching of *G. oblongifolia*, but new shrub growth remedies this (Light 2000).

  Though recent logging has negatively affected *Goodyera oblongifolia* in Maine, the effect of past logging is not clear. Five occurrences note that logging had taken place 35 to 50+ years ago. Of these, one occurrence (ME .014 [Amity]) is historic and perhaps should be classified as extirpated, two have low population numbers (ME .019 [T15 R08 WELS] with three plants and ME .020 [T16 R08 WELS] with one plant), and one has a relatively sizeable population with about 90 plants (ME .016 [Allagash]). It is unknown if the low population numbers of these sites represent detrimental effects of past logging, or if these sites were always marginal habitat for *G. oblongifolia*.

- **Stochastic events,** such blowdown or a moose footstep, could eliminate small populations, and may be the cause for the disappearance of the single plant occurrence at ME .015 (Perham).

- **Invasive exotic species** may pose a threat to *Goodyera oblongifolia*. *Tussilago farfara* (coltsfoot) is present along the logging road and in cedar swamps at ME .020 (T16 R08 WELS). It is likely that this species could be transported throughout the logging road network in the area.

- **Collection** of any orchid species for wild-supplied horticultural collections is a potential threat (Mitchell and Sheviak 1981). Collection of *Goodyera* plants by commercial exploiters and individual collectors for transplantation into terraria, where they are prized for their beautiful leaves, is a threat to the genus as a whole (Chapman 1977). Since patches of *Goodyera* are infrequent, harvest of a whole patch could easily threaten a population, though harvest like this for terraria is not

as common today as it was in the 1950's and 1960's (Light 2000). Even so, in 1992, a collector was charged with illegally digging and removing 85 *Goodyera oblongifolia* plants from Pictured Rocks National Lakeshore in Michigan, a violation of the US Lacey Act (BEN 1993). The defendant pleaded guilty and said he had planned to sell the plants in Europe. He was fined $3525 ($41.47 per plant). Collection of *G. oblongifolia* in Maine is unlikely due to the remote locations of most of these populations (Cutko, personal communication).

- **Low genetic diversity** is likely in clonal populations such as *Goodyera oblongifolia*. Although flowers are not autogamous, the net effect of pollination is similar to autogamy due to the clonal population structure (Ackerman 1975). Inbreeding depression may not be a threat if the population primarily reproduces vegetatively (Ramstetter 2001), which seems to be the case for *G. oblongifolia* in Maine. Though low genetic diversity may compromise the evolutionary potential of a species in the face of environmental change (Ramstetter 2001), the ability of *G. oblongifolia* to hybridize with other *Goodyera* species is likely to be beneficial in regards to its evolutionary potential.

  Genetic threats to population viability can be important in small-sized populations of a few hundred individuals or less (Holsinger and Gottlieb 1991), so it would be valuable to determine factors influencing *Goodyera oblongifolia* success for most of the sites in Maine. Large populations are resistant to effects of demographic stochasticity and ecological and genetic threats (Menges 1991). Only ME .001 (St. John Plantation) is likely to be large enough to be resilient to these threats (with a population of 941 counted in 1991).

- **Trampling** of young, inconspicuous plants by photographers, researchers, timber harvesters, and recreationists is a potential threat for all orchids (Light 1998).

- **Pollution** due to acid rain may be a potential threat to *Goodyera oblongifolia* in Maine.

- **Climate change** may be a potential threat to *Goodyera oblongifolia* in Maine.

DISTRIBUTION AND STATUS

General Status

Goodyera oblongifolia occurs from the Canadian Maritime provinces west to British Columbia and southern Alaska (Figure 1). It is found along the western coast and in mountainous areas in western states and south into Mexico. *Goodyera oblongifolia* can be plentiful where it grows in North America (Light 2000). In the west, masses of this species can carpet the ground, but it is not so abundant in the northeast or Great Lakes region (Light 2000). *Goodyera oblongifolia* is rare in the northeast, where it is only found in Maine (Fernald 1899, Gibson 1905, Morris and Eames 1929, Corrrell 1950,

Case 1964, Cameron 1976, Chapman 1977, Gleason and Cronquist 1991, Brown 1997, Keenan 1998). Maine is the only New England state where *G. oblongifolia* occurrences, current or historical, have been verified (Figure 2 and 3).

The distribution of *Goodyera oblongifolia* is widespread north and south of the glacial maximum in western North America (Kallunki 1976). Its distribution in the glaciated northeast is restricted and considered disjunct (Kallunki 1976). Case (1964) believes that the disjunct populations in the Great Lakes area are remnants of a larger distribution that was broken by glaciation. Ackerman (1975) suggests that these populations established based on the long-distance dispersal abilities of the wind dispersed seed, along with the species' reliance on bumblebee pollinators, a common group.

It is believed that *Goodyera oblongifolia* survived the last glaciation south of the ice in western North America, and possibly in refugia in the Great Lakes region (Correll 1950, Kallunki 1976). Kallunki (1976) suggests the Pacific Northwest as the location of its Pleistocene refugium, because it is very common in that area. After deglaciation, *G. oblongifolia* became established north, to southeastern Alaska (Correll 1950, Kallunki 1976), and east, into the Great Lakes and St. Lawrence River areas, where the cool, moist climate is similar to the Pacific Northwest (Kallunki 1976). Westerly winds provided abundant and continuous dispersal of the dust-like seeds, allowing colonization of suitable forest habitat in the east when they became available following deglaciation (Kallunki 1976).

Goodyera oblongifolia is uncommon in Ontario and is more or less unknown from the southern counties (Whiting and Catling 1986). Note, however, that NatureServe (2002) ranks *G. oblongifolia* as S4 in Ontario. The best places to see it in Ontario are the Bruce Peninsula and Manitoulin Island, where it is locally abundant near some shorelines, in spruce-cedar woods of limestone areas (Whiting and Catling 1986). It is rare in other woodland habitats of southern Ontario, and in Timiskaming, Algoma, and Thunder Bay districts of northern Ontario (Whiting and Catling 1986). *Goodyera oblongifolia* is ranked SR in Quebec, S2 in New Brunswick, S2S3 in Nova Scotia, and SH in Newfoundland Island (NatureServe 2002). See Table 1 for a summary of the status of the occurrence of *G. oblongifolia* in North American states and provinces.

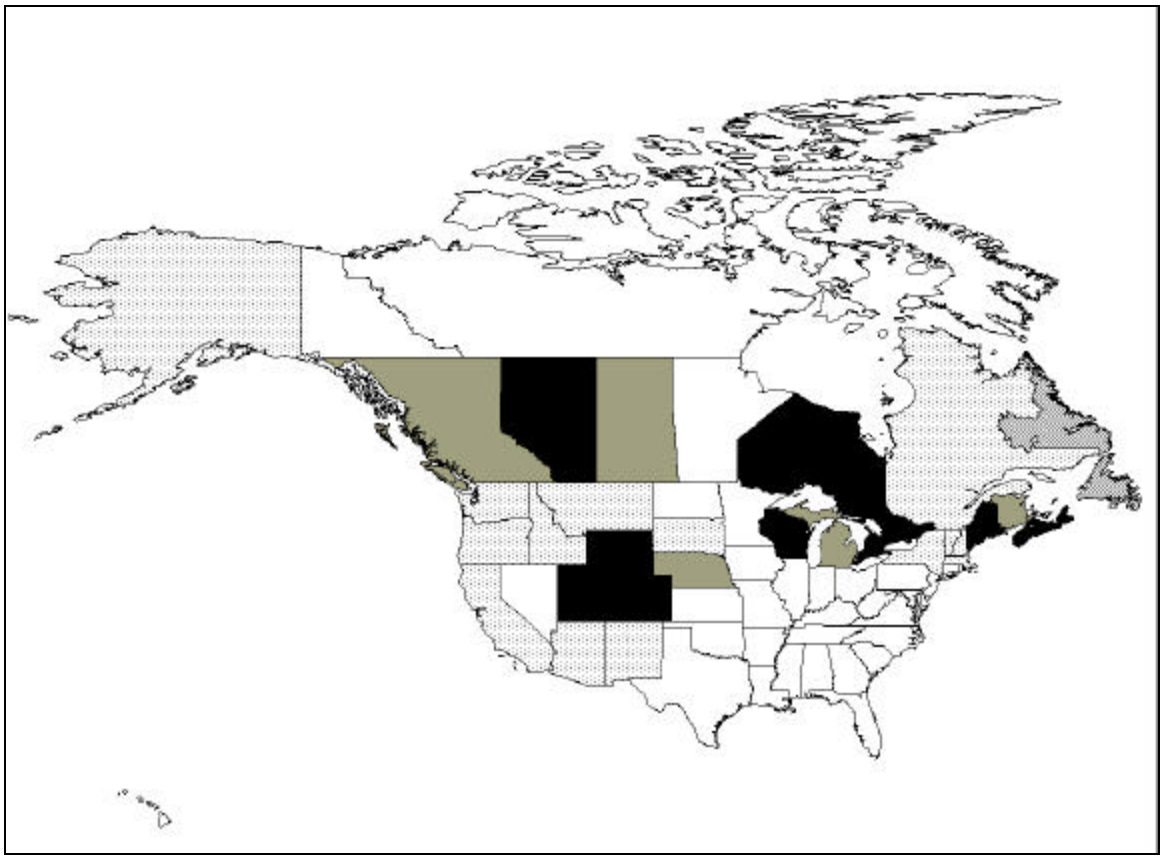

Figure 1. Occurrences of *Goodyera oblongifolia* in North America. States and provinces shaded in gray have one to five current occurrences of the taxon. Areas shaded in black have more than five confirmed occurrences. States with diagonal hatching are designated "historic" or "presumed extirpated," where the taxon no longer occurs. States with stippling are ranked "SR" (status "reported but not necessarily verified). See Appendix for explanations of state ranks.

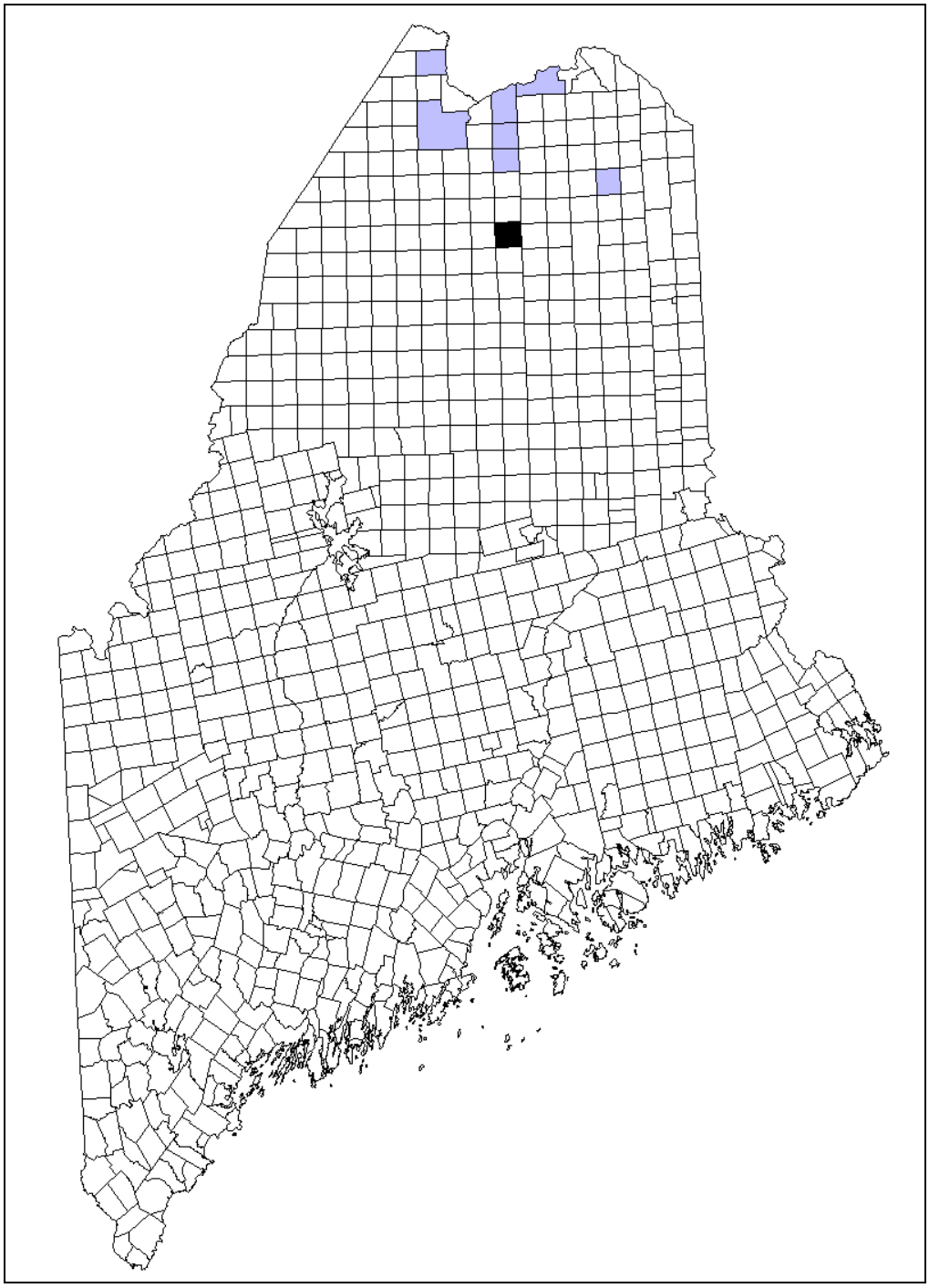

Figure 2. Extant occurrences of *Goodyera oblongifolia* in New England. Town boundaries for Maine are shown. Towns shaded in gray have one to five occurrences of the taxon, while the town shaded in black has more than five occurrences.

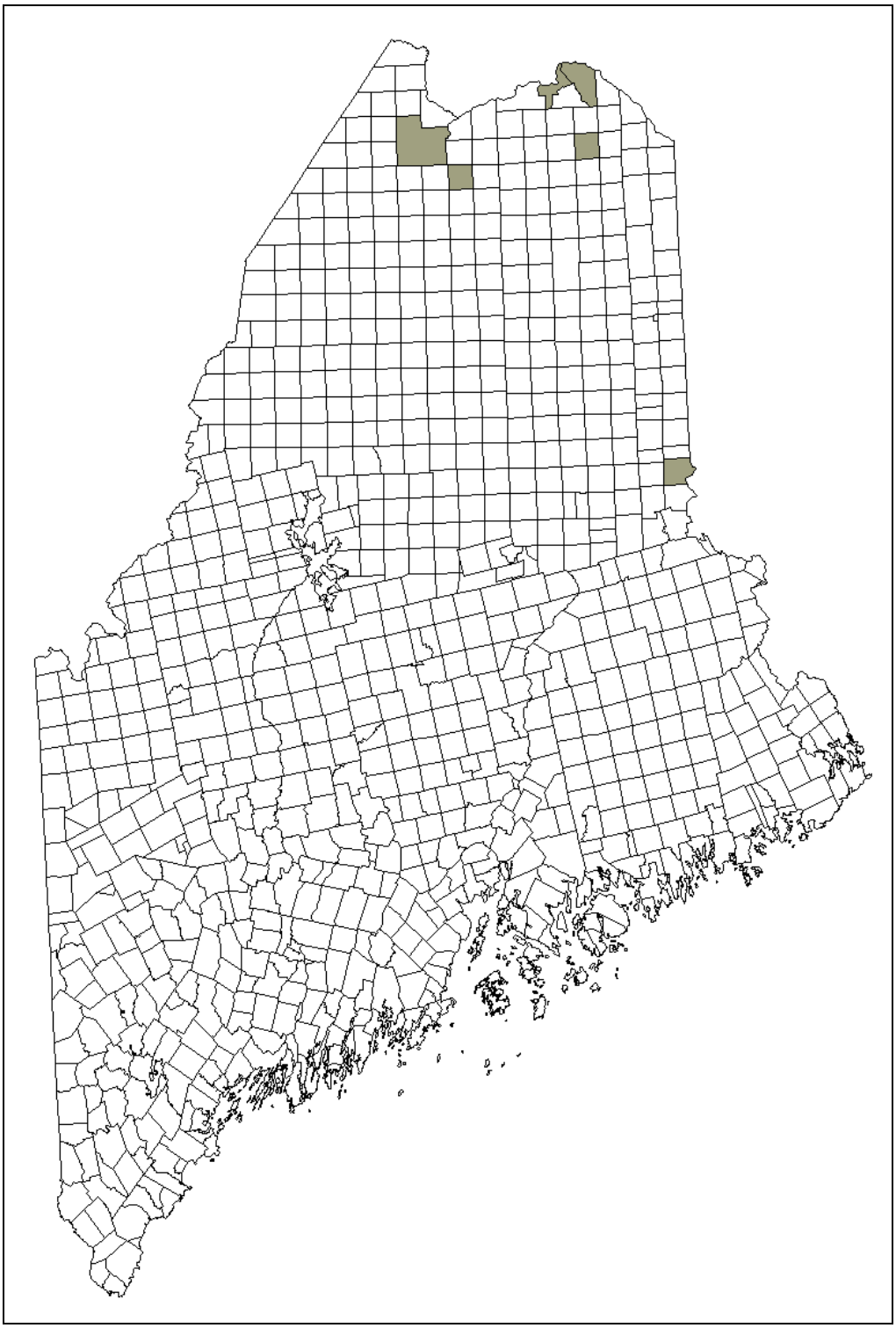

Figure 3. Historical occurrences of *Goodyera oblongifolia* in New England. Towns shaded in gray have one to five historic occurrences of the taxon.

Table 1. Occurrence and status of *Goodyera oblongifolia* in the United States and Canada based on information from Natural Heritage Programs.

OCCURS & LISTED (AS S1, S2, OR T &E)	OCCURS & NOT LISTED (AS S1, S2, OR T & E)	OCCURRENCE REPORTED OR UNVERIFIED	HISTORIC (LIKELY EXTIRPATED)
Maine (S2, E): 14 extant and 6 historic occurrences	Colorado (S4)	Massachusetts (SR): This record annotated as *G. tesselata* (Bruce Sorrie, personal communication)	Newfoundland Island (SH)
Nebraska (S1)	Michigan (S?)	New Hampshire (SR)	
New Brunswick (S2)	Utah (S3)	Vermont (SR): 2 printed records (Bean et al. 1951, see also Jenkins and Zika 1995)	
Saskatchewan (S2)	Wisconsin (S3)	New York (SR): (Gibson 1905)	
	Wyoming (S3)	Alaska (SR)	
	Alberta (S3)	Arizona (SR)	
	British Columbia (S?)	California (SR)	
	Ontario (S4)	Idaho (SR)	
	Nova Scotia (S2S3)	Minnesota (SR): (Brown 1997)	
		Montana (SR)	
		New Mexico (SR)	
		Oregon (SR)	
		South Dakota (SR)	
		Washington (SR)	
		Quebec (SR)	

In New England, *Flora Conservanda* lists *Goodyera oblongifolia* as Division 2, which indicates it is a regionally rare taxon with fewer than 20 occurrences in New England (Brumback and Mehrhoff et al. 1996). *Goodyera oblongifolia* is ranked S2 in Maine. The Maine populations are disjunct and near the southeastern range limit (Brown 1997). There are currently twenty-two records of *G. oblongifolia* in Maine, thirteen of which are extant. Gawler (1983) lists four stations for *G. oblongifolia* in Maine. Fernald (1899) lists the following two Maine stations: Frenchville, Aroostook Co., Maine (Kate Furbish), and Allaguash (as spelled), Aroostook Co., Maine (M. L. Fernald). Baldwin (1884) also lists two stations for Maine: Fort Kent and Frenchville. These distribution records suggest that the increase in number of occurrences is likely related to inventory effort. It is unlikely that early botanists had good access to many remote interior areas of northern Maine.

Goodyera oblongifolia is reported from New Hampshire, New York (Gibson 1905), and northern Vermont (Bean et al. 1951, Gleason and Cronquist 1991). These reports have not been verified with properly identified specimens. Bean et al. (1951) indicate two reliable printed records of *G. oblongifolia* for Vermont. One of these is likely to be the "Woodstock specimen" located at VINS and referred to by Jenkins and Zika (1995); no information was found regarding the other record. They determined that although this specimen lacked locality or date, the collection number matched that in Kittredge's 1931 flora of Vermont. The plant is missing from the herbarium sheet, but from the remaining outline of the leaves, Jenkins and Zika (1995) believe it to be *G. tesselata* or *G. repens*. NatureServe (2002) lists *G. oblongifolia* as SR in Massachusetts. A couple of specimens at NEBC/GH were originally labeled as *G. oblongifolia*, but they were later annotated as *G. tesselata* (Bruce Sorrie, Longleaf Ecological, personal communication). Bruce Sorrie indicated that *G. oblongifolia* has never been verified from Massachusetts, and that suitable boreal habitat is lacking. It is possible that the early reports of *G. oblongifolia* in New Hampshire and New York are also based on misidentifications.

Table 2. New England Occurrence Records for *Goodyera oblongifolia.* Shaded occurrences are considered extant.

State	EO #	County	Town
ME	**.001**	**Aroostook**	**St. John Plantation**
ME	**.002**	**Aroostook**	**Fort Kent**
ME	.003	Aroostook	T12 R08 WELS
ME	.004	Aroostook	Allagash
ME	.005	Aroostook	Madawaska
ME	.006	Aroostook	T15 R09 WELS
ME	.007	Aroostook	T16 R04 WELS
ME	.008	Aroostook	Frenchville
ME	**.009**	**Aroostook**	**T12 R08 WELS**
ME	.010	Aroostook	T12 R08 WELS
ME	**.011**	**Aroostook**	**T12 R08 WELS**
ME	**.012**	**Aroostook**	**T12 R08 WELS**
ME	**.013**	**Aroostook**	**T12 R08 WELS**
ME	.014	Aroostook	Amity
ME	.015	Aroostook	Perham
ME	**.016**	**Aroostook**	**Allagash**
ME	**.017**	**Aroostook**	**T19 R11 WELLS**
ME	**.018**	**Aroostook**	**T16 R08 WELS**
ME	**.019**	**Aroostook**	**T15 R08 WELS**
ME	**.020**	**Aroostook**	**T16 R08 WELS**
ME	**NEW**	**Aroostook**	**T16 R08 WELS**
ME	**NEW**	**Aroostook**	**Fort Kent**

II. CONSERVATION

CONSERVATION OBJECTIVES FOR TAXON IN NEW ENGLAND

The immediate objective for *Goodyera oblongifolia* in New England is to determine the full extent of its occurrence. Two large, new populations were discovered between 1999 and 2002, along with four smaller populations. It is likely that more populations will be found in the northern areas of Maine. As new populations are found, they should be protected by sharing information, conservation easement, site design, voluntary management agreement, and habitat preservation. General conservation objectives for *G. oblongifolia* in New England are to:

- **Determine number** of extant occurrences in New England
- **Secure existence** of all known populations via information sharing, conservation easement, site design, voluntary management agreement, and habitat preservation
- **Maintain high population numbers** at the large sites
- **Increase population numbers** at sites where habitat is appropriate (some of the sites with small population numbers have been harvested for timber and do not currently have suitable habitat)

Conserving viable populations of rare plants in their natural habitat is the goal of conservation land managers (NEWFS 1992) and should be the goal with *Goodyera oblongifolia*. Site design, protection, and habitat management are the three steps used to conserve rare plants in their natural habitats (NEWFS 1992). In general, these should be the goals at all *G. oblongifolia* sites in Maine, and in part have been implemented at ME .016 (Allagash). An ideal conservation goal is to have at least eight extant and viable occurrences for *G. oblongifolia* by 2022. Of the thirteen occurrences currently extant, only five of those are viable (ranked C or better). The following are general conservation actions to achieve the objectives.

1. **Survey likely habitat** for *Goodyera oblongifolia*
2. **Landowner contact and information sharing** to make them aware of the location, status, and vulnerability of *Goodyera oblongifolia* on their property
3. **Implementation of protective measures** such as conservation easement, management agreement, and habitat management plans
4. **Periodic inventory** of known occurrences
5. **Seed banking**
6. **Augmentation and reintroduction**
7. **Research and experimentation**, including determination of size and percentage of habitat and spatial patterning within habitat utilized by this species at each occurrence, determination of management and disturbance histories of sites where *Goodyera oblongifolia* occurs, demographic and genetic studies, habitat requirements, mycorrhizal associations, effects of hydrological change, and germination.

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IV. APPENDICES

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1. **Other Literature References**

2. **Composition of Curtis Medium**

3. **An Explanation of Conservation Ranks Used by The Nature Conservancy and NatureServe**

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2. Composition of Curtis Medium (abbreviated from Arditti et al. 1981, Table 1)

Component	Half strength	Full strength	Double strength
Macroelements			
$Ca(NO_3)_2 \cdot 4H_20$	175 mg	350 mg	700 mg
$FeSO_4 \cdot 7H_20$	2.76 mg	5.53 mg	11.06 mg
KH_2PO_4	60 mg	120 mg	240 mg
$MgSO_4 \cdot 7H_2O$	130 mg	260 mg	520 mg
NH_4NO_3	110 mg	220 mg	440 mg
Microelements			
$AlCl_3$	.03 mg	.03 mg	.03 mg
$CoCl_2 \cdot 6H_2O$	.025 mg	.025 mg	.025 mg
$CuSO_4 \cdot 5H_2O$	.03 mg, .025 mg	.03 mg, .025 mg	.03 mg, .025 mg
$FeCl_3 \cdot 6H_2O$	1.0 mg	1.0 mg	1.0 mg
H_3BO_3	1.0 mg, 6.2 mg	1.0 mg, 6.2 mg	1.0 mg, 6.2 mg
KI	.01 mg, .83 mg	.01 mg, .83 mg	.01 mg, .83 mg
$MnSO_4 \cdot H_2O$	.1 mg, 22.3 mg	.1 mg, 22.3 mg	.1 mg, 22.3 mg
$Na_2MoO_4 \cdot 2H_2O$	.25 mg	.25 mg	.25 mg
$NiCl_2 \cdot 6H_2O$	.03 mg	.03 mg	.03 mg
$ZnCl_2$	3.93 mg	3.93 mg	3.93 mg
$ZnSO_4 \cdot 7H_2O$	1.0 mg	1.0 mg	1.0 mg
Hormones			
Benzyladenine	1.0 mg	1.0 mg	1.0 mg
6-dimethyl-aminopurine	.25 mg	.25 mg	.25 mg
Kinetin	1.0 mg	1.0 mg	1.0 mg
Zeatin	.25 mg	.25 mg	.25 mg
Napthaleneacetic acid	.1 mg	.1 mg	.1 mg
Wuchstoff 66f	.1 ml	.1 ml	.1 ml
Vitamins			
Biotin		1.0 mg	
Ca·pantothenate		1.0 mg	
Folic acid		1.0 mg	
Niacin		1.0 mg	
Pyridoxine·HCl		1.0 mg	
Thiamine·HCl		1.0 mg	
Polyol: *myo*-inositol		.1 mg	
Complex additives			
Coconut water from unripe nuts	25 ml	50 ml	100 ml
Banana homogenate		75 g	75 g
Glucose	10 g	10 g	10 g
Darkening agent: graphite	2 g	2 g	2 g
Solidifier: agar	14 g	14 g	14 g
pH	5.0	5.0	5.0

3. 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.