

New England Plant Conservation Program
Conservation and Research Plan

Diphasiastrum sitchense (Rupr.) Holub
Sitka Clubmoss

Prepared by:
Arthur V. Gilman
Marshfield, Vermont

For:

New England Wild Flower Society
180 Hemenway Road
Framingham, MA 01701
508/877-7630
e-mail: conserve@newfs.org • website: www.newfs.org

Through a cooperative agreement with the
United States Department of Agriculture, U. S. Forest Service
White Mountain National Forest

Approved, Regional Advisory Council, May 2001

SUMMARY

Sitka clubmoss, *Diphasiastrum sitchense* (Rupr.) Holub (Lycopodiaceae), is a low-growing perennial plant of alpine or exposed sub-alpine habitats in New England, with occasional lowland stations in far northern Maine, where it occurs in old fields and other successional habitats. Currently, it is known from one such site in northern Maine, from several sites on Katahdin, Maine, and from Mt. Washington and South Baldface Mountain in New Hampshire. One other population, on Mt. Adams, New Hampshire, has not been recently documented but is presumed to be extant. Three other populations (two from lowland sites in Maine and one from Mt. Monadnock, New Hampshire) are considered to be only historical. Many literature reports of Sitka clubmoss are erroneous, having been based on specimens of the closely related savin-leaved clubmoss (*D. sabinifolium*). Among these erroneous reports are all Vermont reports; this species apparently has never occurred in Vermont. Indeed, the review undertaken for this Plan indicates that Sitka clubmoss is much rarer in New England than was previously known.

This species may always have been a rare element of the native alpine flora of New England, and no population trends can be detected in the scant data available. No imminent threats to alpine sites have been identified, but general threats such as hiker trampling and trail erosion should be guarded against. The one lowland site should be managed to prevent forest succession, vehicular traffic, and other potential threats.

The primary goal for this species is to maintain existing populations within the alpine and sub-alpine zone in particular. To accomplish this, a more complete inventory of the available habitat is critical; information about microhabitat characteristics and plant population biology is also necessary. It is particularly important to recognize recruitment sites and the level and types of disturbance that make sites available for colonization. This species should be added to the New Hampshire list of threatened or endangered species. Educational material should be made available to Baxter State Park naturalists and officials, to White Mountain National Forest botanists and officials, to the U.S. Fish and Wildlife Service, and to a wider public as well. Plant reintroduction is not considered feasible at this time.

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) 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:

Gilman, Arthur V. 2001. *Diphasiastrum sitchense* (Rupr.) Holub (Sitka clubmoss) Conservation and Research Plan. New England Wild Flower Society, Framingham, Massachusetts, USA. <http://www.newsfl.org>

© 2001 New England Wild Flower Society

I. BACKGROUND

INTRODUCTION

Sitka clubmoss, *Diphasiastrum sitchense* (Rupr.) Holub, also long known as *Lycopodium sitchense* Rupr. is a member of the fern-ally family, Lycopodiaceae. It is listed in *Flora Conservanda* New England (Brumback and Mehrhoff et al. 1996) as a Division 2 or regionally rare species on the basis of one extant station in Maine, one historical station in Vermont, and an undetermined number of stations in New Hampshire. In Maine and Vermont, Sitka clubmoss is listed as an endangered species; it is not, however, tracked by the New Hampshire Natural Heritage Inventory. Since *Flora Conservanda* was published, one additional station has been found in Maine, and a clearer picture of how many New Hampshire stations are extant has emerged. Vouchers for the Vermont station have been examined and determined to be misidentified; the species is therefore excluded from the flora of Vermont.

DESCRIPTION

Sitka clubmoss is a short, 5cm – 10cm (2 – 4 inch) tall, ground-hugging plant of mossy, fine-textured appearance (see photos in Tryon and Moran 1998; Lellinger 1985). In comparison with other clubmosses (versus nonvascular true mosses and seed-bearing, flowering plants), it is relatively easy to identify on the basis of the following characters:

- **Spore-cases in cones** (strobili) at tips of branches
- **Peduncles of the cones absent** or $\leq 1\text{cm}$ (0.4") in length vs. usually present, often $\geq 1\text{cm}$ (0.4") in *D. sabinifolium* and always present in other *Diphasiastrum* species
- **Leaves arranged in whorls of 5** vs. 4 in other *Diphasiastrum* species and 8 in *Lycopodium annotinum* var. *pungens*
- **Leaves spreading**, not appressed to axis more than 0.1 of their length vs. ≥ 0.3 in *D. sabinifolium* and ≥ 0.5 in other taxa
- **Stem and branches terete (round)** vs. flattened and dorsiventral in other *Diphasiastrum* species.

Sitka clubmoss is easily confused with savin-leaved clubmoss (*D. sabinifolium* (Willd.) Holub), which is considered (Wilce 1965) to be of hybrid origin with Sitka clubmoss as one parent and groundcedar clubmoss (*D. tristachyum* (Pursh) Holub) as the other. Savin-leaved clubmoss has a similar, fine-textured, "needle-leaved" appearance, which is derived from its Sitka clubmoss parent. The most readily observed characteristics that distinguish the two are the 5-ranked leaves and the terete branches of Sitka clubmoss. Savin-leaved clubmoss has 4-ranked leaves on dorsiventral branches. Nevertheless, their similarity is the cause of much

confusion in literature reports. Many such reports (e.g., Pease 1924, Dole 1937, Scamman 1947, Pease 1964, Seymour 1969, Campbell and Eastman 1980, Critical Areas Program 1981, Seymour 1982, Critical Areas Program 1985) and many Natural Heritage (Natural Areas) Program Element Occurrence Records are based on misidentified specimens of *D. sabinifolium* (Appendix 2). Studies undertaken for this Plan revealed that, with such erroneous records excluded, *D. sitchense* is much rarer than has been shown in New England botanical literature.

In the alpine zone, *D. sitchense* might also be confused with bristly clubmoss (*Lycopodium annotinum* L. var. *pungens* (LaPylaei) Desv.). As pointed out by Harris et al. (1964), however, bristly clubmoss has leaves in whorls of 8 (5 in Sitka clubmoss) and has stiffly pointed leaves (soft and more or less flexible leaves in Sitka clubmoss).

TAXONOMIC RELATIONSHIPS, HISTORY, AND SYNONYMY

Sitka clubmoss was originally described as a typical clubmoss of the genus *Lycopodium* (Ruprecht 1845) and only recently has been transferred to the segregate genus *Diphasiastrum* (Holub 1975). In North America, the genus *Diphasiastrum* has been accepted as a segregate of *Lycopodium* (Wagner and Beitel 1990), although some systematists (Øllgaard 1990) continue to recognize the group as section *Complanata* of *Lycopodium* (Victorin 1925, Wilce 1965).

The genus consists of a small (ca. 15) number of species, occurring primarily in boreal and north-temperate regions, but occurring as far south as the tropics in mountainous regions of Central America, Southeast Asia, and even South Africa. Wilce (1965) postulated a Himalayan/ East Asian origin for the group. The north-temperate and boreal species have been extensively studied (Victorin 1925, Wilce 1965, Beitel 1979, Wagner and Beitel 1994). Currently, four species, one rare but well-known hybrid (*D. sabinifolium*), and several other hybrids are known in New England.

Farwell (1916) considered the taxon *sitchense* to be a variety of the wide-ranging *Lycopodium complanatum* L., but this disposition was not widely accepted and seems unlikely. Fernald (1923) considered it to be a variety of *D. sabinifolium*, based primarily on “the tendency to dorsiventral branchlets and looser habit being found in the plant which is more characteristic of woods and thickets, the tendency to more terete branchlets and compact habit in the plant which more often occurs in the open.” The fact that Willdenow based his name (*sabinifolium*) on a mixed collection was taken as further evidence by Fernald (1923) that he (Willdenow) “did not regard [the two taxa] as distinct species.” Wilce (1965) and Beitel (1979), however, presented extensive morphological evidence that *sitchense* is not a variety of *sabinifolium*. Wilce (1965) postulated that *sabinifolium* is a hybrid having *sitchense* as one of its progenitors. This close relationship results in a close resemblance between the two, and is likely the cause of confusion as to the identity of New England populations. Recent taxonomists

(Lellinger 1985, Wagner and Beitel 1994) have not questioned that taxon *sitchense* is a valid species. Taxon *sabinifolium*, whatever its origin, also meets morphological, biological, and evolutionary tests as a species, and is accepted as such in this treatment.

Based on its 5-ranked, non-appressed leaves and terete branches (vs. 4-ranked, appressed leaves on flattened or complanate branches), *D. sitchense* has been considered primitive within the genus (Victorin 1925, Wilce 1965). This hypothesis has not, however, been tested with molecular data.

SPECIES BIOLOGY

Like ferns and other fern-allies, *D. sitchense* reproduces by spores and has independent gametophyte and sporophyte generations. Upon germination, a spore produces a small, subterranean, haploid gametophyte, which in turn produces female and male gametes (egg and sperm). Upon fusion (fertilization), a diploid sporophyte is formed, which is the large-bodied, above-ground plant.

Spore germination takes place only in the dark (Whittier 1981, Whittier and Britton 1995, Whittier 1998) and is presumably dependent on the spore migrating downward through interstices in the soil to a depth where light is excluded. The gametophyte is without chlorophyll, and its nutrition is dependent on a mycorrhizal association with an undetermined fungal partner. The dark requirement for germination “must be an advantage for gametophytes that need to encounter a soil-dwelling fungus with which to establish a relationship” (Sheffield 1996). Many spore-reproducing plants form a spore bank over time in undisturbed soils and germinate in response to disturbance as spores are exposed to light (Sheffield 1996), but the importance of disturbance events to lycopods seems to be that they allow spores to penetrate to a sufficient depth for germination and establishment. It is also possible that disturbance in some manner promotes mycorrhizal presence.

Gametophytes may grow relatively slowly and take several years to mature, although very little is known about this stage in nature (Whittier 1981). Sporophytes may appear several to many years after the first occurrence of a spore rain onto suitable habitat. For example, juvenile sporophytes of the closely related *D. digitatum* (Dill.) Holub have been observed at one site in central Vermont approximately 10 years after it was made available for colonization by scraping of topsoil from a hillside (A. Gilman, personal observation).

The breeding system is unknown, but published reports for other members of the genus (Soltis and Soltis 1988, Major and Ódor 1999) suggest that it is primarily outbreeding. Wagner et al. (1985) considered the occasional appearance of hybrids in pteridophytes with subterranean gametophytes to be evidence of significant outbreeding. Considering the prevalence of hybrids in *Diphasiastrum* (Wagner 1990), outbreeding seems to be likely.

However, the breeding system could also include crossing between two sibling gametophytes or crossing within the same gametophyte (intragametophyte breeding or selfing). Selfing would seem to be especially likely if there is rare long-distance dispersal of spores to relatively rare habitat patches – for example, if only one spore reaches a particular habitat. Because selfing of a haploid organism involves completely homologous chromosomes, it “is the most extreme form of inbreeding that can occur” (Holsinger 1990). Selfing and consequent lack of genetic variation may therefore have a significant “founder effect” in this species in its widely separated New England habitats. The consequences of rarity in *D. sitchense* in terms of population structure and the partitioning of variability (between or within populations), resulting from inbreeding in isolated populations at the edge of the species’ range, could be significant.

No studies of the age of *Diphasiastrum sitchense* clones have been undertaken. Oionnen (1967, 1968, both cited in Horn, 1997) found that clones of its congener *D. complanatum* (L.) Holub in Sweden may live to a great age, upwards of 800 years. The potential age of a particular clone is probably best regarded as indefinite, because vegetative expansion is limited only by habitat suitability. The growth pattern is capable of taking advantage of a micro-patchy habitat, in that the long-ranging rhizomes may surmount minor obstacles and pioneer patches unsuitable for other species. This has been termed a “guerilla” or “foraging” strategy (Callaghan et al. 1986) that allows a species to take advantage of empty habitat patches by invasion, with the forward-growing tips of the plant being supported by the well-established main body.

The population structure of New England populations is unknown. Major and Ódor (1999) found that, in the closely related *D. complanatum*, patches frequently contained more than one clone. Because the growth pattern of a single plant often results in a “fairy-ring” type of body, it is often assumed that a patch consists of a single clone. However, unless all parts are obviously radiating from a common center this cannot be assumed, especially given the tendency of the individual to live to great age, and to “re-invade” the center of the fairy ring.

During its lifetime, a particular clone may produce a phenomenal number of spores. Each sporangium, of which there are typically upwards of 50 in a given strobilus, and hundreds or thousands on each plant, can produce upwards of 500 spores. If sporulation occurs each year, then during a long lifetime, a particular clone may produce many millions of spores. Spore distribution has not been studied, but in ferns is highly correlated with proximity to the parent plant, with numbers falling off very rapidly with increasing distance (Dyer and Lindsay 1992, and references therein). In clubmosses, enough spores are probably produced to form a spore rain over a large region. Spore dispersal is no doubt enhanced by the open, often windy habitats typical of this plant. Therefore, the availability of colonizable sites is presumably the major limiting factor in *Diphasiastrum* biology. On primary evidence, however, establishment of new populations is a rare event, and there appears to be a reliance on vegetative (vs. sexual) propagation in this genus overall (Wagner 1990). Colonization and sporophyte establishment may require disturbance events, but conservation of existing populations may in turn require

long-term lack of disturbance. In the New England environment, this species appears to fit a pattern of :

- **Rare establishment in disturbed (or micro-disturbed) habitat patches** that are only ephemerally suitable for recruitment:
 - Disturbance in the alpine zone from frost-heaving; death of mat-forming plants,
 - Disturbance in lowland sites associated with abandonment of agriculture, logging roads, borrow-pits, power lines, etc.
- **Long-term presence in stable habitats** (alpine):
 - Indefinite vegetative spread but lack of specialized means of vegetative increase (such as bulbils)
 - Ability to thrive in micro-patchy environment via “foraging” growth strategy
- **Medium-term presence in successional habitats** (old fields):
 - Limit of vegetative increase determined by succession of fields to closed-canopy forest
- **Presence in only a fraction of seemingly suitable habitats:**
 - Many apparently suitable habitat patches occur but do not have this species

HABITAT/ECOLOGY

In the alpine zone, Sitka clubmoss occurs on slightly wind-sheltered slopes and flats, not on exposed ridges that are bare or nearly bare of snow in winter. Some sites are sheltered by adjacent topography, especially near but just below the heads of gullies. Such sites may be snowbank communities (sensu NH Natural Heritage Inventory and Maine Natural Areas Program). Some of the associated plants on Katahdin are common members of the alpine flora such as highland rush (*Juncus trifidus*) and three-toothed cinquefoil (*Sibbaldiopsis [Potentilla] tridentata*); others are more restricted plants of lee slopes such as mountain heath (*Phyllodoce caerulea*) and moss-plant (*Harrimanella [Cassiope] hypniodes*).

In sub-alpine and lowland boreal areas, it is a plant of semi-open (not full canopy) coniferous forests and grassy openings. Label data from various specimens from eastern Canada (MT) generally indicate dry, acidic soils, although some habitats are also noted as mossy or damp. Typical associates noted on herbarium labels and on Natural Heritage Program Element Occurrence records are lichens (often *Cladina*, reindeer moss) and heath plants such as Labrador tea (*Rhododendron [Ledum] groenlandicum*, rhodora (*R. canadense*) and sheep-laurel (*Kalmia angustifolia*). Black or white spruce (*Picea mariana*, *P. glauca*) are often noted nearby. Such plants are typical of acidic soils. No measurements of

soils preferred by this species are reported but other members of the genus are usually found in acidic to highly acidic soils of pH 3.0-5.0 (Horn 1997; Bennert 1999).

Oionnen (1967, cited in Horn 1997) was able to correlate ages of specific clones of the closely related *D. complanatum* with local history of fires, evidence that that species is able to colonize fire-opened habitat patches. Disturbance of forested habitat by fire may have provided suitable habitat for *D. sitchense* on Mt. Monadnock in southern New Hampshire, as that previously forested summit was burned numerous times in the 19th century (Baldwin 1974). Fire is a frequent disturbance factor in the boreal forest (Elliott-Fisk 1988), and at least one specimen seen (Canada: Quebec: Knob Lake, *Grayson 128*, 30 June 1953, MT!) has label data indicating it was collected in a “lichen-woodland area burned over about 30 years ago.”

THREATS TO TAXON

This species apparently has always been a rare component of the alpine vegetation of New England. No particular threat to it has been identified in the alpine zone. However, the plants may be subject to trampling, erosion caused by hikers, and similar factors. At sub-alpine and lowland sites, forest succession appears to be the most significant threat, although vehicles and gravel extraction may also pose threats.

DISTRIBUTION AND STATUS

General Status

Diphasiastrum sitchense is a globally secure boreal species occurring in appropriate habitats across northern North America, from Labrador to Alaska and the Aleutian Islands; it also occurs in Kamschatka (Wilce 1965). States and provinces in which it occurs are listed in Table 1, and its North American range is shown in Figure 1.

In eastern North America, the taxon reaches a southern range limit in northern New England, with most stations in the alpine and sub-alpine zone of the White Mountains (New Hampshire) and Katahdin (Maine), and lowland stations in northern Maine. One reported station in Vermont (Winslow 1911) is excluded based on a review of the supporting specimens (Gilman 2000). Sitka clubmoss is also known from the Adirondack Mountains of New York (House 1924, Mitchell and Tucker 1997) and along the north shore of Lake Superior (A. Gilman, personal observation), but a report from Michigan (Wilce 1965) was based on misidentified specimens (Beitel 1979). In the western U.S., it is known from Montana, Idaho, Washington, and Oregon, as well as Alaska (Wilce 1965). A variety, *D. sitchense* var. *nikoense* (Franch. & Sav.) Takeda, occurs in Japan and the Kurile Islands (Wilce 1965).

Table 1. Occurrence and status of Sitka clubmoss 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 (S1; T): 2 element occurrences (EOs) [4 EOs in error]	New Hampshire (SR); verified with this report	Vermont (E, SRF): See Appendix 2; Gilman (2000)	Not applicable
New York (S1; E): 4 EOs	Alaska (SR): Wilce (1965)	Michigan (SRF): Beitel (1979)	
Idaho (S2)	Washington (SR): Wilce (1965)	Yukon Territory (SR)	
Saskatchewan (S2)	Oregon (SR): Wilce (1965)	New Brunswick (SR)	
Prince Edward Island (S1?)	Montana (S3)	Quebec (SR)	
Alberta (S2)	British Columbia (S?)		
Manitoba (S1)	Ontario (S4)		
	Labrador (S4?)		
	Newfoundland (S3/S4)		
	Nova Scotia (S4)		

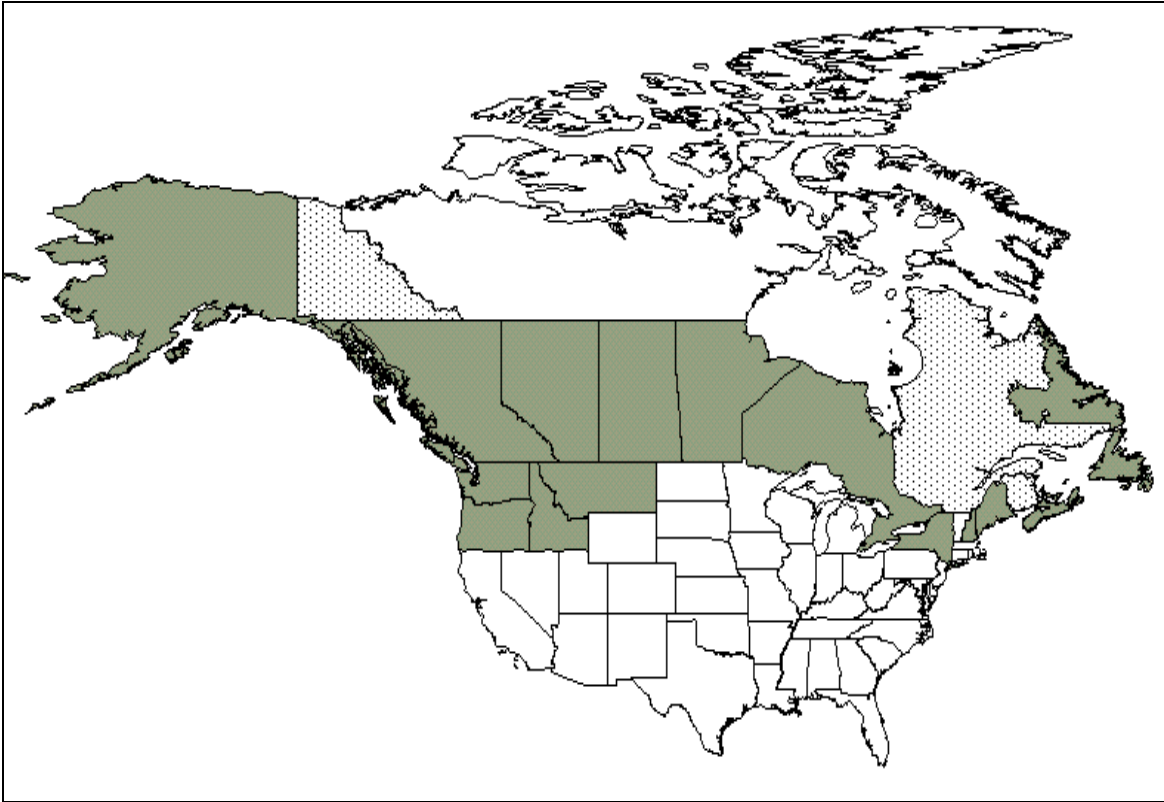


Figure 1. Occurrences of *Diphasiastrum sitchense* in North America. States and provinces shaded in gray have one or more confirmed, extant occurrences of the taxon. Stippling indicates that the taxon is ranked "SR" by the Association for Biodiversity Information (see Table 1 and Appendix for explanation of ranks), for which additional verification is lacking.

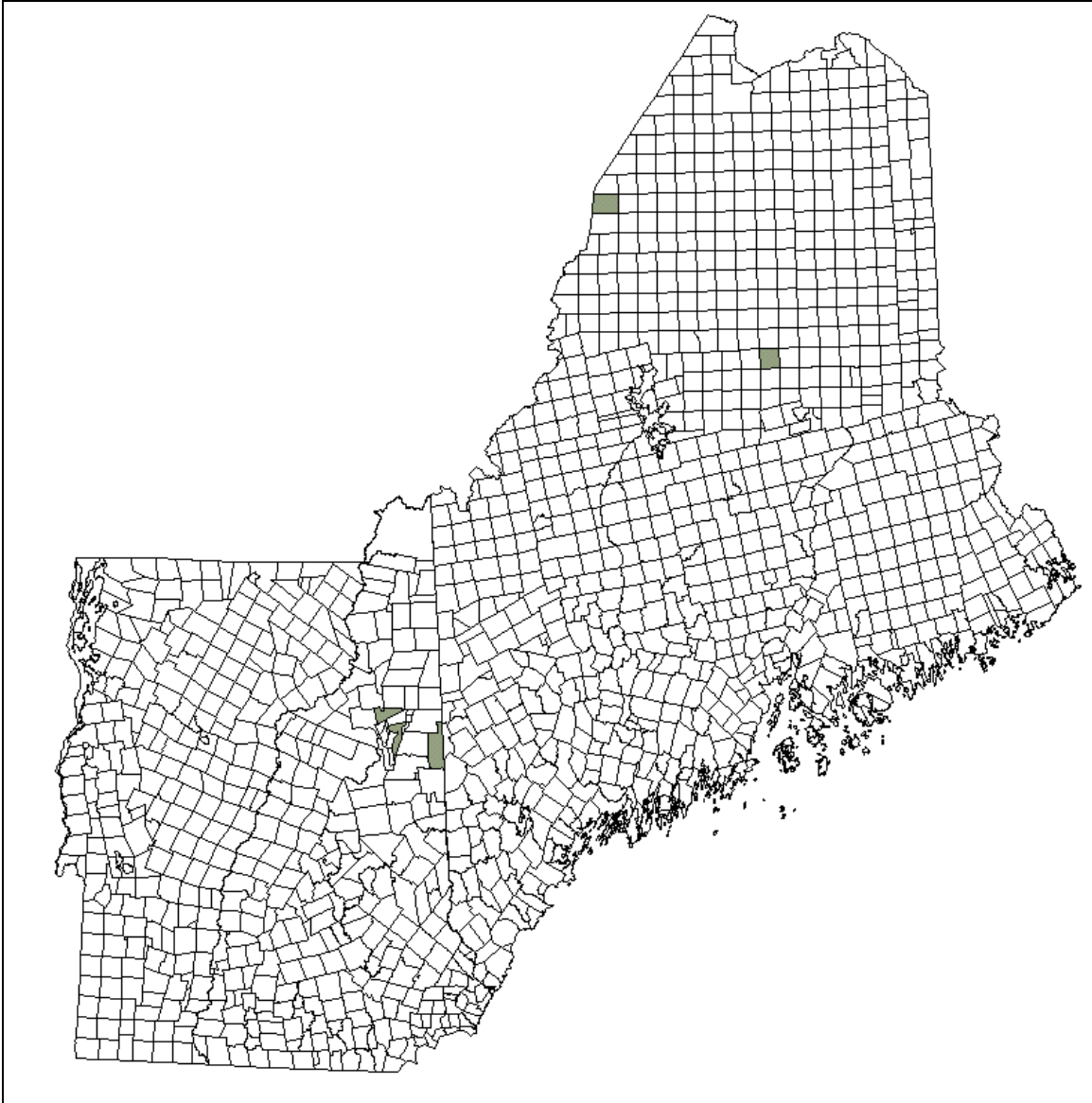


Figure 2. Extant occurrences of *Diphasiastrum sitchense* in New England. Town boundaries for Maine, New Hampshire, and Vermont are shown. Towns with gray shading have 1-5 current occurrences.

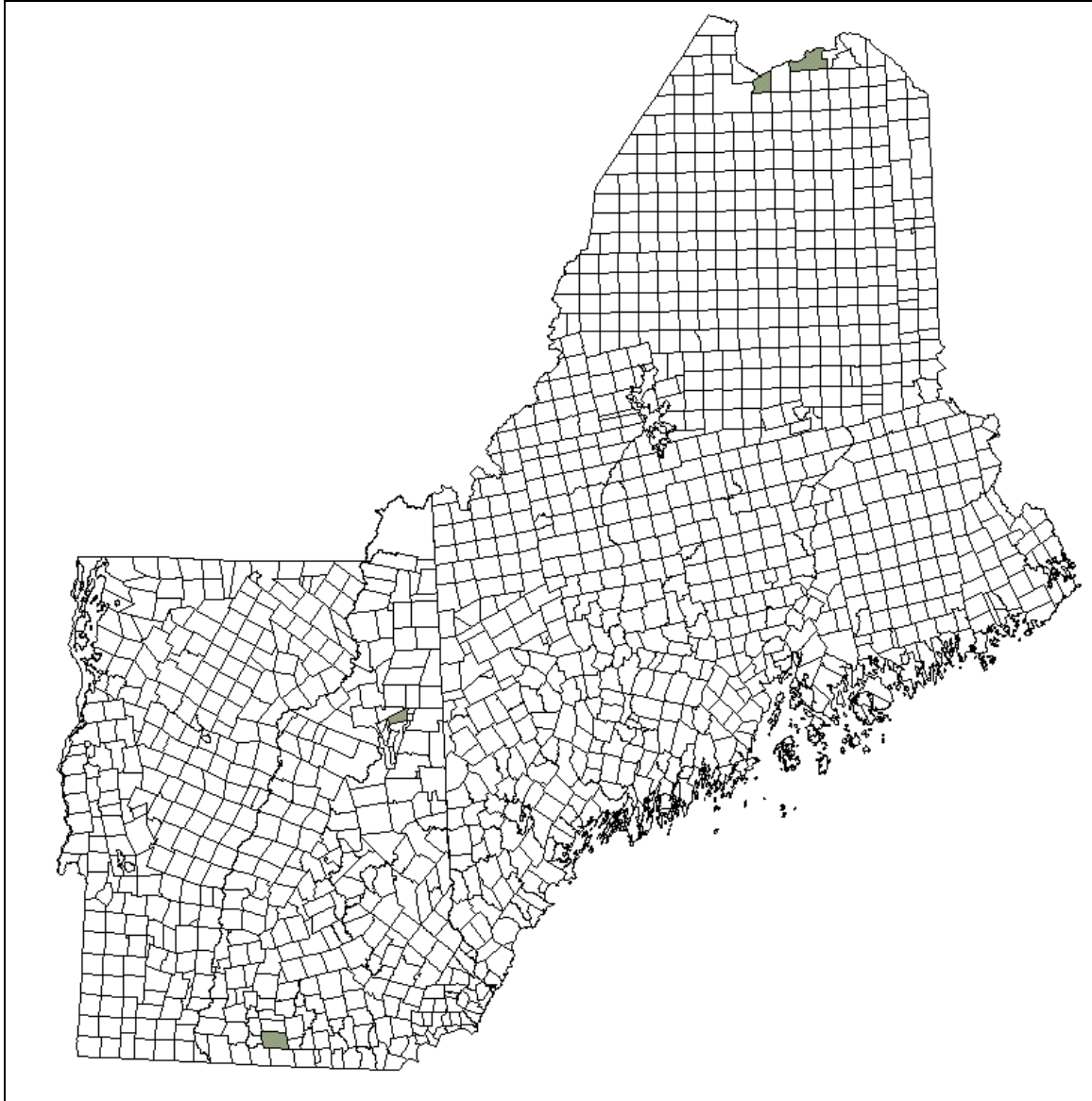


Figure 3. Historic occurrences of *Diphysastrum sitchense* in New England. Town boundaries for Maine, New Hampshire, and Vermont are shown. Towns with gray shading have 1-5 historic records for the taxon.

Status of All New England Occurrences – Current and Historic

In New England, Sitka clubmoss occurs only in Maine and New Hampshire (see Appendices). In *Flora Conservanda* New England (Brumback and Mehrhoff et al. 1996), it has been assigned to Division 2 as a "regionally rare" taxon. In Maine, there have been four sites, including Mt. Katahdin, where it is extant at several widely scattered locales. It is not known from other mountains in Maine. One lowland site, at Daaquam in northwestern Aroostook County, is extant, but two other lowland sites in northern Aroostook County are considered historical.

In New Hampshire, the species has been recorded from Mt. Washington, where several stations have been documented; from Mt. Adams, where it is presumed to be extant although no information more recent than 1953 is available; from South Baldface Mountain, where it is extant; and from Mt. Monadnock, where it was collected over 100 years ago and not observed since.

Several Vermont stations have been reported (Appendix 2); however, supporting specimens for each station have been reviewed and determined to be *D. sabinifolium*. Most specimens in local herbaria were so annotated either by Wilce or by Beitel, both of whom reviewed specimens in connection with graduate studies at the University of Michigan. One fragmentary specimen labeled *sitchense* by Beitel (Orleans Co: Willoughby, Mt. Pisgah, Winslow 10111, 25 July 1910, VT!) supports the record of this species (first reported in Winslow 1911). However, review of this specimen, which is mounted together with a specimen of *D. sabinifolium* collected on the same date and in the same locale, shows it not to be *D. sitchense* (Gilman 2000). A search in 2000 failed to locate either taxon at this locale. The species is therefore excluded from the flora of Vermont, even historically. The status at each known station is discussed below, and further details are given in Table 2.

<p>Table 2. New England Occurrence Records for <i>Diphasiastrum sitchense</i>. Information on sub-populations is listed for certain occurrences. Element occurrences for New Hampshire are distinguished by roman numerals by the author. Shaded occurrences are considered extant.</p>			
State	Element Occurrence Number	County	Town
ME	.001	Aroostook	Fort Kent
ME	.002	Aroostook	St. Francis
ME	.004	Piscataquis	Mt. Katahdin Twp.
ME	.004	Piscataquis	Mt. Katahdin Twp.
ME	.004	Piscataquis	Mt. Katahdin Twp
ME	.004	Piscataquis	Mt. Katahdin Twp
ME	.004	Piscataquis	Mt. Katahdin Twp
ME	.004	Piscatquis	Mt. Katahdin Twp.
ME	.004	Piscataquis	Mt. Katahdin Twp
ME	.007	Aroostook	Daaquam T11 R17 WELS
NH	I	Carroll	Chatham
NH	II	Cheshire	Jaffrey
NH	III	Coos	Sargent Purchase
NH	III	Coos	Sargent Purchase
NH	III	Coos	Sargent Purchase
NH	IV	Coos	Thompson & Meserve Purchase
NH	V	Coos	Low & Burbank Grant

CURRENT CONSERVATION MEASURES IN NEW ENGLAND

No known conservation management actions are being taken to protect *Diphasiastrum sitchense* at this time. Most extant occurrences are on land protected by state, federal, or private conservation agencies. Because the taxon is listed as state-threatened in Maine, it falls under Maine legislation (5 M.R.S.A., Section 13076-13079, Endangered Species). Because it is not as yet listed in New Hampshire, the species receives no legal protection there; however, it is being considered for state listing as of Spring 2001.

II. CONSERVATION

CONSERVATION OBJECTIVES FOR THE TAXON IN NEW ENGLAND

Sitka clubmoss is rare in New England, and is at the southern edge of its naturally occurring range. Furthermore, review of specimens that support literature references and Element Occurrence records has shown in it to be much rarer even than previously known. On the other hand, not all suitable habitat, especially in the alpine zone of New Hampshire, has been specifically searched for this species. It appears, however, that stations are few, small, and widely separated.

While some stations may occur in disturbed or manipulated habitats, most are on publicly owned natural terrain: the alpine zone of the White Mountains in New Hampshire, and on Katahdin, Maine. Given care, these populations can be conserved over time. However, additions to the current population base are unlikely to occur except through discovery of additional extant populations. Based on the extent of habitat available, both in the White Mountains and, presumably, at scattered locations in northern Maine, it would appear that such discoveries can be achieved.

Alpine and sub-alpine habitats of known populations are on lands unlikely to undergo major human intrusions (land conversion, road-building, development, forest harvesting, etc.) but may experience ongoing and/or unpredictable human intrusions from hikers, trails, fires, etc. Therefore, populations of this species are considered both in need of protection from such intrusions, and protectable because of their location on the physical and political landscapes. Populations occurring at lowland sites in northern New England are also worthy of protection in that they may be sources of genetic diversity. These populations may benefit from active management, especially maintenance of open conditions.

The primary conservation goals for this taxon are to protect all alpine occurrences from impacts due to human activity to the extent possible, search for additional populations, determine numbers of clones, and study clonal productivity and fertility.

III. LITERATURE CITED

- Baldwin, H. I. 1974. The flora of Mount Monadnock, New Hampshire. *Rhodora* 205-228.
- Beitel, J. M. 1979. The clubmosses *Lycopodium sitchense* and *L. sabinifolium* in the upper Great Lakes region. *Michigan Botanist* 18: 3-13.
- Bennert, W. 1999. *Die seltenen und gefährdeten Farnpflanzen Deutschlands*. Bundesamt für Naturschutz, Bonn, Germany.
- Callaghan, T. V., B. Svensson and A. Headly. 1986. The modular growth of *Lycopodium annotinum*. *Fern Gazette* 13: 65-76.
- Campbell, C. S. and L. M. Eastman. 1980. Flora of Oxford County, Maine. Life Sciences and Agriculture Experiment Station Technical Bulletin 99: 1-243. University of Maine, Orono, Maine, USA.
- Critical Areas Program. 1981. Rare Vascular Plants of Maine. State Planning Office. Augusta, Maine, USA.
- Critical Areas Program. 1985. Rare Vascular Plants of Maine. State Planning Office. Augusta, Maine, USA.
- Dole, E. J. 1937. *Flora of Vermont* Third Edition. Free Press Printing Company. Burlington, Vermont, USA.
- Dyer, A. and S. Lindsay. 1992. Soil spore banks of temperate ferns. *American Fern Journal* 82: 89-124.
- Eggleston, W. W. 1902. The discovery of *Comandra livida* and *Lycopodium sitchense* on Mt. Washington. *Rhodora* 4: 97-98.
- Elliott-Fisk, D. 1988. The boreal forest. Pages 31-62 in M. G. Barbour. and W. D. Billings (Editors), *North American Terrestrial Vegetation*. Cambridge University Press. New York, New York, USA.
- Farwell, O. A. 1916. Fern Notes. Annual Report of the Michigan Academy of Sciences. 18: 94.

- Fernald, M. L. 1901. The vascular plants of Mt. Katahdin. *Rhodora* 3: 166-176.
- Fernald, M. L. 1923. *Lycopodium sabinaefolium* and *L. sitchense*. *Rhodora* 25: 166.
- Gilman, A. V. 2000. Vermont status of *Diphasiastrum sitchense*. *Vermont Fern Notes* 7(3): 27-32. [Privately published; reprints available from the author].
- Harris, S. K., J. H. Langenheim and F. L. Steele. 1964. *Appalachian Mountain Club Field Guide to the Mountain Flowers of New England*. Appalachian Mountain Club, Boston, Massachusetts, USA.
- Holsinger, K. E. 1990. Population genetics of mating system evolution in homosporous ferns. *American Fern Journal* 80: 153-162.
- Holub, J. 1975. *Diphasiastrum*, a new genus in Lycopodiaceae. *Preslia* 14: 97-100.
- Horn, K. 1997. Verbreitung, Ökologie und Gefährdung der Flachbärlappe (*Diphasiastrum* spp., Lycopodiaceae, Pteridophyta) in Niedersachsen und Bremen. *Naturschutz Landschaftspflege in Niedersachsen. Heft* 38: 1-85.
- House, H. D. 1924. Annotated list of the ferns and flowering plants of New York State. *New York State Museum Bulletin* 254: 1-759.
- Lellinger, D. A. 1985. *Field Guide to the Ferns and Fern Allies of North America*. Smithsonian Institution Press. Washington, D. C, USA.
- Major, Á. and P. Ódor. 1999. Genet composition of *Diphasiastrum complanatum* in western Hungary: a case study. *American Fern Journal* 89:106-179.
- Mitchell, R. S. and G. C. Tucker. 1997. Revised Checklist of New York State Plants. *New York State Museum Bulletin* 490: 1-400.
- Natureserve: an online encyclopedia of life [web application]. 2001. Version 1.2. Arlington, Virginia. <http://www.natureserve.org/>
- New Hampshire Natural Heritage Inventory. 2000. Rare and Imperiled Plants of New Hampshire. DRED - Division of Forests & Lands. Concord, New Hampshire, USA.
- Oionnen, E. 1967. Sporal regeneration of ground pine (*Lycopodium complanatum* L.) in southern Finland in the light of the dimensions and age of its clones. *Acta Forest Fenn.* 83: 1-85.

Oionnen, E. 1968. The size of *Lycopodium clavatum* L. and *L. annotinum* L. stands as compared to that of *L. complanatum* L. and *Pteridium aquilinum* (L.) Kuhn stands, the age of the tree stand and the dates of fire on the site. *Acta Forest Fenn.* 87: 1-153.

Øllgaard, B. 1990. Lycopodiaceae. Pages 31-39 in K. Kubitzki and P. S. Green (Editors), *The Families and Genera of Vascular Plants. I. Pteridophytes and Gymnosperms.* Springer-Verlag, Berlin, Germany.

Pease, A. T. 1924. Vascular flora of Coös County, New Hampshire. *Proceedings of the Boston Society of Natural History* 37: 39-388.

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

Rugg, H. G. 1924. Botanizing on Mount Ktaadn. *American Fern Journal* 14: 285.

Ruprecht, F. J. 1845. *Distributio cryptogamarum vascularum in imperio Rossico.* Beitrage sur Pflanzenskunde des Russischen Reiches. 3. St. Petersburg, Russia.

Scamman, E. 1947. Ferns and Fern Allies of New Hampshire. *New Hampshire Academy of Science, Bulletin No. 2.* Durham, New Hampshire, USA.

Seymour, F. C. 1969. *The Flora of New England.* Charles E. Tuttle Company. Rutland, Vermont, USA.

Seymour, F. C. 1982. *The Flora of New England.* Second Edition. *Phytologia Memoirs V.* Plainfield, New Jersey, USA.

Sheffield, E. 1996. From pteridophyte spore to sporophyte in the natural environment. Pages 541-549 in J. M. Camus, M. Gibby and R. J. Johns (Editors), *Pteridology in Perspective.* Royal Botanic Gardens at Kew, London, United Kingdom.

Soltis, D. E. and D. P. Soltis. 1988. Estimated rates of intragametophytic selfing in lycopods. *American Journal of Botany* 75: 248-256.

Tryon, A. and R. C. Moran. 1998. *The Ferns and Allied Plants of New England.* Massachusetts Audubon Society. Lincoln, MA.

Victorin, Fr. Marie. 1925. Les Lycopodiniées du Quebec et leurs formes mineures. *Contributions du Laboratoire de Botanique de l'Université de Montreal* 3: 1-117.

Wagner, F. S. 1990. Cytological problems in *Lycopodium* s.l. *Annals of the Missouri Botanical Garden* 79: 718-729.

- Wagner, W. H. and J. M. Beitel. 1990. Generic classification of modern North American Lycopodiaceae. *Annals of the Missouri Botanical Garden* 79: 676-686.
- Wagner, W. H. and J. M. Beitel. 1994. Lycopodiaceae. Pages 18-37 in Flora of North America Editorial Committee (Editors). *Flora of North America North of Mexico*. Volume 2. Pteridophytes and Gymnosperms. Oxford University Press, New York, New York, USA.
- Wagner, W. H., F. S. Wagner and J. M. Beitel. 1985. Evidence for interspecific hybridization in pteridophytes with subterranean mycoparasitic gametophytes. *Proceedings of the Royal Society of Edinburgh* 86B: 273-281.
- Whittier, D. P. 1981. Gametophytes of *Lycopodium digitatum*, etc., as grown in axenic culture. *Botanical Gazette* 142: 519-524.
- Whittier, D. P. 1998. Germination of spores of the Lycopodiaceae in axenic culture. *American Fern Journal* 88: 106-113.
- Whittier, D. P. and D. M. Britton. 1995. Gametophyte of *Diphasiastrum* × *habereri* *American Fern Journal* 85: 89-94.
- Wilce, J. H. 1965. Section *Complanata* of the genus *Lycopodium*. *Nova Hedwigia Heft*. 19: 1-233.
- Winslow, E. J. 1911. Interesting plants found in Vermont in 1910. *Vermont Botanical Club Bulletin* 6:11-13.

IV. APPENDICES

- 1. Exsiccatae.**
- 2. Exclusions of literature reports and Element Occurrence records.**
- 3. An explanation of conservation ranks used by The Nature Conservancy and the Association for Biodiversity Information.**

1. Exsiccatae

MAINE: AROOSTOOK CO: Ft. Kent: *Fernald*, 15 June 1898 (GH); Stevens Mt., *Williams*, 22 August 1900 (HNH, UMASS, GH, MT); “in loam, upland spruce woods,” *Williams, Robinson & Fernald*, 11 August 1901 (SJFM, UMASS, VT, HNH, NEBC, GH); Stevens Mt., *Collins*, 22 August 1900 (MT); hillside, *Pease*, 12 July 1903 (GH); *Moulton*, in part, 10 July 1904 (MAINE); open places in spruce woods, *Eaton*, 20 July 1904 (GH); *Knight*, 1905 (HNH); sunny hillside, *Knight*, 10 August 1906 (GH). **St. Francis:** Dry knoll in pasture, *Fernald*, 7 August 1893 (GH); abundant in hillside pasture, *Fernald*, 15 June 1898 (GH). **PISCATAQUIS CO: Mt. Katahdin Twp. (T3 R9 WELS):** Katahdin, *Briggs*, August 1892 (MAINE, HNH, GH); near the head of Saddle Brook, *Fernald*, 9 July 1900 (GH); “west headwall, also saddle,” *White*, August 1930 (UMASS); West Headwall, N. Basin, *no. coll.*, 25 June 1988 (MAINE).

NEW HAMPSHIRE: CARROLL CO: Chatham: S. Baldface Mtn., *Haley 12751* (NY, n.v., cited in Wilce 1965); S. Baldface Mtn., elevation 3020', snowbank heath area on big bench, 70' N of trail junction cairn. *Sperduto 5412*, 20 August 1997 (NHA). **CHESHIRE CO: Jaffrey:** Mt. Monadnock, summit, *W. Deane* in 1891 (US, n.v., cited in Wilce, 1965). **COOS CO: Sargent Purchase:** Mt. Washington, Alpine Garden, *Eggleston 2425*, 17-24 August 1901 (VT, HNH, SJFM, GH, MT); “near top of Tuckerman’s Ravine, *Steyermark 129* (MO, n.v., cited in Wilce 1965); Ball Crag 5600', *Harries 011*, 24 August 1960 (HNH); 5300' above Alpine Garden Trail, *Zika 1580*, 26 June 1980 (VT); rocky slope above the Alpine Garden at Huntington Ravine, elevation ca. 5100 ft., locally well established, uncommon in the mtns., *Crow 3057*, 26 June 1980 (NHA). **Thompson and Meserve Purchase:** Mt. Washington, off the Carriage Road near tree line, *Eggleston s.n.*, August 1901 (GH). **Low and Burbank Grant:** Dry soil near top of Great Gulf, King’s Ravine, Mt. Adams, *Steele*, 7 August 1953 (NEBC).

2. Exclusions of literature reports and Element Occurrence records.

Sitka clubmoss is usually considered (Wilce 1965, Wagner and Beitel 1994) to be one parent of the hybrid savin-leaved clubmoss, *D. sabinifolium* (Willd.) Holub, the other parent being the relatively common groundcedar clubmoss, *D. tristachyum* (Pursh) Holub. This determination is based on morphological intermediacy and on floristic evidence. The hybrid hypothesis is at present being tested by isozyme and cpDNA analyses by (J. Chr. Vogel, personal communication). This putative hybrid progeny of *D. sitchense* occurs in a broad zone overlapping both parents' ranges, which are adjacent and barely overlapping.

Savin-leaved clubmoss occurs sporadically throughout northern New England with about 65 stations overall, ca. 48 prior to 1980 and 17 recently vouchered (Gilman, unpub. data). Its superficial similarity to *D. sitchense* was the basis of Fernald's (1923) transfer of taxon *sitchense* to varietal status under *sabinifolium*. *D. sabinifolium* has frequently been confused with *D. sitchense* in herbaria and in literature reliant upon misidentified herbarium specimens (e.g., Pease 1924, Scamman 1947, Pease 1964, Seymour 1969, CAP 1981, Seymour 1982, CAP 1985). Notwithstanding a superficial similarity, the two taxa can reliably be distinguished on morphological characters (Beitel 1979). Review and annotation of specimens in regional herbaria (VT, NHA, HNH, MAINE, GH, and NEBC) has resulted in the exclusion of numerous stations that had been reported for *D. sitchense* (see Table A-1).

Table A-1. Exclusions. The following stations have been reported in error, based on misidentification of specimens of <i>Diphasiastrum sabinifolium</i>.			
State	Locality	Reference/ EO Number	Specimen(s)
ME	Brownville	Churchill 1901, CAP 1981, EO .003	<i>Parlin</i> n.d (NEBC); <i>Parlin</i> , 1905 (NHA)
ME	Farmington	Churchill 1901, Seymour 1969, 1982, EO .005	<i>Trundy</i> , 1907 (MAINE); <i>Trundy</i> , 1908 (VT); <i>Hyland</i> , 1966 (MAINE)
ME	Sumner	Seymour 1969, 1982, Campbell & Eastman 1980, EO .006	<i>Adams</i> , 1943 (NEBC).
NH	Randolph	Scamman 1947 Pease 1964	<i>Pease</i> 20,083, 1927 et seqq. (NEBC).
NH	Colebrook	Pease 1924, 1964, Scamman 1947	<i>Pease</i> , 1907 (NEBC); <i>Pease</i> 16,947 & <i>Fernald</i> (NEBC, NHA).
NH	Stark	Pease 1964	<i>Pease</i> 29544, 23 June 1942 (NEBC).
NH	Whitefield	Pease 1964	<i>Pease</i> 37550, 30 July 1957 (NEBC).
NH	Dummer	Pease 1964	<i>Harris</i> 7431, 30 October 1949 (NEBC).
NH	Milan	Pease 1924, Scamman 1947, Pease 1964	<i>Pease</i> in 1912 (NEBC, NHA)
NH	Gorham	Pease 1924, Scamman 1947, Pease 1964	<i>Pease</i> 17,925, 30 August 1920 (GH, NEBC); <i>Pease</i> 20,295, 26 June 1928 (NEBC).
VT	Brighton	Seymour 1969, 1982	<i>Pease</i> , 1940 (NEBC); <i>McCauley</i> , 1943 (VT)
VT	Westmore	Winslow 1911, numerous others, EO .001	<i>Winslow</i> 10111; <i>Rugg s.n.</i> , 25 July 1910 (VT, HNH, UMASS, NEBC, GH).
VT	Walden	Dole 1937, Seymour 1969, 1984	<i>Knowlton</i> , 1918 (PH, not seen, cited in <i>Wilce</i> 1965).
VT	Hartland	Dole 1937, Seymour 1964, 1984	<i>Darling</i> 1907 (MT) and numerous others

Based on these findings, Sitka clubmoss is excluded from the flora of Vermont (see also Gilman, 2000).

3. An explanation of conservation ranks used by The Nature Conservancy and the Association for Biodiversity Information

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 **C** 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 **C** 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.