

*Conservation Assessment  
for  
Broad-Leaved Twayblade (Listera Convallarioides)*



USDA Forest Service Eastern Region

Joann Hoy  
21 Steam Mill Road  
Auburn, New Hampshire  
[conserve@newfs.org](mailto:conserve@newfs.org) • [www.newfs.org](http://www.newfs.org)

WHITE MOUNTAIN NATIONAL FOREST



*This Conservation Assessment was prepared to compile the published and unpublished information on the subject taxon or community; or this document was prepared by another organization and provides information to serve as a Conservation Assessment for the Eastern Region of the Forest Service. It does not represent a management decision by the U.S. Forest Service. Though the best scientific information available was used and subject experts were consulted in preparation of this document, it is expected that new information will arise. In the spirit of continuous learning and adaptive management, if you have information that will assist in conserving the subject taxon, please contact the Eastern Region of the Forest Service – Threatened and Endangered Species Program at 310 Wisconsin Avenue, Suite 580 Milwaukee, Wisconsin 53203*

## Table of Contents

<b>SUMMARY</b> .....	4
<b>PREFACE</b> .....	4
<b>BACKGROUND</b> .....	5
<b>DESCRIPTION</b> .....	6
<b>TAXONOMIC RELATIONSHIPS, HISTORY, AND SYNONYMY</b> .....	7
<b>SPECIES BIOLOGY</b> .....	7
<b>HABITAT/ECOLOGY</b> .....	9
<b>THREATS TO THE TAXON</b> .....	9
<b>DISTRIBUTION AND STATUS</b> .....	10
<b>CURRENT CONSERVATION MEASURES IN REGION 9</b> .....	21
<b>CONSERVATION</b> .....	22
<b>GENERAL CONSERVATION ACTIONS FOR <i>LISTERA CONVALLARIOIDES</i></b>	22
<b>RECOMMENDED CONSERVATION ACTIONS FOR EACH OCCURRENCE</b> ..	24
<b>ACKNOWLEDGMENTS</b> .....	28
<b>LITERATURE CITED</b> .....	28
<b>APPENDICES</b> .....	32

## SUMMARY

A conservation plan for *Listera convallarioides* (Swartz) Nuttall (broad-leaved twayblade) was set in motion by the White Mountain National Forest (WMNF) because the orchid has been given sensitive-species status. That status prescribes a site-specific conservation plan for each occurrence and investigation of potential sites before initiating ground-disturbing activities. This plan is for U.S. Forest Service Region 9, which extends from the East Coast through Minnesota and down to Missouri, Illinois, Indiana, Ohio, West Virginia, and Maryland.

*Listera convallarioides* is a North American endemic, with a global rank of G5 (widespread and secure). *Listera convallarioides* most often grows in circumneutral to somewhat acidic muck in forest seeps and northern white cedar swamps in the eastern part of its range. Some populations grow in moist sand along streams under cedars, and it is abundant in moist interdunal woods near the northern Great Lakes. In mountainous regions of western North America, it can be found growing with moss and grasses, in damp, often shady spots. It apparently requires cool, moist growing conditions, and is found in exceptionally cool ravines and at moderately high elevations (2,000–3,200 feet [600–975 m]) in its southernmost range in New Hampshire.

*Listera convallarioides* can be locally abundant, even where it is uncommon. Large colonies of several hundred plants are not uncommon, forming dense groundcover. Most sites visited in New Hampshire in 2001 had hundreds of plants, ranging from densely gathered to scattered. Timber harvesting, road building, and other human disturbance to habitat and hydrology are probably the biggest threats to *L. convallarioides* persistence.

The conservation objectives for *L. convallarioides* in Region 9 are to buffer northern white cedar swamps that harbor *L. convallarioides* and forest seeps from logging and recreational use, to discover what the orchid prefers in its habitat, and to search for extant populations in likely habitat, and perhaps in historical sites. The goal is to protect wetlands where *L. convallarioides* is known to be, to conserve the four good-quality populations (800+ plants) in New Hampshire and to search for four or five more good-quality populations. The population size is based on Natural Heritage rankings and reports of stable populations in provinces and states where the orchid is not rare. The number of populations is an estimate of what it will take to maintain the orchid's presence in this part of its range, based on the number of historical and present occurrences.

## PREFACE

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.

This document should be cited as follows:

Hoy, Joann M. 2002. *Listera convallarioides* (Broad-Leaved Twayblade) Conservation and Research Plan for U.S. Forest Service Region 9. New England Wild Flower Society, Framingham, Massachusetts, USA.

Additional copies of this conservation plan may be obtained from  
Conservation Plan Coordinator  
New England Wild Flower Society  
180 Hemenway Road  
Framingham, MA 01701-2699  
508/877-7630; conserve@newfs.org  
© 2002 New England Wild Flower Society

## **BACKGROUND**

### Introduction

*Listera convallarioides* is a North American endemic, with a global rank of G5 (widespread and secure). At the edges of its range, it can be locally rare (e.g., New Hampshire and Wisconsin).

Recently the U.S. Forest Service in Region 9 added *Listera auriculata*, *L. cordata*, and *L. convallarioides* to its list of sensitive species. Although these twayblades are not listed under the Endangered Species Act, they are locally rare, and the National Forests will use this plan and those for *L. auriculata* and *L. cordata* (Hoy 2001, 2002) to develop management strategies to protect and enhance populations and habitat.

The conservation objectives for *L. convallarioides* in U.S. Forest Service Region 9 are to preserve potential genetic diversity at the southeast fringe of its range and to maintain its range across eastern North America.

## DESCRIPTION

Swartz (1800) first described *Listera convallarioides*, based on a collection identified only as from North America. He called it *Epipactis convallarioides*. The description below is based on Coleman and Magrath (in preparation) and Case (1987).

*Listera convallarioides* is a terrestrial orchid with slender, fibrous roots that are somewhat stoloniferous. It is between 5 and 37 cm tall. Its two sessile, subopposite leaves are glabrous; broadly ovate to elliptic, oval, or suborbicular; obtuse to (rarely) acute or apiculate; 20–70 mm long and 15–58 mm wide. It has a loosely flowered, terminal raceme, 20–120 mm long, with floral bracts that are rhombic-ovate to lanceolate, semitranslucent, and 3–5 mm by 1–2.5 mm. Below the leaves the stem is glabrous; the peduncle and rachis are densely whitish glandular-pubescent. The pedicels and ovaries are glandular-pubescent, with the ovaries becoming glabrate. A plant may have 5–20 flowers that are yellowish-green, sometimes with a tinge of purple. The sepals and petals are reflexed away from the column and lip. The dorsal sepal is ovate-lanceolate to elliptic and 4.5–5 mm by 1.5–2 mm, and the lateral sepals are lanceolate, acute to obtuse, falcate, and 4.5–5.5 mm by 1.5–1.8 mm. The petals are linear, falcate, and 4–5 mm by 0.8–1 mm. The lip is cuneate, tapering to a slender claw. The lip apex is dilated and has a shallow notch with rounded lateral lobes and a tiny tooth in the sinus between the lobes. The base of the lip has an inconspicuous triangular tooth on either side. The column is slender, slightly curved, and slightly expanded at the apex, 2.5–4 mm by 1 mm. Seed capsules are ellipsoid, 8 mm by 5 mm, and glabrous.

There are eight North American species in the genus *Listera*. *Listera convallarioides* may overlap in habitat and distribution with *L. australis* (southern twayblade), *L. borealis* (northern twayblade), *L. cordata* (heart-leaved twayblade), and *L. auriculata* (auricled twayblade). All but *L. borealis* are found in Region 9. *Listera convallarioides* has a lip that is attached at the base by a narrow claw and that is widest and merely notched at its distal end. All the other twayblades in Region 9 have cleft lips and are clawless. See the key in Appendix 2.

*Listera convallarioides* hybridizes with *L. auriculata*. The parent plants have distinctly different flower morphology and habitat preferences. *Listera auriculata* prefers (or tolerates) acidic soils on frequently disturbed riverbanks and lake shores. *Listera convallarioides* grows

on soils with higher nutrient availability, usually in forest seeps or conifer swamps. The rare hybrid, *Listera* × *veltmanii*, has been found growing with one or the other of its parents. It is intermediate between the two in pubescence and shape of its lip. Like *L. convallarioides*, it has a claw, but it is shorter; the lip broadens at the distal end, but not as much. The hybrid has a shallower cleft in its lip than *L. auriculata*, but more than a notch like *L. convallarioides*. It has small, uncurved auricles. It is taller than either parent, appears to have a longer flowering season, and is found in more disturbed habitat than its nearby parents (Catling 1976). The parents and hybrid could be easily distinguished from each other in the collections Catling examined. In two cases he found evidence of backcrossing with *L. convallarioides*. The hybrid is known from New Brunswick, Newfoundland, Quebec, Ontario, Michigan, Wisconsin, and New Hampshire (Cody and Munro 1980, Coleman and Magrath in preparation).

## TAXONOMIC RELATIONSHIPS, HISTORY, AND SYNONYMY

*Listera convallarioides* was first identified in 1800 by Swartz, who put it into *Epipactis*. Elliott (1824) classified it as *Listera*. Chamisso (1828) apparently misidentified Alaskan *L. convallarioides*, giving it a new name: *Listera eschscholziana*. The synonym *Diphryllum convallarioides* (Swartz) O. Kuntze can be dismissed; *Diphryllum*, proposed in 1808, was never clearly connected to *Listera* Brown. Two synonyms that were published after 1823, *Ophrys convallarioides* (Wright ex House 1905) and *Bifolium convallarioides* (Nieuwland 1913), were based on publication priority of those genus names. *Listera* has since been conserved as the correct genus name (Gleason and Cronquist 1991). It is part of the Neottieae tribe (Dressler 1993), which has several genera, including another North American genus, *Epipactis*.

## SPECIES BIOLOGY

Little is known specifically of *Listera convallarioides* biology; however, results from studies of other members of the genus may be applicable to *L. convallarioides*. Rasmussen (1995) reviews the research done, mostly on *L. ovata* (common twayblade), a widespread, weedy European species, including seed storage and culture. Details from that review that may be pertinent to *L. convallarioides* are mentioned below.

*Listera convallarioides* can be locally abundant, even where it is uncommon. Brown (1997) reports that large colonies of several hundred plants are not uncommon, forming dense groundcover in Vermont and Maine. Nylander (1921) also found them abundant in Maine in some years. Most sites visited in New Hampshire in 2001 had hundreds of plants, densely clustered to scattered (personal observation). Fred Case (Cranbrook Institute of Science, personal communication) reports acres of *L. convallarioides* in Minnesota. Extensive colonies form in the upper Great Lakes region where freshets wet the forest floor during heavy rains (Case 1987). In California, large, dense colonies grow in water along stream banks (Coleman 1995).

I could find no studies of *L. convallarioides*' mycorrhizal partners. Fungi that infect *L. cordata* (heart-leaved twayblade) sprouts persist in mature plants. *Listera ovata* roots harbor fungi, but its rhizomes do not (Rasmussen 1995). Fungal parasites, however, appear to be common; Correll (1950) notes that *L. convallarioides* is exceptionally susceptible to fungal attacks. Case (1987) reported many blackened stems in populations that grow in intermittent freshets in forests near the Great Lakes.

Slight invertebrate herbivory was apparent at New Hampshire sites in 2001. I have found one report of herbivory (possibly rodent) as a notable problem.

*Listera convallarioides* flowers from June to September (Coleman and Magrath in preparation); in Region 9, it has mostly finished flowering by mid-August (Brackley 1985, Case 1987, Brown 1997). The leaves appear well before the flowering spike elongates (Brackley 1985). It is not known how long it takes for *L. convallarioides* to mature. Estimates for the age of *L. ovata* at first flowering range from 7 to 15 years (Rasmussen 1995).

Twayblades have a small nectary that attracts nonspecific small flying insects, and all have a common pollination mechanism. Ackerman and Mesler (1979) describe pollination in *L. cordata*. A nectary runs down the middle of the lip, and another lies at the base of the column. An insect that visits the flower touches trigger hairs on the column. A dab of glue squirts on the insect, and the pollinia are immediately dropped on the glue. The stigma is covered for about a day, and then is exposed for pollination. This mechanism helps prevent self-pollination. Many species of *Listera* have fetid-smelling nectar (Brackley 1985), but this scent has not been noted in *L. convallarioides*.

Because twayblade nectaries and columns are quite accessible, pollination requires no specific insect body shape (Ackerman and Mesler 1979). *Listera cordata* visitors in California were often fungus gnats (Mycetophilidae), and other Diptera and some Hymenoptera (Ackerman and Mesler 1979). Hapeman (2000) shows a photograph of *L. auriculata* being visited by a small dipterid, perhaps a fungus gnat. It is possible that *L. convallarioides* is also pollinated by fungus gnats.

The dust-sized seeds are produced in the summer and most likely disperse by wind. It is not known whether they germinate the same year or are dormant for a time. Vinogradova (1996) reports for *L. cordata* that the first green leaf appears after 2–3 years of development underground. *Listera cordata* and *L. auriculata* adults overwinter by a shoot at the base of the current year's stem (Reddoch and Reddoch 1997). *Listera convallarioides* also does, with the shoot developing gradually through the summer (personal observation of herbarium specimens).

Studies of vegetative reproduction in other species in the genus may apply to *L. convallarioides*. *Listera cordata* did not reproduce vegetatively in California populations studied by Ackerman and Mesler (1979) in redwood forests. Disconnected *L. cordata* roots



contain some starch and can produce shoots. The root-tip meristem transforms directly into a shoot meristem. It sheds the root cap after a shoot meristem with leaf primordia forms beneath. New roots arise at nodes of the shoot (Rasmussen 1995).

## HABITAT/ECOLOGY

*Listera convallarioides* most often grows in circumneutral to somewhat acidic muck in forest seeps, northern white cedar swamps, boreal forests, and other wet-mesic forests in the eastern part of its range (Case 1964, Catling 1976, Cody and Munro 1980, Case 1987, Marie-Victorin 1995, Thompson and Sorenson 2000, unpublished data from New Hampshire field forms, personal observations). Some populations grow in moist sand along streams under cedars (Case 1964, Voss 1972). Case (1987) reports it as abundant in moist interdunal woods near the northern Great Lakes. Cody and Munro (1980) report it from forested floodplains and bottomlands. In mountainous regions of western North America, it can be found growing with moss and grasses, in damp, often shady spots (Correll 1950, Coleman 1995). It apparently requires cool, moist growing conditions, and is found in exceptionally cool ravines and at moderately high elevations (2,000–3,200 feet [600–975 meters]) in its southernmost range in New Hampshire.

Typical associates of *L. convallarioides* in Region 9 are *Mnium* and other mosses, rough sedge (*Carex scabrata*), dwarf enchanter's nightshade (*Circaea alpina*), golden saxifrage (*Chrysosplenium americanum*), asters, and violets. It apparently rarely grows in peat moss (*Sphagnum* spp.; e.g., Case 1964, and personal observation), but is often near it (Cody and Munro 1980). Characteristic species in the seeps and headwaters that harbor *L. convallarioides* are lady-fern (*Athyrium filix-femina*), intermediate wood fern (*Dryopteris intermedia*), twisted stalk (*Streptopus amplexifolius*), false hellebore (*Veratrum viride*), bedstraw (*Galium* spp.), and long beech fern (*Phegopteris connectilis*). Common trees in the surrounding forest are northern white cedar (*Thuja occidentalis*), balsam fir (*Abies balsamea*), red maple (*Acer rubrum*), mountain maple (*Acer spicatum*), sugar maple (*Acer saccharum*), yellow birch (*Betula alleghaniensis*), and paper birch (*Betula papyrifera*).

## THREATS TO THE TAXON

Harvesting the canopy over a seep or in a northern white cedar (*Thuja occidentalis*) swamp affects *Listera convallarioides* habitat in several ways. Increased light might encourage other plants to outcompete *L. convallarioides*, dry out the habitat, or make it too warm. Moving logging equipment through a seep or swamp may seriously alter water flow and drainage by creating microdams and channels and by compacting the substrate. Because many seeps never freeze and so remain softer than the surrounding soil, they are vulnerable to vehicles even in winter (Thompson and Sorenson 2000). The farther apart populations of plant species that grow in scattered seeps are, the less likely that they could recover from local extinctions. This may be because seeds cannot disperse very far or because pollination is disrupted (Harrison et

al. 2000). Although logging northern white cedar continues in the region, affecting habitat for *L. convallarioides*, it is presently an issue at only one site tracked in this plan (NH .018 [Stark]).

Hydrological changes in the forested swamps that *L. convallarioides* often inhabits could eliminate the plant. Roads can obstruct water flow. Road salt and artificial impoundments also affect the habitat: northern white cedar is salt-sensitive and cannot stand long impoundment (Johnston 1990, Thompson and Sorenson 2000). Any major activity upslope from a swamp or seep is likely to significantly affect the water quality and quantity below. Beavers also alter hydrology. Groundwater that feeds the swamps can also be altered, primarily by humans using it. In the ravine settings that *L. convallarioides* inhabits in the White Mountain National Forest, hikers, trail maintainers, and plant researchers can trample the plants or affect drainage by increasing erosion or building water bars.

Global climate change is ongoing and is likely to affect temperature, precipitation, and storm severity and frequency in Region 9 (Hansen et al. 2001). These changes will affect different plants in different ways, leading to changes in range and in community species composition (Halpin 1997, McCarty 2001). Climate change is likely to affect *L. convallarioides* through the arrival of new competitors, loss of northern white cedar habitat (or its movement north), warming groundwater and thus microclimate in seeps, change in size of the subalpine area (it is not yet clear whether that will increase, decrease, or stay about the same [Halpin 1997]), change in number and type of pollinators and herbivores, and change in timing of leaf-out for the canopy. Change of climate might also make *L. convallarioides* more susceptible to its fungal parasites (reported in Correll 1950 and Case 1987). Because of land use that leads to forest fragmentation, *L. convallarioides* at the edges of its range may not be able to migrate to accommodate these changes. Hunter (1993), which gives reasons for preserving fringe populations of even common species, points out that plants and animals adapted to conditions at the edge of their range may be well-adapted to a climate change.

Disruption of pollinators by changes in habitat, either nearby logging or climatic effects, cannot be evaluated without knowing more about *L. convallarioides* pollinators. Invasive plants are not a problem in the reports I have seen or sites I have visited, but could be introduced by logging equipment, recreational vehicles, railways, and hikers. McCarty (2001) suggests that invasive plants in general could become more and more troublesome as the climate warms. Another influence on community structure of forested swamps, especially northern white cedar, is excessive deer browse, which can prevent regeneration and change the character of the forest (Johnston 1990).

## **DISTRIBUTION AND STATUS**

### General Status in Region 9

*Listera convallarioides* is a North American endemic, with a global rank of G5 (widespread and secure; NatureServe 2001). Because it prefers cool, moist forests, it spreads in a northern band across most of the continent, with a gap across the drier climates in Minnesota and South

Dakota and areas to the north. In the west, it is restricted to mountainous areas, from British Columbia to Arizona and Nevada. Table 1 (below) summarizes the distribution and status of the species in North America.

States in U.S. Forest Service Region 9 that list *L. convallarioides* as Endangered or Threatened are New Hampshire and Wisconsin. Wisconsin has five extant sites, none in a National Forest. In New Hampshire, the White Mountain National Forest holds three of the eight extant sites.

In other Region 9 states, *L. convallarioides* populations are not tracked, because it is either common or at least not rare. In northern Michigan and the Upper Peninsula, it is frequently found, so the Hiawatha and Huron-Manistee National Forests probably have populations. In the northern half of Vermont, *L. convallarioides* is occasional to locally abundant (Thompson and Sorenson 2000; Everett Marshall, Vermont Nongame and Natural Heritage Program, personal communication). The Green Mountains in Vermont may have *L. convallarioides* populations in forest seeps; however, northern white cedar swamps are not found there (Thompson and Sorenson 2000). In Maine, *L. convallarioides* appears in most counties (except for the coast), in rich moist woods, in northern white cedar swamps, and among alders along riverbanks (Josselyn Botanical Society 1995, herbarium labels from the herbarium at University of Maine, Orono).

<b>Table 1. Occurrence and status of <i>Listera convallarioides</i> in the United States and Canada based on information from Natural Heritage Programs</b>			
<b>OCCURS &amp; LISTED (AS S1, S2, OR T &amp; E)</b>	<b>OCCURS &amp; NOT LISTED (AS S1, S2, OR T &amp; E)</b>	<b>OCCURRENCE REPORTED OR UNVERIFIED<sup>1</sup></b>	<b>HISTORICAL (LIKELY EXTIRPATED)</b>
Alaska: S1	Nova Scotia: S3S4	California: SR	Minnesota: SH?
Arizona: S1	Ontario: S4	Idaho: SR	New York: SH
Colorado: S2		Maine: SR	
New Hampshire: S2		Michigan: SR	
South Dakota: S1		Montana: SR	
Wisconsin: S1		Nevada: SR	
Wyoming: S1		Oregon: SR	
Alberta: S2		Utah: SR	
Prince Edward Island: S1?		Vermont: SR	
		Washington: SR	
		British Columbia: SR	
		New Brunswick: SR	
		Newfoundland: SR	
		Quebec: SR	

<sup>1</sup>SR means "status reported." For *L. convallarioides* in some cases (e.g., Maine and Michigan), SR indicates that the orchid is rather common and widespread.

*Listera convallarioides* is not tracked in three of the five states in which it occurs in Region 9: Maine, Michigan, and Vermont. New York has five historical records for the plant, four from Lewis County (1881 and 1927) and one from Jefferson County (1927). These two counties are near the east end of Lake Ontario. Minnesota has one record, from 1924 in Cook County. It seems odd that *L. convallarioides* has been reported only once in Minnesota, as it has abundant seemingly appropriate habitat in northern white cedar swamps (Minnesota Department of Natural Resources 1993, Smith 1993).

In New Hampshire and Wisconsin, *L. convallarioides* has been reported in 27 sites. Eleven of those occurrences have not been seen for more than 20 years. Two new sites for New Hampshire were located in 2001 (personal observation). Wisconsin has six extant sites and three historical records (pre-1970) in Bayfield, Iron, and Ashland Counties. I was not allowed to see details for the Wisconsin sites. Table 2 shows occurrences for Region 9 National Forests and New England states where *L. convallarioides* is tracked.

Element Occurrence (EO) quality ranks are based on the size, condition, and landscape context of a rare species population. They range from A (excellent) to D (poor). The rank E applies to element occurrences that are extant but unranked because of a lack of information. The rank H applies to sites for which no observations have been made for more than 20 years and are considered historical. The rank X applies to sites that are known to be extirpated. See Appendix 3 for more details.

For *L. convallarioides*, EO rank specifications have been published in Chase 2001, which is quoted here:

A = 1,000+ genets with evidence of reproduction in excellent habitats of large size and high natural integrity . . .

B = 100–999 genets in habitat of good to excellent condition and landscape context and with minimal threats to viability . . .

C = 10–99 genets in habitat of fair to excellent condition and landscape context . . .

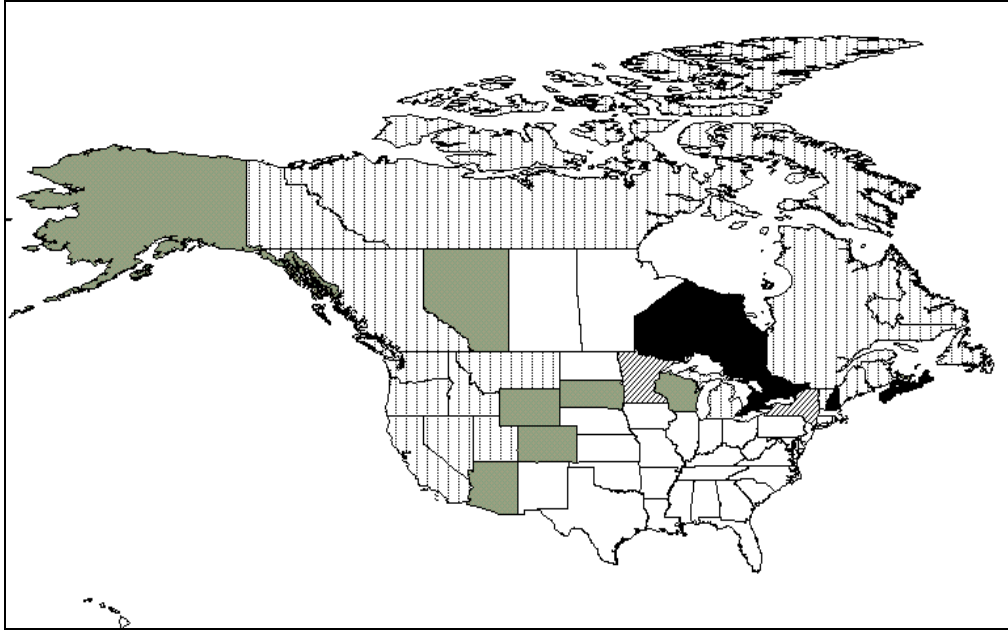
D = 1–9 genets in habitat of poor to excellent condition and landscape context . . .

**Table 2. Region 9 occurrence records for *Listera convallarioides*. Shaded occurrences are considered extant.**

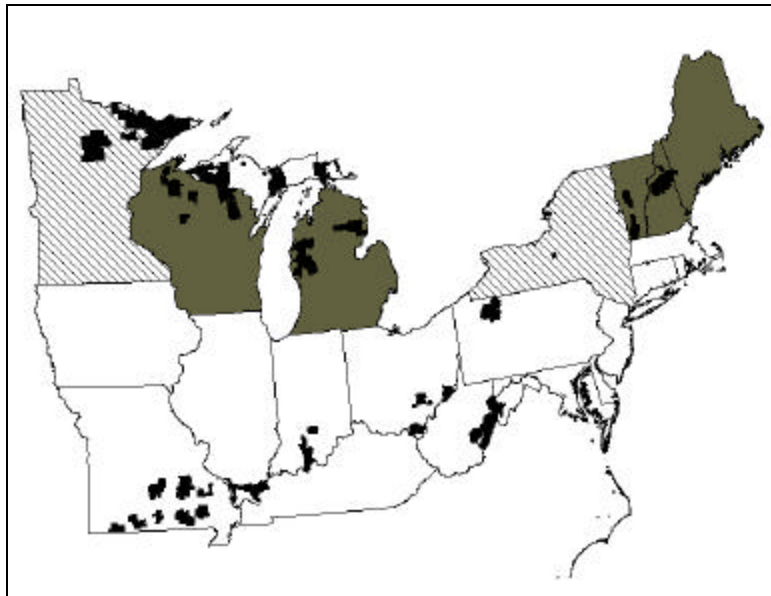
State	EO #	County	Town	Site Ownership	First Observed	Last Observed	Description	EO Rank	Population Size (date)	Comments	Threats
NH	.001	Coos	Dixville Notch	Unknown	1906	1906		H		Specimen at Ames Herbarium	
NH	.002	Coos	Dummer	Unknown	1964	1964				Herbarium specimen at University of New Hampshire	
NH	.003	Coos	Pittsburg	Unknown	1973	1973	Northern white cedar bog			Herbarium specimen at University of New Hampshire	
NH	.004	Grafton	Franconia	White Mountain National Forest (WMNF)	1888	1888		H		Herbarium specimen at New York Botanical Garden	
NH	.005	Grafton	Bethlehem	WMNF	1925	2001	Subneutral forest seep	AB	~800 (2001)		Water bars
NH	.006	Coos	Randolph	Town of Gorham	1984	1999	Streamside seep	A	>100 (1984); 8 (1999)	Ice storm in 1998 damaged the canopy	None known
NH	.009	Coos	Stark	WMNF	1991	2001	Acidic <i>Sphagnum</i> seep in forest	C	11 (1991); 28 (2001)	Unsuccessful search for nearby source population, 2001	Trampling
NH	.010	Coos	Stratford	NH State Forest	1988	1988	Forest seep	C			Logging; snowmobile trail

**Table 2. Region 9 occurrence records for *Listera convallarioides*. Shaded occurrences are considered extant.**

State	EO #	County	Town	Site Ownership	First Observed	Last Observed	Description	EO Rank	Population Size (date)	Comments	Threats
NH	<b>.011</b>	Coos	Stratford	NH State Forest	1988	1988	Forest seep	C			Logging; snowmobile trail
NH	.012	Coos	Pittsburg	NH state park	1955	1955				Pease 1964	
NH	.013	Coos	Pittsburg	NH state forest	1907	1907				Pease 1964	
NH	.014	Coos	Colebrook	NH state park	1917	1935		H		Pease 1964	
NH	.015	Coos	Colebrook	Unknown	1907	1907		H		Pease 1964	
NH	.016	Coos	Carroll	WMNF	1909	1909		H		Pease 1964	
NH	<b>.017</b>	Coos	Sargent's Purchase	WMNF	1987	2001	Acidic <i>Sphagnum</i> seep in forest	AB	>1,000 (2001)		Stray hikers from nearby trail
NH	<b>.018</b>	Coos	Stark	Private	1997	1997	Northern white cedar swamp	A	Hundreds		Logging
NH	<b>new</b>	Coos	Colebrook	Private	2001	2001	Forest seep	A	Several hundred		None

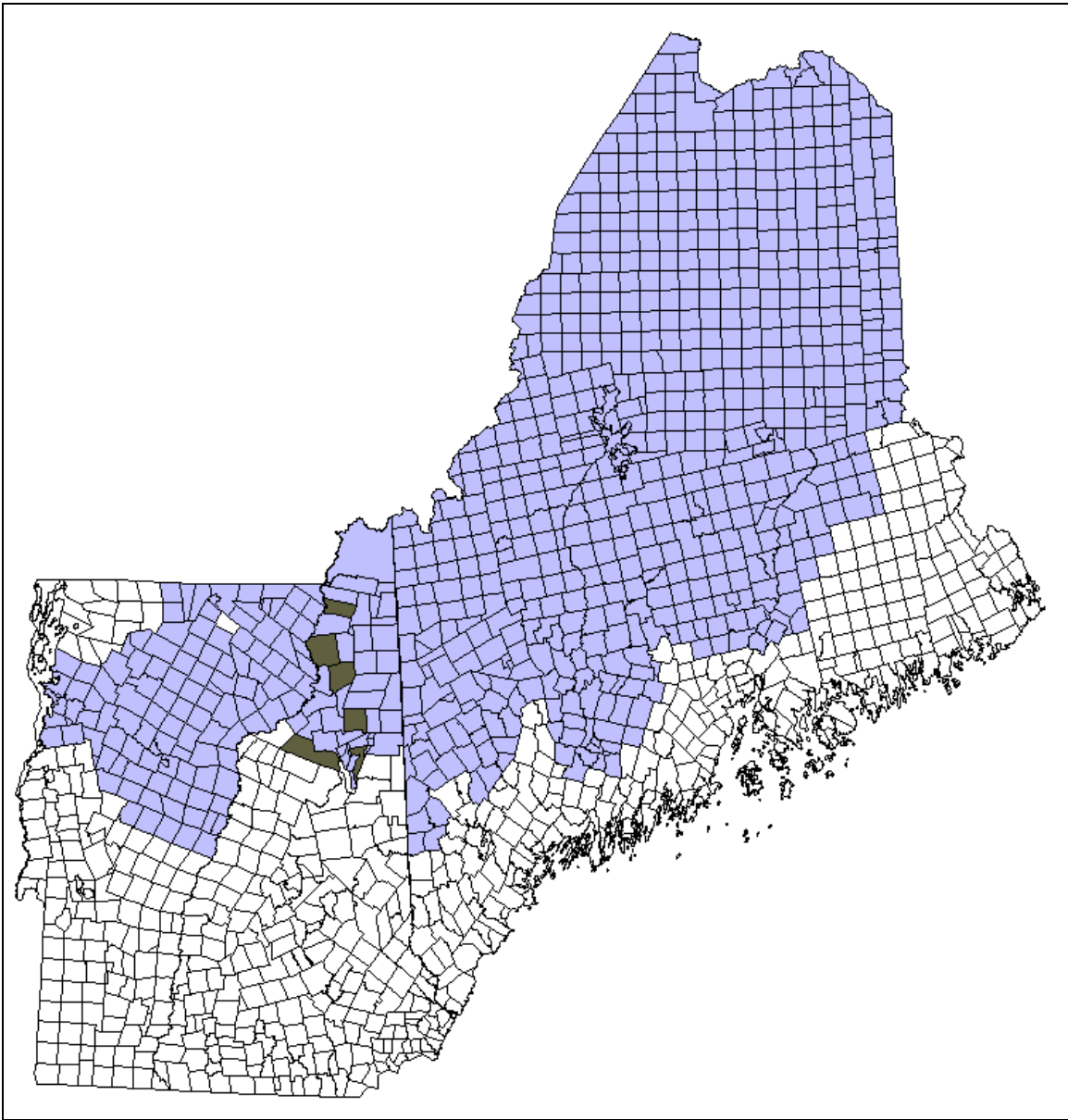


**Figure 1. Distribution of *Listera convallarioides* in North America.** States and provinces shaded in gray have one to five (or an unspecified number of) current occurrences. Areas shaded in black have more than five extant occurrences. Stippling indicates states and provinces in which the taxon is ranked SR ("status reported") with no further information. See Appendix 3 for an explanation of NatureServe ranks. Diagonal hatching indicates states in which the taxon is considered historical.

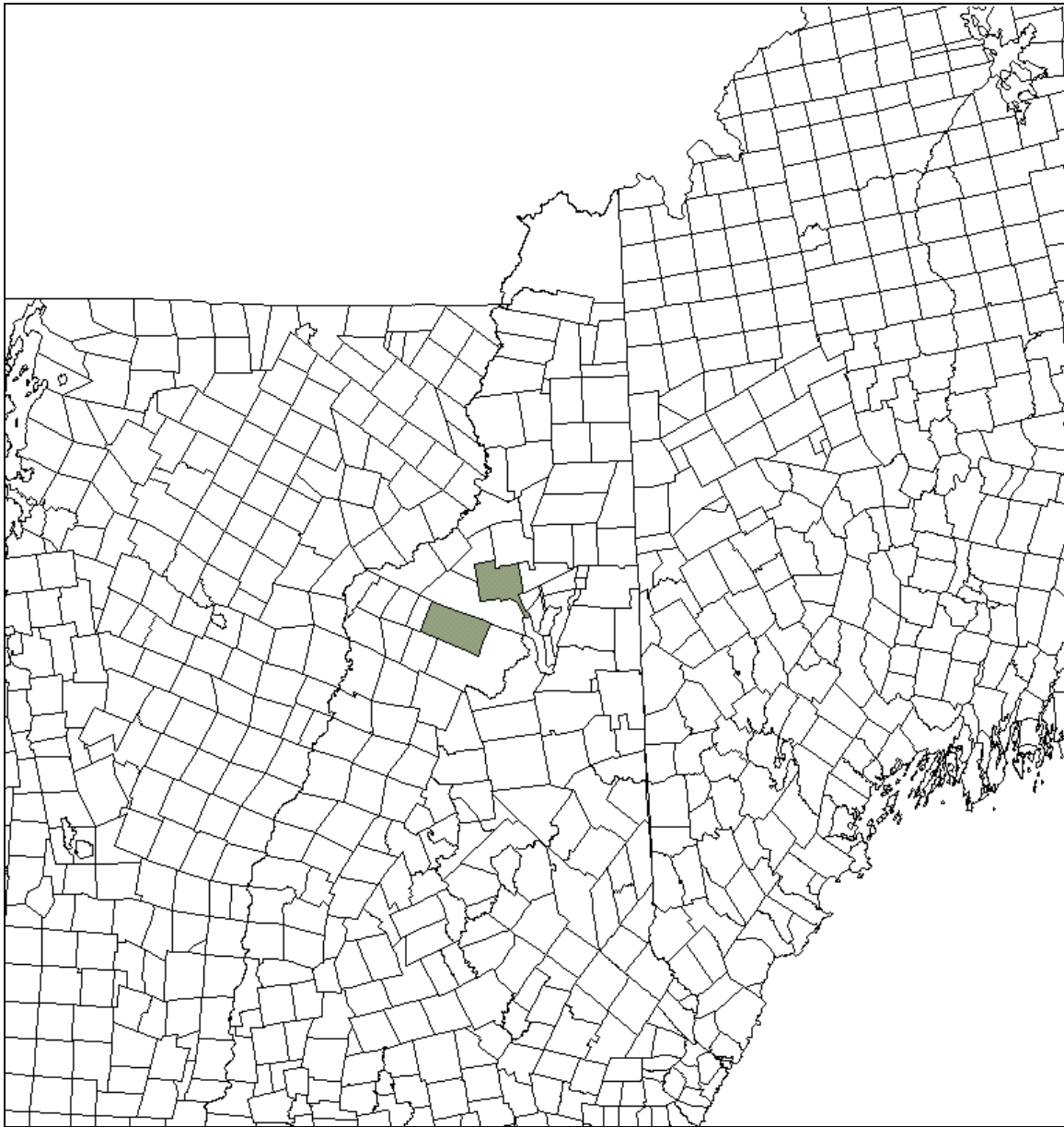


**Figure 2. States in Region 9 from which *Listera convallarioides* has been recorded.** Shading indicates that the taxon is extant; diagonal hatching indicates a rank of "historical" or "extirpated." Black polygons indicate National Forest boundaries.





**Figure 3. Extant occurrences of *Listera convallarioides* in New England.** Town boundaries for New Hampshire, Maine, and Vermont are shown. Towns shaded in dark gray have one to five confirmed, current occurrences of the taxon. Light gray shading shows reported distribution in Maine, New Hampshire, and Vermont counties.



**Figure 4. Historical occurrences of *Listera convallarioides* in New England.** Town boundaries for New Hampshire and adjacent states are shown. Towns shaded in gray have one to five historical records of the taxon. Data on county-level historical distributions are not available.

Status of Tracked Region 9 Occurrences — Current and Historical

Status of New Hampshire Occurrences

**NH .001 (Dixville Notch)** — Very little is known about this 1906 collection. The specimen is in the Ames Herbarium at Harvard University. The Element Occurrence (EO) rank is H.

**NH .002 (Dummer)** — Very little is known about this 1964 collection. The specimen is at the University of New Hampshire herbarium.

**NH .003 (Pittsburg)** — This 1973 collection is from a stream in a northern white cedar (*Thuja occidentalis*) bog fringing some alder swales near beaver ponds. Black spruce (*Picea mariana*) was growing nearby.

**NH .004 (Franconia)** — Very little is known about this record from Mount Lafayette. The specimen, collected in 1888, is at the New York Botanical Garden. The EO rank is H.

**NH .005 (Bethlehem)** — This population was recorded from a 1925 collection at the New York Botanical Garden. A search in July 2001 turned up what may be the same population, approximately 800 plants in a subneutral forest seep. The surrounding forest was old-growth until the hurricane of 1938 destroyed part of it. In 1939, this area was logged. Today's forest comprises large yellow birches (*Betula alleghaniensis*) and smaller red spruce (*Picea rubens*) and balsam fir (*Abies balsamea*). The seep runs uphill for 100+ m, with scattered *Listera convallarioides* at various points and a large dense colony at a flat, open spot in the middle of the seep. At that point, the substrate is 2–3 cm of leaf litter over muck that is at least 15 cm deep. Some of the twayblades were standing in flowing water; others were on moist moss (cf. *Mnium*). Other associated plants were rough sedge (*Carex scabrata*), an aster (*Aster* cf. *puniceus*), long beech fern (*Phegopteris connectilis*), peat moss (*Sphagnum* spp.), sweet-scented bedstraw (*Galium triflorum*), and dwarf enchanter's nightshade (*Circaea alpina*), with peat moss and *L. convallarioides* the dominant species. Water bars drain a hiking trail into the lower part of the seep, but do not seem to affect the area where *L. convallarioides* is growing. The EO rank is AB.

**NH .006 (Randolph)** — This population of more than 100 plants in a seep near a cold stream was first seen in 1984. Observations in 1997 and 1999 were of just a few plants in two patches, with signs of herbivory or flood damage. Associated plants were zigzag goldenrod (*Solidago flexicaulis*), lady-fern (*Athyrium filix-femina*), mountain maple (*Acer spicatum*), and rough bedstraw (*Galium asprellum*). The surrounding community includes yellow birch (*Betula alleghaniensis*), red spruce (*Picea rubens*), striped maple (*Acer pensylvanicum*), Pennsylvania bitter-cress (*Cardamine pensylvanica*), tall meadow-rue (*Thalictrum pubescens*), drooping woodreed (*Cinna latifolia*), mosses, and liverworts. The 1998 ice storm caused heavy damage to the canopy. The EO rank is A.

**NH .009 (Stark)** — This small population in a cool, seepy ravine was first recorded in 1991. At the time, 11 *L. convallarioides* were found, none in flower. A survey on 23 June 2001 turned up 28 plants, none in flower. The habitat and leaf morphology leave little doubt that the orchid is indeed *L. convallarioides*, but no flowering stem has yet been found to confirm that

identification. The associated plants (typical in other *L. convallarioides* sites) were long beech fern (*Phegopteris connectilis*), moss (cf. *Mnium*), dwarf enchanter's nightshade (*Circaea alpina*), northern three-lobed bedstraw (*Galium trifidum*), common wood-sorrel (*Oxalis montana*), lady-fern (*Athyrium filix-femina*), oak fern (*Gymnocarpium dryopteris*), twisted stalk (*Streptopus amplexifolius*), drooping woodreed (*Cinna latifolia*), sweet white violet (*Viola blanda*), false hellebore (*Veratrum viride*), and an aster (*Aster* cf. *macrophyllus*). The population hugs a trail used by humans and moose, and is at risk from trampling by both. At an August visit in 2001, part of the area where the plants were growing looked as though it had been used as a seat by hikers. A search in suitable habitat for a nearby subpopulation that might serve as a seed source for this flowerless group was unsuccessful. A more determined rock climber might have better luck, however. The EO rank is C.

**NH .010 (Stratford)** — This large population was seen once, in 1988, in the headwaters of a mountain stream among cold, mossy seeps. The plants were a dense crowd, mostly vegetative, with occasional fertile plants. The area showed signs of logging and snowmobile use. The EO rank is C.

**NH .011 (Stratford)** — This large population was seen once, in 1988, on a different slope from NH .010, in the headwaters of a mountain stream among cold, mossy seeps. The plants were a dense group, mostly vegetative, with occasional fertile plants. The area showed signs of logging and snowmobile use. This occurrence may be close enough to .010 to be considered the same population. The EO rank is C.

**NH .012 (Pittsburg)** — Very little is known about this 1955 collection from Lake Francis State Park. It is reported in Pease 1964.

**NH .013 (Pittsburg)** — Very little is known about this 1907 collection from Connecticut Lakes State Forest. It is reported in Pease 1964.

**NH .014 (Colebrook)** — Very little is known about these 1917 and 1935 observations. They are reported in Pease 1964. The EO rank is H.

**NH .015 (Colebrook)** — Very little is known about this record. The 1907 site in a cedar bog is reported in Pease 1964. The EO rank is H.

**NH .016 (Carroll)** — Very little is known about this record. The 1909 site is reported in Pease 1964. The EO rank is H.

**NH .017 (Sargent's Purchase)** — This large population in an acidic Sphagnum seep was first discovered in 1987, when it had 50+ plants. In 1997, it had 100+ plants, and in 2001, it had 1,000+ plants. The surrounding forest is northern hardwood–spruce–fir. The plants closest to the dense colony of *Listera convallarioides* were peat moss (*Sphagnum* spp.), mosses (cf. *Mnium*), twisted stalk (*Streptopus amplexifolius*), dwarf enchanter's nightshade (*Circaea alpina*),

whorled aster (*Aster acuminatus*), and another aster (*Aster* cf. *puniceus*). *Listera convallarioides*, peat moss, and mosses dominated part of this seep, with most of the orchids growing on a slope running at least 15 m uphill. Other parts of the seep had a considerable population of rough sedge (*Carex scabrata*). Part of the seep runs parallel to a popular hiking trail. The trail has been moved away from the seep, but the old track was still being used occasionally in June 2001. Two other New Hampshire rarities, heart-leaved twayblade (*Listera cordata*) and northern wild-licorice (*Galium kantschaticum*), appear downslope from the *L. convallarioides*, even closer to the trail. The EO rank is AB.

**NH .018 (Stark)** — This population of hundreds of plants was found in a northern white cedar swamp in 1997. About 30% of the plants had immature capsules. They were growing in muck with northern white cedar (*Thuja occidentalis*), heart-leaved twayblade (*Listera cordata*), tall white bog orchid (*Platanthera dilata*), wood sorrel (*Oxalis* sp.), bunchberry (*Cornus canadensis*), blunt-leaved orchid (*Platanthera obtusata*), peat moss (*Sphagnum* sp.), and bedstraw (*Galium* sp.). The forest nearby is actively being logged. The EO rank is A.

**NH new (Colebrook)** — This population of several hundred plants is scattered along a hillside seep in a transitional montane spruce-fir forest. In August 2001, about 20% of the plants had immature capsules. They were growing in muck among northern wild-licorice (*Galium kantschaticum*), drooping woodreed (*Cinna latifolia*), peat moss (*Sphagnum* spp.), long beech fern (*Phegopteris connectilis*), northern gooseberry (*Ribes oxycanthroides*), false hellebore (*Veratrum viride*), New England aster (*Aster novae-angliae*), and foam-flower (*Tiarella cordifolia*). The dominant species are northern wild-licorice, peat moss, and long beech fern. The forest is young second growth and is now part of a nature preserve. The EO rank is A.

## CURRENT CONSERVATION MEASURES IN REGION 9

Two states in Region 9 list *Listera convallarioides* as Threatened: Wisconsin and New Hampshire. In Wisconsin, this designation prohibits taking of plants from another's land or from public lands, except in the course of forestry, agriculture, or utility activity (Wisconsin Department of Natural Resources 2001). I have been unable to get details on the five extant sites in Wisconsin or their protection status.

The three extant sites in the White Mountain National Forest in New Hampshire are being protected by rerouting trails and by buffering the seepy habitats from trail maintenance operations and logging. Forest Service staff have been monitoring presence of the plant. Two other sites in New Hampshire are protected on privately owned conservation land. Another site is owned by a town and is protected as part of its water supply. One site in a State Forest and another on private land are vulnerable to logging operations. State agencies are not compelled to follow the Natural Heritage recommendations, however, because *L. convallarioides* is on New Hampshire's list of rare plants, I recommend consulting the New Hampshire Natural

Heritage Inventory regarding measures to preserve the species before starting any new project (New Hampshire Code of Administrative Rules, Res-N 303.03).

## CONSERVATION

Conservation Objectives for *LISTERA CONVALLARIOIDES* in REGION 9

In its entire range, *Listera convallarioides* is widespread and secure. At the limits of its range in U.S. Forest Service Region 9, however, pressure on *L. convallarioides* habitat threatens its persistence.

The conservation objectives for *L. convallarioides* in Region 9 are to buffer habitats that harbor *L. convallarioides* (mostly northern white cedar swamps and forest seeps) from logging and recreational use, to discover what the orchid prefers in its habitat, and to search for extant populations in likely habitat, and perhaps in historical sites. The goal is to protect wetlands where *L. convallarioides* is known to be, to conserve the four good-quality populations (800+ plants) in New Hampshire and to search for and protect four or five more good-quality populations. The population size is based on Natural Heritage rankings (Chase 2001) and reports of stable populations in provinces and states where the orchid is not rare. The number of populations is an estimate of what it will take to maintain the orchid's presence in this part of its range, based on the number of historical and present occurrences.

## GENERAL CONSERVATION ACTIONS FOR *LISTERA CONVALLARIOIDES*

1. **Contact landowners** and inform them of the species' status. Get permission to monitor sites and conduct research.
2. **Ensure that trail maintainers and logging operators know to protect seepy habitat** in harvest areas and along trails. Follow best practices for sensitive areas.
3. **Study habitat preferences.** This information would aid the search for new populations and focus on areas that would benefit from protection.
4. **Search for historical populations and new populations** in likely habitat. Collect detailed information, including size, condition, trends, associated species, landscape context, and threats.
5. **Institute regular monitoring** of extant sites to collect population data. This information can be used to head off possible threats to extant populations.

## Landowner Communications

Contact landowners and ask for permission to monitor or search for *Listera convallarioides*. Let them know the habitat needs of the plant (so far as we know them) and encourage them not to interfere with hydrology while logging or clearing land. In many cases, reasonable protection may involve nothing more than formalizing good forestry practices that are already in use.

## Sensitive Land Use

Preserving *L. convallarioides* requires logging and trail-maintenance practices that will be least damaging to the hydrology that supports its habitat. Sensitive-species status in the National Forests mandates individual site plans prior to ground-disturbing activity. Undisturbed forest floor, soil moisture, and canopy are essential to shade-loving plants, giving them an edge over competitors (Carlson 1999). The plans should designate an appropriate buffer zone (minimum of 30 meters; the exact width depends on site conditions) with no logging or with selective thinning only (Chase et al. 1995, Thompson and Sorenson 2000). They should minimize or avoid hydrological and canopy changes that result from trail and road building or maintenance (Chase et al. 1995, Carlson 1999).

## Habitat and Species Biology

Searching for new populations presupposes an accurate description of *L. convallarioides* preferred habitat. Studying populations in states where the orchid is not rare (e.g., Vermont, Maine) might help answer these questions:

What type of habitat is most likely to harbor populations?

How does slope, with its effect on water velocity and hence substrate and water depth, affect populations?

What range of water pH, alkalinity, and temperature does *L. convallarioides* enjoy? How is it dispersed between patches of habitat?

Does it need perennial water or can it tolerate dry periods?

Hall et al. (2001) found that environmental influences that correlated with plant species in a seep are pH, concentration of major ions, percentage of open water, and substrate height above the water table. Although growing conditions for northern white cedar are fairly well defined (Johnston 1990, Sperduto and Engstrom 1998, Thompson and Sorenson 2000), the microhabitat for *L. convallarioides* could use clarification.

It would also be useful to discover whether *L. convallarioides* has a variety of pollinators, to rule out dependence on a single, perhaps vulnerable, insect. More knowledge about the fungus

that sometimes attacks *L. convallarioides* might let us know whether it affects long-term survival of a population.

### **Searching for Occurrences**

Searching for new populations in likely habitat should emphasize sites at a distance from trails and in wilderness areas. In the White Mountain National Forest, this means forested seeps at elevations between 1,200 and 3,500 feet (360 and 1100 m), as there is little northern white cedar habitat in the forest (Sperduto and Engstrom 1998). Good spots for seeps are stream headwaters, the base of steep slopes, and benches on the side of a mountain. Elsewhere in New Hampshire, northern white cedar swamps are also likely habitat. At a new site, surveyors should collect detailed information, including size of the population, condition, associated species, landscape context, and threats.

*Listera convallarioides* is not rare in Vermont and Maine, so why is it threatened in New Hampshire? A comprehensive survey of sites in Vermont and Maine might shed light on *L. convallarioides* distribution in New England.

### **Monitoring Populations**

It may be possible to monitor population demography annually. Information on seed production and seedling establishment could be used to head off possible threats to extant populations. These data could tell us whether *L. convallarioides* appears in different places year to year, stays put, or does not appear in some years, like many orchids (Rasmussen and Whigham 1998, Gillman and Dodd 1998). At many sites, however, monitoring should be limited to estimation or presence/absence, to protect the habitat from trampling (Elzinga et al. 1999).

## **RECOMMENDED CONSERVATION ACTIONS FOR EACH OCCURRENCE**

### **New Hampshire**

**NH .001 (Dixville Notch)** — It seems unlikely, without more details, that this population can be relocated. Perhaps a de novo search, based on local knowledge and topographic maps, would be successful.

**NH .002 (Dummer)** — It seems unlikely, without more details, that this population can be relocated. Perhaps a de novo search, based on local knowledge and topographic maps, would be successful.

**NH .003 (Pittsburg)** — *Listera convallarioides* was last seen here in 1973. The site was described accurately enough to make searching for an extant population a reasonable option.



Get landowner permission to search. If a population is discovered, collect detailed site information and evaluate its conservation potential.

**NH .004 (Franconia)** — *Listera convallarioides* was last seen here in 1888. The Mount Lafayette alpine area has been damaged by hikers, but *L. convallarioides* populations would most likely be at lower elevations. Study of the topographic maps for the area might indicate likely habitat for a search.

**NH .005 (Bethlehem)** — Assess current water bars and trail maintenance to decide whether a new approach is necessary (e.g., stepping stones, rerouting trail). Monitor the population annually, if possible, to collect demographic information. Observe pollinators in the spring and dispersal agents during seed dispersal.

**NH .006 (Randolph)** — Make sure the landowner is aware of the status of the plant and its location on the property. With permission, monitor annually and collect demographic data, to follow the population's reaction to canopy change.

**NH .009 (Stark)** — Search surroundings thoroughly for a larger, reproductive population. If possible, reroute the trail farther from the *L. convallarioides* population or try to encourage hikers to sit in a different spot. Continue monitoring by White Mountain National Forest staff and collect demographic data.

**NH .010 (Stratford)** — Make sure the landowner is aware of the status of the plant and its location on the property. With permission, collect detailed information, including size of the population, condition, associated species, landscape context, and threats. Determine if this occurrence is the same population as NH.011 (that is, if they are within 1 kilometer of each other).

**NH .011 (Stratford)** — Make sure the landowner is aware of the status of the plant and its location on the property. With permission, collect detailed information, including size of the population, condition, trends, associated species, landscape context, and threats. Determine if this occurrence is the same population as NH.010.

**NH .012 (Pittsburg)** — It seems unlikely, without more details, that this population can be relocated. Perhaps a de novo search, based on local knowledge and topographic maps, would be successful.

**NH .013 (Pittsburg)** — It seems unlikely, without more details, that this population can be relocated. Perhaps a de novo search, based on local knowledge and topographic maps, would be successful.

**NH .014 (Colebrook)** — *Listera convallarioides* was last seen here in 1935. The site was described accurately enough to make searching for an extant population a reasonable option.

Get landowner permission to search. If a population is discovered, collect detailed site information and evaluate its conservation potential.

**NH .015 (Colebrook)** — It seems unlikely, without more details, that this population can be relocated. Perhaps a de novo search, based on local knowledge and topographic maps, would be successful.

**NH .016 (Carroll)** — It seems unlikely, without more details, that this population can be relocated. Perhaps a de novo search, based on local knowledge and topographic maps, would be successful.

**NH .017 (Sargent's Purchase)** — Make the adjacent, old trail less accessible to hikers. Continue monitoring by White Mountain National Forest staff and collect demographic data. Observe pollinators in the spring and dispersal agents during seed dispersal.

**NH .018 (Stark)** — Make sure the landowner is aware of the status of the plant and its location on the property. Investigate the likelihood of logging that might threaten the habitat, and discuss with the owner the necessity of protecting the water regime and canopy at the site. With permission, monitor the population every five years.

**One new site (2001)** — Monitor the population annually, if possible, to collect demographic information. Observe pollinators in the spring and dispersal agents during seed dispersal.

### **Prioritized Implementation Table**

The prioritized implementation table (Table 3) lists and ranks actions that should be undertaken in order to implement the conservation plan for *Listera convallarioides*. The schedule is subject to revision based on annual review of conservation objectives. Conservation actions are arranged in priority order based on the following definitions:

**Priority 1** — An action that should be taken to prevent irreversible declines in the species' status in Region 9.

**Priority 2** — An action that should be taken to prevent or reverse significant declines in the species' status in Region 9.

**Priority 3 and 4** — All other actions necessary to meet the conservation objectives.

As landowner contact is required for each site to gain site access and permission to perform other research activities, it is considered a priority action and is not listed separately for each occurrence unless special circumstances exist. Conservation activities will take place only with landowner permission.

**Table 3. Prioritized implementation table for *Listera convallarioides*. Landowner permission is prerequisite to these actions.**

No action should be undertaken without the review of conservation professionals and the prior consultation and consent of state Natural Heritage Progra

State	EO #	Town	First Priority	Second Priority	Third Priority	Fourth Priority
NH	.001	Dixville Notch				Search likely habitat
NH	.002	Dummer				Search likely habitat
NH	.003	Pittsburg			Search likely habitat	
NH	.004	Franconia			Search likely habitat	
NH	.005	Bethlehem	Assess trail maintenance and adjust if necessary	Monitor and collect demographic data		Observe at pollination and dispersal times
NH	.006	Randolph	Make landowner aware of plant			
NH	.009	Stark	Search for source population	Steer hikers away from population; monitor population		
NH	.010	Stratford	Make landowner aware of plant	Make detailed survey		
NH	.011	Stratford	Make landowner aware of plant	Make detailed survey		
NH	.012	Pittsburg				Search likely habitat
NH	.013	Pittsburg				Search likely habitat
NH	.014	Colebrook			Search likely habitat	
NH	.015	Colebrook				Search likely habitat
NH	.016	Carroll				Search likely habitat
NH	.017	Sargent's Purchase	Make old trail less accessible	Monitor and collect demographic data		Observe at pollination and dispersal times
NH	.018	Stark	Make landowner aware of plant	Investigate logging threat; discuss habitat protection		Monitor every 5 years
NH	new	Colebrook		Monitor and collect demographic data		Observe at pollination and dispersal times

## ACKNOWLEDGMENTS

For their help in working out this plan, I would like to thank George Argus for making the manuscript of the *Listera* chapter of *Flora of North America* available; staff of the White Mountain National Forest, especially Leighlan Prout; Everett Marshall of the Vermont Nongame and Natural Heritage Program; the Wisconsin Natural Heritage Program; the New York Natural Heritage Program; and the New Hampshire Natural Heritage Inventory. Comments from two anonymous reviewers helped me improve the plan. Many thanks to Bill Nichols of the New Hampshire Natural Heritage Inventory for comments and advice on this report.

## LITERATURE CITED

- Ackerman, J. D., and M. R. Mesler. 1979. Pollination biology of *Listera cordata* (Orchidaceae). *American Journal of Botany* 66: 820–824.
- Brackley, F. E. 1985. The orchids of New Hampshire. *Rhodora* 87: 1–117.
- Brown, P. M. 1997. *Wild Orchids of the Northeastern United States*. Cornell University Press, Ithaca, New York, USA.
- Carlson, B. D. 1999. *Threatened and Endangered Species in Forests of Maine: A Guide to Assist with Forestry Activities*. Edited by J. M. Sweeney. Champion International. Distributed by UMCE State Communications Office, Orono, Maine, USA.
- Case, F. W., Jr. 1964. A hybrid twayblade and its rarer parent, *Listera auriculata*, in northern Michigan. *Michigan Botanist* 3: 67–70.
- Case, F. W., Jr. 1987. *Listera*. Pages 130–143 in *Orchids of the Western Great Lakes region*. Revised edition. Cranbrook Institute of Science, Bloomfield Hills, Michigan, USA.
- Catling, P. M. 1976. On the geographical distribution, ecology, and distinctive features of *Listera × veltmanii* Case. *Rhodora* 78: 261–269.
- Chamisso, A. 1828. *Listera* R. Br. *Linnaea* 3: 33–34.
- Chase, V. P. 2001. Ranking specifications for rare plant species that occur in areas impacted by the 1998 ice storm. In K. F. Crowley and B. D. Kimball, Evaluation of rare plant populations and exemplary natural communities in areas impacted by the 1998 ice storm in New Hampshire, final report. New Hampshire Natural Heritage Inventory, Department of Resources and Economic Development, Concord, New Hampshire, USA.

Chase, V. P., L. S. Deming, and F. Latawiec. 1995. Buffers for wetlands and surface waters: A guidebook for New Hampshire municipalities. Audubon Society of New Hampshire, Concord, New Hampshire, USA.

Cody, W. J., and D. Munro. 1980. The genus *Listera* (twayblades) in New Brunswick. *Canadian Field-Naturalist* 94: 443–446.

Coleman, R. A. 1995. *The Wild Orchids of California*. Cornell University Press, Ithaca, New York, USA.

Coleman, R. A., and L. K. Magrath. In preparation. *Listera* chapter for *Flora of North America: North of Mexico*. Unpublished manuscript.

Correll, D. S. 1950. *Native Orchids of North America: North of Mexico*. Chronica Botanica Company, Waltham, Massachusetts, USA.

Dressler, R. L. 1993. *Phylogeny and Classification of the Orchid Family*. Dioscorides Press, Portland, Oregon, USA.

Elliott, S. 1824. *Sketch of the Botany of South-Carolina and Georgia*. Volume 2. Schenck, Charleston, South Carolina, USA.

Elzinga, C. L., D. W. Salzer, and J. W. Willoughby. 1999. *Measuring and Monitoring Plant Populations*. BLM Technical Reference 1730-1. Bureau of Land Management, Denver, Colorado, USA.

Gillman, M. P., and M. E. Dodd. 1998. The variability of orchid population size. Pages 65–71 in S. Waite (Editor), *Orchid Population Biology, Conservation, and Challenges*. London, Linnaean Society, UK.

Gleason, H. A., and A. Cronquist. 1991. *Manual of Vascular Plants of Northeastern United States and Adjacent Canada*. Second Edition. New York Botanical Garden, Bronx, New York, USA.

Hall, B. R., D. J. Raynal, and D. J. Leopold. 2001. Environmental influences on plant species composition in ground-water seeps in the Catskill Mountains of New York. *Wetlands* 21: 125–134.

Halpin, P. N. 1997. Global climate change and natural-area protection: Management responses and research directions. *Ecological Applications* 7: 828–843.

- Hansen, A. J., R. P. Neilson, V. H. Dale, C. H. Flather, L. R. Iverson, D. J. Currie, S. Shafer, R. Cook, and P. J. Bartlein. 2001. Global change in forests: Responses of species, communities, and biomes. *BioScience* 51: 765–779.
- Hapeman, J. R. 2000. *Listera convallarioides* (Sw.) Nutt. Orchids of Wisconsin: An interactive flora. Available at [http://www.wisc.edu/botany/Orchids/Orchids\\_of\\_Wisconsin.html](http://www.wisc.edu/botany/Orchids/Orchids_of_Wisconsin.html).
- Harrison, S., J. Maron, and G. Huxel. 2000. Regional turnover and fluctuation in populations of five plants confined to serpentine seeps. *Conservation Biology* 14: 769–779.
- House, H. D. 1905. Further notes on the orchids of central New York. *Bulletin of the Torrey Botanical Club* 32: 373–382.
- Hoy, J. M. 2001. *Listera auriculata* (auricled twayblade) Conservation and Research Plan. New England Wild Flower Society, Framingham, Massachusetts, USA.
- Hoy, J. M. 2002. *Listera cordata* (heart-leaved twayblade) Conservation and Research Plan for U.S. Forest Service Region 9. New England Wild Flower Society, Framingham, Massachusetts, USA.
- Hunter, M. L., Jr. 1993. Of puffins and parochialism: Why is it important to conserve species that are locally rare, but globally common? *Maine Naturalist* 1: 39–42.
- Johnston, W. F. 1990. *Thuja occidentalis* L., northern white cedar. Pages 580–589 in R. M. Barnes and B. H. Honkala, *Silvics of North America*. Volume 1, *Conifers*. U.S. Government Printing Office, Washington, DC, USA.
- Josselyn Botanical Society of Maine. 1995. The Checklist of the Vascular Plants of Maine. Bulletin 844. Maine Agricultural and Forest Experiment Station, Orono, Maine, USA.
- Marie-Victorin, Frère. 1995. *Flore Laurentienne*. University of Montreal Press, Quebec, Canada.
- McCarty, J. P. 2001. Ecological consequences of recent climate change. *Conservation Biology* 15: 320–331.
- Minnesota Department of Natural Resources, Natural Heritage Program. 1993. Minnesota's native vegetation: A key to natural communities. Version 1.5. Minnesota Department of Natural Resources, St. Paul, Minnesota, USA.
- NatureServe. 2001. An on-line encyclopedia of life. *Listera convallarioides*. Association for Biodiversity Information, Arlington, Virginia, USA. Available at <http://www.natureserve.org>.

Nieuwland, J. A. 1913. An older name for *Listera*. *American Midland Naturalist* 3: 128–129.

Nylander, O. O. 1921. The orchids of northern Maine: Part 2. *Maine Naturalist* 1: 64–69.

Pease, A. S. 1964. *A Flora of Northern New Hampshire*. New England Botanical Club, Cambridge, Massachusetts, USA.

Rasmussen, H. N. 1995. *Terrestrial Orchids: From Seed to Mycotrophic Plant*. Cambridge University Press, Cambridge, UK.

Rasmussen, H. N., and D. F. Whigham. 1998. The underground phase: A special challenge in studies of terrestrial orchid populations. Pages 49–64 in S. Waite (Editor), *Orchid Population Biology, Conservation, and Challenges*. London, Linnaean Society, UK.

Reddoch, J. M., and A. H. Reddoch. 1997. The orchids in the Ottawa District: Floristics, phytogeography, population studies, and historical review. *Canadian Field-Naturalist* 111: 1–183.

Smith, W. R. 1993. *Orchids of Minnesota*. University of Minnesota Press, Minneapolis, USA.

Sperduto, D. D., and B. Engstrom. 1998. Northern white cedar swamps of New Hampshire. New Hampshire Natural Heritage Inventory and Nature Conservancy, Eastern Region, Boston, Massachusetts, USA.

Swartz, O. P. 1800. *Kongl. Vetenskaps Academiens nya Handlingar* 21: 232.

Thompson, E. H., and E. R. Sorenson. 2000. *Wetland, Woodland, Wildland: A Guide to the Natural Communities of Vermont*. Vermont Department of Fish and Wildlife and the Nature Conservancy, Hanover, New Hampshire, USA.

Vinogradova, T. N. 1996. The early stages of *Listera cordata* (L.) R. Br. development in natural conditions. *Moskovskoe Obshchestvo i Spya Telei Prirody Biulletin*, NS otd. 101: 83–92. Summary in English.

Voss, E. G. 1972. *Michigan Flora. Volume I, Monocots and Gymnosperms*. Cranbrook Institute of Science and University of Michigan Herbarium, Bloomfield Hills, Michigan, USA.

Wisconsin Department of Natural Resources. 2001. Summary of administrative rule NR 27: Endangered and threatened species. Available at <http://www.dnr.state.wi.us>.

## APPENDICES

### 1. Personal Communication References

### 2. Key to *Listera* Species in U.S. Forest Service Region 9

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

#### Personal Communication References

Frederick W. Case, Jr.  
7275 Thornapple Lane  
Saginaw, Michigan 48609 USA

Everett Marshall  
Nongame and Natural Heritage Program  
Vermont Department of Fish and Wildlife  
103 South Main Street  
Waterbury, Vermont 85671 USA

#### Key to *Listera* Species in U.S. Forest Service Region 9

Adapted from Coleman and Magrath (in preparation) and Case (1987). Habitats are for Region 9.

1. Lip deeply cleft into pointed, linear lobes.....2.
1. Lip expanded at apex, or, if cleft, with rounded lobes.....3.
  2. Lip with basal lobes (auricles) rounded and curved back, partly surrounding the column; moist woods, peatlands .....*L. australis*
  2. Lip with basal lobes pointed and projecting outward like horns, away from the column; wet woods, northern white cedar swamps .....*L. cordata*
3. Lip about as broad at the apex as at the base; banks of streams and rivers, shores of large lakes.....*L. auriculata*
3. Lip broader at the apex than at the base.....4.
  4. Lip with a short claw (lip appearing stalked).....5.
  4. Lip with no claw (lip sessile) .....6.



- 5. Base of lip with inconspicuous triangular tooth on each side; lip slightly notched; rich humus in open woods, forest seeps.....*L. convallarioides*
- 5. Base of lip with distinct lobe on each side; lip deeply notched.....*L. × veltmanii*
- 6. Lip angled downward; base of lip without lobe; moist, rich areas, disturbed sites .....*L. ovata*
- 6. Lip not angled downward; base of lip with two lobes; shady, moist Appalachian forests.....*L. smallii*

### **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 been made for more than 20 years. An X rank is utilized for sites that are known to be extirpated. Not all EOs have received such ranks in all states, and ranks are not necessarily consistent among states as yet.

