Lycopodium annotinum

Stiff Club-moss

Lycopodiaceae

Lycopodium annotinum by Bob Cunningham, 2017

***Lycopodium annotinum* Rare Plant Profile**

New Jersey Department of Environmental Protection
Division of Parks and Forestry
New Jersey Forest Service
Office of Natural Lands Management
New Jersey Natural Heritage Program

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Life History

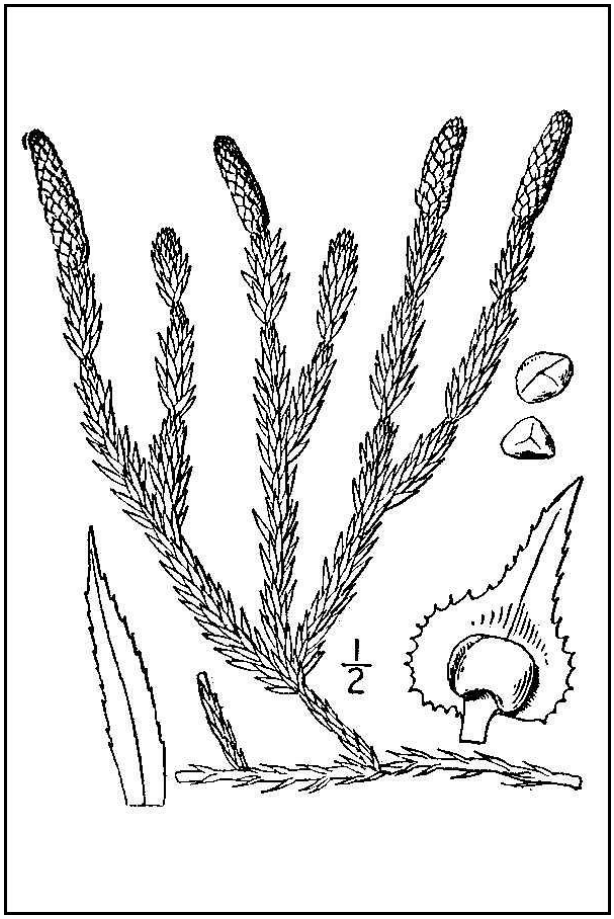
Lycopodium annotinum (Stiff Club-moss), like other pteridophytes, has a life cycle with two independent generations. Spores produced by mature plants first develop into gametophytes, which in *L. annotinum* are nonphotosynthetic subterranean organisms that depend on mycorrhizae for nutrition. The gametophytes eventually develop structures that produce male and female reproductive cells (gametes), a process which may require 6–15 years for completion in some club-mosses. Male gametes (sperm) develop in an antheridium and a female gamete (egg) develops in an archegonium. After fertilization occurs the more recognizable sporophytes appear, initially maintaining an attachment to the gametophytes but eventually becoming independent (Raven 1986). Eames (1942) reported that club-moss spores require 2–3 years for germination, and that gametophyte development may proceed for 10–25 years before a sporophyte is produced. A single gametophyte often produces two or more sporophytes (Rimgailė-Voicik and Naujalis 2022).

A typical *Lycopodium annotinum* gametophyte is initially somewhat club-shaped, but as it develops the wider end spreads and forms a button-like disk with inrolled edges. The sex organs are situated just inside the margin. As the gametophyte expands it becomes more furrowed and saddle-shaped (Eames 1942). Because they develop underground, the gametophytes of *L. annotinum* are likely to go unnoticed. When setting out to describe gametophytes of North American lycopods, Spessard (1917) searched for tiny developing sporophytes then removed the surrounding soil with forceps, finding the gametophytes of various species at depths of 1–7 centimeters. Techniques for locating and extracting club-moss gametophytes have not changed much during the past century (Rimgailė-Voicik and Naujalis 2022).

A sporophyte of *Lycopodium annotinum* is an evergreen perennial plant with a simple or sparsely branched horizontal stem (rhizome) that creeps on or near the surface of the substrate or in leaf litter. The age of a plant can be determined to some extent by annual growth compressions on the rhizomes (Primack 1973), although that may be of limited use for long-lived plants in which older parts of the stem have died off. At intervals along the lateral stem, simple or few-forked erect stems are produced with clear separations that delimit their annual growth. The erect branches bear eight rows of small leaves that are elliptic, serrate, and firm. Spores are produced in narrow, conelike structures that are solitary and sessile at the ends of the upright stems. (See Britton and Brown 1913, Fernald 1950, Gleason and Cronquist 1991, Montgomery and Fairbrothers 1992, Wagner and Beitel 2022). Mature *Lycopodium annotinum* plants also reproduce vegetatively, and what appears to be a large population may sometimes be a single clone (Wittig et al. 2007).

The creeping stems of *Lycopodium annotinum* intermittently produce roots that maintain arbuscular mycorrhizal associations (Wang and Qiu 2006). Water and nutrients taken up by roots may be selectively moved to different parts of a plant, providing it with a modular growth pattern. Nutrients such as phosphorus that are often in short supply can be recycled from older or decaying stems and shuttled to the portions of the plants where they are most needed (Headley et al. 1985), and water taken up by older roots can be allocated to newer shoots to promote growth (Headley et al. 1988). Stoloniferous growth allows a plant to forage in a patchy environment where resource availability is unpredictable (Sutherland and Stillman 1988), and

selective allocation of resources to the most successful modules allows *L. annotinum* to avoid adversity by transferring water and nutrients away from portions of the plant that wind up in unfavorable microhabitats (Callaghan et al. 1986). The loss of a growing apex promotes opportunistic branching of the horizontal stem, increasing the plant's chances of reaching a favorable microsite (Svensson and Callaghan 1988).



Left: Britton and Brown 1913, courtesy USDA NRCS 2022a. Right: *Lycopodium annotinum* by talaakso (2017) is licensed under CC BY 2.0.

Pollinator Dynamics

Because *Lycopodium annotinum* is a non-flowering plant, pollination does not take place. Fertilization is dependent on water, which allows the movement of biflagellate sperm cells toward a receptive egg cell (Raven 1986).

Cross-fertilization in pteridophytes requires sperm from the gametophyte of one sporophyte to fertilize the egg of a gametophyte from a different sporophyte. Fertilization that occurs between two gametophytes with the same sporophyte parent, or between two gametes produced by the same gametophyte, are both considered to be forms of self-fertilization (Haufler 2002). Because *Lycopodium* gametophytes develop below ground and produce both male and female gametes a

high frequency of self-fertilization might be expected, but that does not appear to be the case. A genetic investigation of *L. annotinum* and two other club-mosses by Soltis and Soltis (1988) found that the rates of self-fertilization between gametes from the same gametophyte were extremely low and in fact were zero for five out of the six *L. annotinum* populations studied, although the mechanism for achieving inter-gamete fertilization was unknown. Haufler (2002) noted the predominance of outcrossing among pteridophytes in general and reviewed a number of ecological, genetic, developmental and chemical factors that may contribute to the high rates of cross-fertilization.

Seed Dispersal

Dispersal in *Lycopodium annotinum* is carried out by spores rather than seeds. Mature plants release a copious amount of sulphur-colored spores that are flammable due to a high content of oils (Britton and Brown 1913, Fernald 1950). A detailed description of spore morphology was provided by Wilce (1972). The dust-like spores are transported by wind and may be deposited locally or thousands of kilometers away (Kessler 2010).

In New Jersey, mature sporangia may be found on *Lycopodium annotinum* from late June through October (Hough 1983) and August–October is reported for populations in the southeastern U. S. (Weakley 2015). In recent years, a second round of sporangia development during mid-winter has been reported from sites in Germany and Poland (Śliwińska-Wyrzychowska and Bogdanowicz 2008). The authors were hesitant to attribute the observations to climate change, noting that the second round of spore production may have previously been overlooked due to lower levels of fieldwork being conducted during winter months.

Habitat

The sporophytes and gametophytes of *Lycopodium annotinum* usually occupy different habitats (Eames 1942, Bruce and Beitel 1979, Wittig et al. 2007, Rimgailė-Voicik and Naujalis 2022). Regarding his early quests to locate club-moss gametophytes, Eames (1942) stated that "*...it is useless to search where mature and fruiting plants are abundant; the sexual plants have not been found where mature plants are numerous and only rarely are they discovered even near the borders of colonies*."

Open spaces are generally needed for gametophyte development, and in suitable sites the small subterranean plants are often found in clusters (Bruce and Beitel 1979). Close associations of gametophytes in patches of favorable habitat may be one of the factors that facilitates outcrossing (Haufler 2002). Populations of club-moss gametophytes are often found at sites that have experienced small-scale forest disturbances such as fires or clearing, and typical habitats include slopes, exposed sandy or rocky places, dry pine forests or plantations, abandoned fields, roads, paths, ski trails, or utility corridors (Rimgailė-Voicik and Naujalis 2022). Eames (1942) suggested that habitat differences between the two generations of club-mosses were due to successional changes that take place during the extended period between spore germination and sporophyte development, and Wittig et al. (2007) noted that *L. annotinum* clones in forests are

likely to be the same age as the forest stand. However, some recruitment from spores into established populations of *Lycopodium annotinum* has also been documented (Eriksson 1989).

In contrast with the open, disturbed sites utilized for establishment, the sporophyte generation of *Lycopodium annotinum* is often associated with shaded locations. Typical habitats include moist coniferous or deciduous forests with a rocky or somewhat acidic substrate (Beitel 1979, Odor 1996, Montgomery 1982, Montgomery and Fairbrothers 1992, Rhoads and Block 2007, Weakley 2015, Wagner and Beitel 2022). The club-moss may also be found in open rocky or grassy sites (Beitel 1979, Montgomery and Fairbrothers 1992, Wagner and Beitel 2022).

Data from British Columbia was used to calculate the species' microsite preferences such as elevation (0–2500 meters, average = 1126m) and slope gradient (0–200 percent, average = 17%) (Klinkenberg 2020). Klinkenberg also quantified the most favorable moisture regime as 4 (mesic) on a scale of 0 (very xeric) to 8 (hydric) and identified the nutrient regime as C (medium). A more comprehensive description of the soil and moisture regimes is provided by the B. C. Ministry of Forests (1998). In a mesic water regime, the primary water source is precipitation in moderate to fine-textured soils or limited seepage in coarse textured soils. Water is removed somewhat slowly relative to the supply and moisture availability generally reflects climatic input. A medium nutrient regime, in which an average amount of nutrients are available, is associated with sites at which the water pH generally falls between 5.5 and 6.5.

Wetland Indicator Status

Lycopodium annotinum is a facultative species, meaning that it occurs in both wetlands and nonwetlands (U. S. Army Corps of Engineers 2020).

USDA Plants Code (USDA, NRCS 2022b)

LYAN2

Coefficient of Conservatism (Walz et al., 2018)

CoC = 8. Criteria for a value of 6 to 8: Native with a narrow range of ecological tolerances and typically associated with a stable community (Faber-Langendoen 2018).

Distribution and Range

The native global range of *Lycopodium annotinum* extends throughout the northern hemisphere including North America, Europe and Asia (POWO 2022). In parts of its range, the species has been described as one of the most common club-mosses (Beitel 1979). The map in Figure 1 shows the extent of Stiff Club-moss in the United States and Canada.

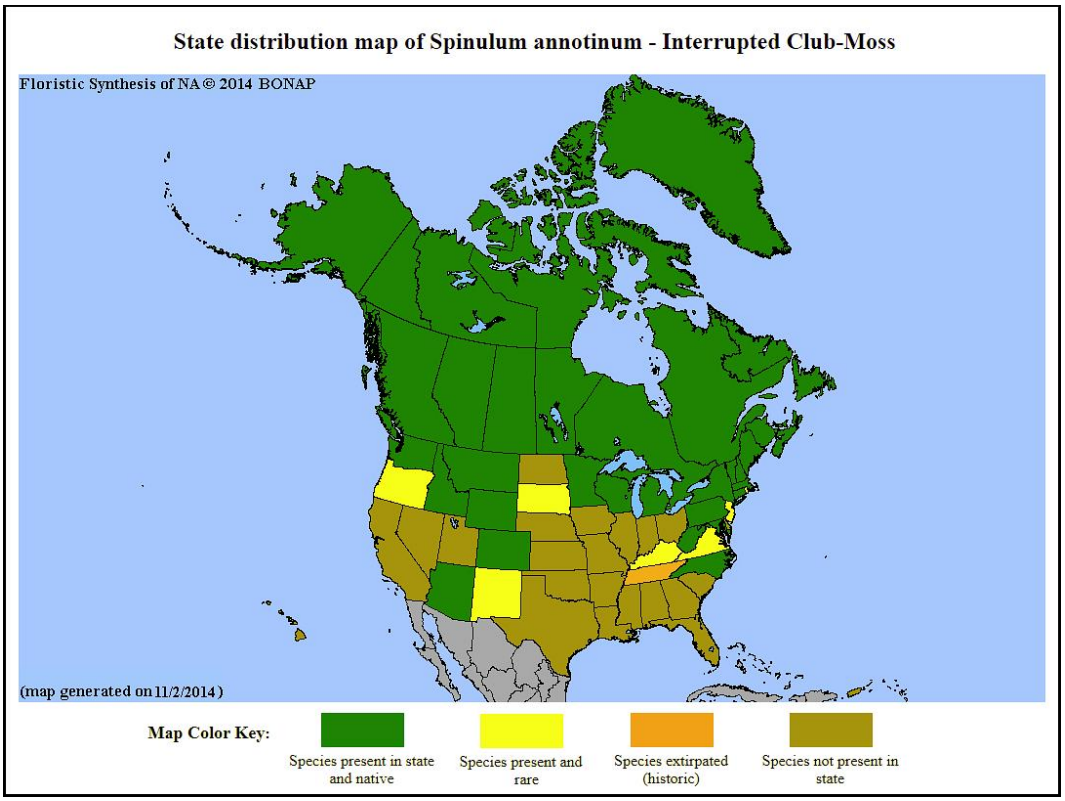


Figure 1. Distribution of L. annotinum in North America, adapted from BONAP (Kartesz 2015).

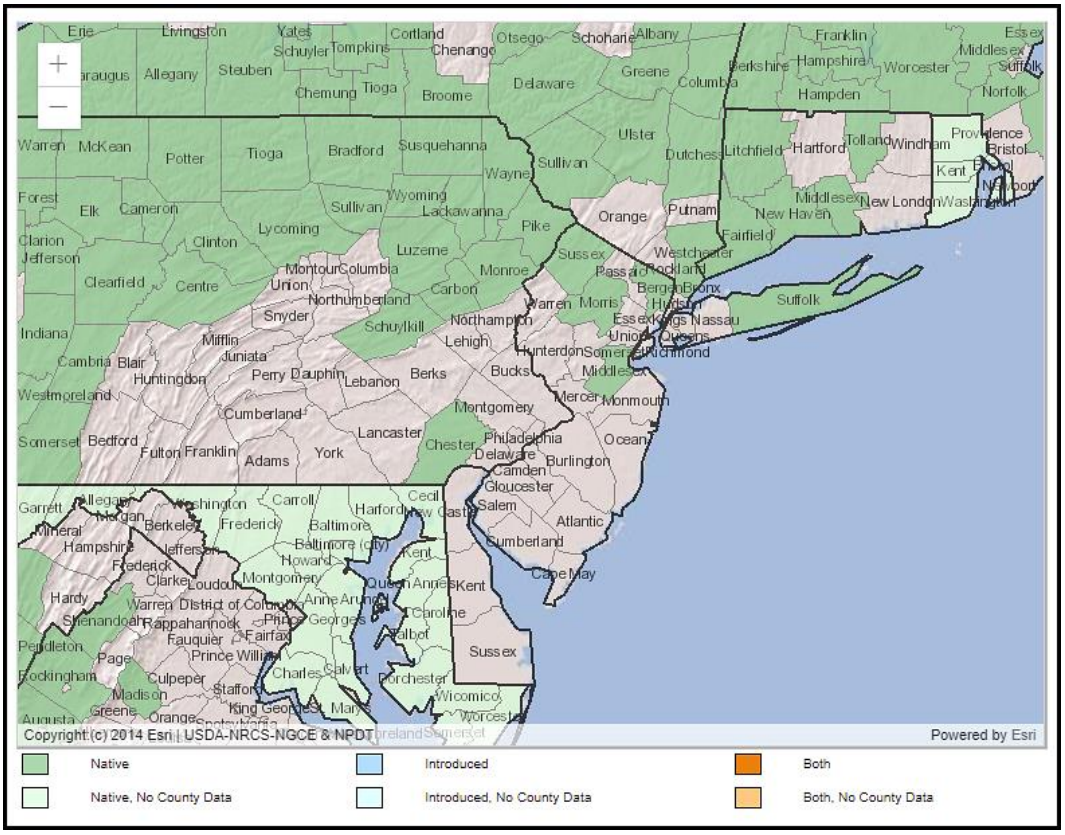


Figure 2. County records of L. annotinum in New Jersey and vicinity (USDA NRCS 2022b).

The USDA PLANTS Database (2022b) shows records of *Lycopodium annotinum* in four New Jersey counties: Bergen, Middlesex, Morris, and Sussex (Figure 2, above). The data include historic observations and do not reflect the current distribution of the species.

Conservation Status

Lycopodium annotinum is considered globally secure. The G5 rank means the species has a very low risk of extinction or collapse due to a very extensive range, abundant populations or occurrences, and little to no concern from declines or threats (NatureServe 2022). The map below (Figure 3) illustrates the conservation status of *L. annotinum* in North America. The club-moss is secure, apparently secure, or unranked throughout Canada and much of it U. S. range. *Lycopodium annotinum* is critically imperiled (very high risk of extinction) in two states, imperiled (high risk of extinction) in two states, vulnerable (moderate risk of extinction) in two states, and possibly extirpated in Tennessee.

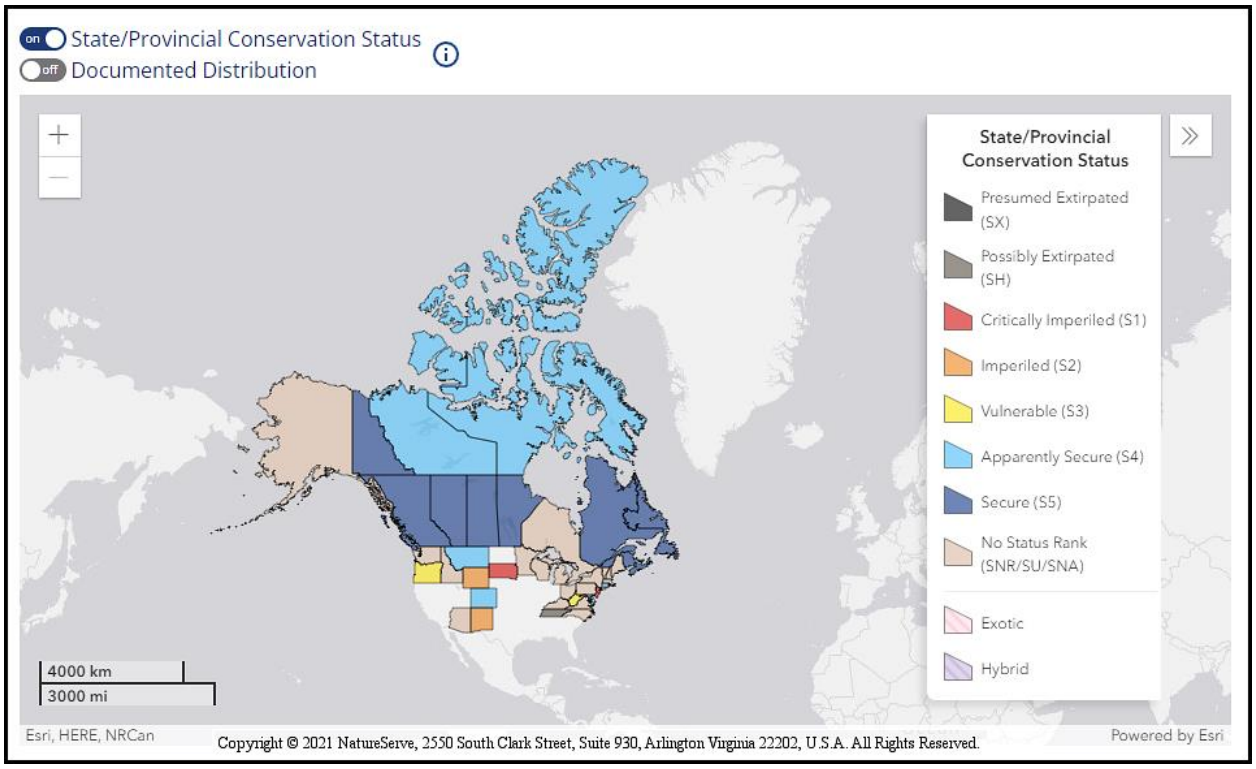


Figure 3. Conservation status of L. annotinum in North America (NatureServe 2022).

Lycopodium annotinum is critically imperiled (S1) in New Jersey (NJNHP 2022). The rank signifies five or fewer occurrences in the state. A species with an S1 rank is typically either restricted to specialized habitats, geographically limited to a small area of the state, or significantly reduced in number from its previous status. Stiff Club-moss is also listed as an endangered species (E) in New Jersey, meaning that without intervention it has a high likelihood of extinction in the state. Although the presence of endangered flora may restrict development in certain communities, being listed does not currently provide broad statewide protection for plants. Additional regional status codes assigned to the club-moss signify that the species is

eligible for protection under the jurisdictions of the Highlands Preservation Area (HL) and in the New Jersey Pinelands (LP) (NJNHP 2010).

The earliest report of *Lycopodium annotinum* in New Jersey was from Bergen County (Britton 1881), and a number of collections were made from sites in Morris and Sussex Counties during the 1930s (Mid-Atlantic Herbaria 2022). Montgomery reported in 1982 that Stiff Club-moss was only documented at a single site since 1950 and it had not been seen there in two decades, but later that year another historic population was relocated (Snyder 2000). At the turn of the century, *L. annotinum* was still only present at a single New Jersey site (Breden et al. 2006). In 2011 a new population was discovered and two occurrences are presently considered extant in the state, both of which have an estimated viability rank of 'Excellent' (NJNHP 2022).

Threats

Once established, the modular vegetative growth habit of *Lycopodium annotinum* sporophytes can allow the species to persist for a very long time in undisturbed forests (Wittig et al. 2007), and clones have been reported to live for as long as 250 years (Callaghan et al. 1986). However, disturbance or removal of the forest canopy is detrimental to Stiff Club-moss. Česonienė et al. (2018) found that *L. annotinum* was one of the most sensitive species to canopy disturbance and observed that the club-moss had disappeared entirely following a clear-cut in a Lithuanian forest. Adverse effects have also been reported in cases of partial clearing. Śliwińska-Wyrzychowska and Bogdanowicz (2012) reported that the potential for sexual reproduction was significantly higher in intact habitats. *L. annotinum* plants in an undisturbed forest in Poland produced six times more sporophylls than those in disturbed habitats, while the plants at disturbed sites were more likely to produce sporophylls early in the season and to have them wither prior to spore release. Another study in Poland found that even when clumps of trees were left standing in cut-over areas, the *L. annotinum* beneath the remaining trees showed decreases in both vertical shoot growth and overall patch size (Bogdanowicz et al. 2015).

A moderate increase in available light may have some benefits for *L. annotinum*, as plants growing under deciduous shrubs were found to be more vigorous than those beneath evergreen shrubs (Svensson et al. 1994). Nevertheless, any potential benefits appear to be offset by damages from other consequences of canopy removal. The primary environmental factor identified as contributing to the decline of *Lycopodium annotinum* colonies in partially cleared forests was a decrease in moisture, but it was also noted that canopy disturbance precipitated an increase in other plant species that may compete with the club-moss for resources (Bogdanowicz et al. 2015).

Aside from habitat disturbance, few other threats have been identified for *Lycopodium annotinum*. Many club-mosses are extensively collected for floral, horticultural or other decorative uses and the long-term impacts on populations are poorly understood. However, *L. annotinum* is not one of the species that is traditionally harvested because it tends to dry out quickly and become discolored (Nauertz and Zasada 2001).

Management Summary and Recommendations

Conservation of extant populations of *Lycopodium annotinum* in states where the species is rare should focus on land protection and habitat maintenance. If left alone in an undisturbed forested site, it seems likely that the species will be able to persist for a long time. Healthy populations in intact habitat probably require little in the way of monitoring other than periodic confirmation that site conditions remain unchanged.

Searches for new populations may prove fruitful, particularly in open or early successional habitat in the vicinity of extant or historic occurrences. Because spores are able to travel for long distances and the club-moss spends such a long period of time below ground during the gametophyte generation, sporophytes may occasionally crop up in unexpected places.

Rimgailė-Voicik and Naujalis (2022) emphasized the need for more research on the gametophyte generation of club-mosses. A better understanding of gametophyte establishment and development could be used to locate and protect developing populations of *L. annotinum*, and possibly even to create opportunities for the establishment of new occurrences in areas where the species is critically imperiled. Knowing ways to foster natural colonization may be a more practical way of maintaining the species than offsite propagation and reintroduction, particularly in light of the species' complex and lengthy developmental process. Leopold (2005) noted that all of the club-mosses are difficult to grow, and while Benca (2014) reported successful cultivation of many native species including *L. annotinum* the work was limited to laboratory propagation of clones and did not include an outplanting component.

Synonyms

The accepted botanical name is *Lycopodium annotinum* L. (NJNHP 2022). Some authors now recognize *Spinulum* as a distinct genus (Kartesz 2015, Weakley 2015). The species has previously been divided into a number of varieties (Fernald 1915, 1950) which are now thought to be environmentally induced forms, but Weakley (2015) and Wagner and Beitel (2022) recommend further study of the taxon. Orthographic variants, synonyms, and common names are listed below (ITIS 2021, USDA 2022b, POWO 2022).

Botanical Synonyms	**Common Names**
Spinulum annotinum (L.) A. Haines	Stiff Club-moss
Lycopodium annotinum var. *annotinum* L.	Interrupted Clubmoss
Lycopodium annotinum var. *acrifolium* Fernald	Bristly Clubmoss
Lycopodium annotinum var. *alpestre* Hartm.	
Lycopodium annotinum ssp. *alpestre* (Hartm.) Á. Löve & D. Löve	
Lycopodium annotinum var. *pungens* (Bach. Pyl.) Desv.	
Lycopodium annotinum ssp. *pungens* (Bach. Pyl.) Hultén	
Lycopodium annotinum var. *subpungens* Macoun ex Nessel	
Lycopodium annotinum f. *angustatum* (Takeda) Satou	
Lycopodium annotinum f. *groenlandicum* Nessel	

Lycopodium annotinum f. *montanum* Nessel
Lycopodium annotinum f. *proliferum* Lepage
Lycopodium dubium Zoëga
Lepidotis annotina (L.) P. Beauv.

References

B. C. Ministry of Forests. 1998. Field Manual for Describing Terrestrial Ecosystems. Land Management Handbook Number 25, ISSN 0229-1622. Available at https://www.for.gov.bc.ca/hfd/pubs/Docs/Lmh/Lmh25/01-Site.pdf

Beitel, J. M. 1979. Clubmosses (*Lycopodium*) in North America. Fiddlehead Forum 6(5): 1–8.

Benca, Jeffrey P. 2014. Cultivation techniques for terrestrial clubmosses (Lycopodiaceae): Conservation, research, and horticultural opportunities for an early-diverging plant lineage. American Fern Journal 104(2): 25–48.

Bogdanowicz, Monika, Anna Śliwińska-Wyrzychowska, Anna Świercz, and Marcin Kiedrzyński. 2015. The dynamics of stiff clubmoss *Lycopodium annotinum* L. patches in clumps of trees left on the clear-cutting in pine forest Leucobryo-Pinetum. Folia Forestalia Polonica 57(1): 11–17.

Breden, T. F., J. M. Hartman, M. Anzelone and J. F. Kelly. 2006. Endangered Plant Species Populations in New Jersey: Health and Threats. New Jersey Department of Environmental Protection, Division of Parks and Forestry, Office of Natural Lands Management, Natural Heritage Program, Trenton, NJ. 198 pp.

Britton, N. L. 1881. A preliminary catalogue of the flora of New Jersey. Geological Survey of New Jersey, Office of the Survey, Rutgers College, New Brunswick, NJ. 233 pp.

Britton, N. L. and A. Brown. 1913. An Illustrated Flora of the Northern United States and Canada in three volumes: Volume I (Ferns to Buckwheat). Second Edition. Reissued (unabridged and unaltered) in 1970 by Dover Publications, New York, NY. 680 pp.

Bruce, James G. and Joseph M. Beitel. 1979. A community of *Lycopodium* gametophytes in Michigan. American Fern Journal 69(2): 33–41.

Callaghan, T. V., A. D. Headley, B. M. Svensson, Li Lixian, J. A. Lee, and D. K. Lindley. 1986. Modular growth and function in the vascular cryptogam *Lycopodium annotinum*. Proceedings of the Royal Society of London, Series B. Biological Sciences 228(1251): 195–206.

Česonienė, Laima, Remigijus Daubaras, Paulius Kaškonas, Vilma Kaškonienė, Audrius Sigitas Maruška, Nicola Tiso, and Marcin Zych. 2018. Initial impact of clear-cut logging on dynamics of understory vascular plants and pollinators in Scots pine-dominated forests in Lithuania. Turkish Journal of Agriculture and Forestry 42: 433–443.

Cunningham, Bob. 2017. Cover photo of *Lycopodium annotinum*. Used with permission.

Eames, Arthur E. 1942. Illustrations of some *Lycopodium* gametophytes. American Fern Journal 32(1): 1–12.

Eriksson, Ove. 1989. Seedling dynamics and life histories of clonal plants. Oikos 55(2): 231–238.

Faber-Langendoen, D. 2018. Northeast Regional Floristic Quality Assessment Tools for Wetland Assessments. NatureServe, Arlington, VA. 52pp.

Fernald, M. L. 1915. The American variations of *Lycopodium annotinum*. Rhodora 17(198): 123–125.

Fernald, M. L. 1950. Gray's Manual of Botany. Dioscorides Press, Portland, OR. 1632 pp.

Gleason, H. A. and A. Cronquist. 1991. Manual of Vascular Plants of Northeastern United States and Adjacent Canada. Second Edition. The New York Botanical Garden, Bronx, NY. 910 pp.

Haufler, Christopher H. 2002. Homospory 2002: An odyssey of progress in pteridophyte genetics and evolutionary biology. BioScience 52(12): 1081–1093.

Headley, Alistair D., Terry V. Callaghan, and John A. Lee. 1985. The phosphorus economy of the evergreen tundra plant, *Lycopodium annotinum*. Oikos 45: 235–245.

Headley, A. D., T. V. Callaghan, and J. A. Lee. 1988. Water uptake and movement in the clonal plants, *Lycopodium annotinum* L. and *Diphasiastrum complanatum* (L.) Holub. New Phytologist 110: 497–502.

Hough, Mary Y. 1983. New Jersey Wild Plants. Harmony Press, Harmony, NJ. 414 pp.

ITIS (Integrated Taxonomic Information System). Accessed March 9, 2022 at http://www.itis.gov

Kartesz, J. T. 2015. The Biota of North America Program (BONAP). Taxonomic Data Center. (http://www.bonap.net/tdc). Chapel Hill, NC. [Maps generated from Kartesz, J. T. 2015. Floristic Synthesis of North America, Version 1.0. Biota of North America Program (BONAP) (in press)].

Kessler, Michael. 2010. Biogeography of Ferns. In K. Mehltreter, L. R. Walker, and J. M. Sharpe. Fern ecology. Cambridge University Press, Cambridge, United Kingdom. Available at https://www.zora.uzh.ch/id/eprint/42711/9/Kessler_Fern_Ecology_Book_2010.pdf

Klinkenberg, Brian. 2020. *Lycopodium annotinum*. E-Flora BC: Electronic Atlas of the Plants of British Columbia [https://ibis.geog.ubc.ca/biodiversity/eflora/]. Lab for Advanced Spatial

Analysis, Department of Geography, University of British Columbia, Vancouver (accessed January 9 2022).

Leopold, Donald J. 2005. Native Plants of the Northeast: A Guide for Gardening and Conservation. Timber Press, Portland, OR. 308 pp.

Mid-Atlantic Herbaria. 2022. https://midatlanticherbaria.org/portal/index.php. Accessed January 9, 2022.

Montgomery, James D. 1982. Habitat preservation and rare pteridophytes in New Jersey. In William J. Cromartie (ed.). New Jersey's Endangered Plants and Animals. Stockton State College Center for Environmental Research, Pomona, NJ.

Montgomery, J. D. and D. E. Fairbrothers. 1992. New Jersey Ferns and Fern Allies. Rutgers University Press, New Brunswick, NJ. 293 pp.

NatureServe. 2022. NatureServe Explorer [web application]. NatureServe, Arlington, VA. Accessed March 9, 2022 at https://explorer.natureserve.org/

Nauertz, Elizabeth A. and John C. Zasada. 2001. *Lycopodium*: Growth form, morphology, and sustainability of a non-timber forest product. In: Iain Davidson-Hunt, Luc C. Duchesne, and John C. Zasada (eds.). Forest communities in the third millennium: Linking research, business, and policy toward a sustainable non-timber forest product sector. Proceedings of the meeting October 1-4, 1999, Kenora, Ontario, Canada. USDA Forest Service, North Central Research Station, St. Paul, MN.

NJNHP (New Jersey Natural Heritage Program). 2010. Special Plants of NJ - Appendix I - Categories & Definitions. Site updated March 22, 2010. Available at https://www.nj.gov/dep/parksandforests/natural/heritage/spplant_ap1.html#state

NJNHP (New Jersey Natural Heritage Program). 2022. Biotics 5 Database. NatureServe, Arlington, VA. Accessed February 1, 2022.

Ódor, Péter. 1996. A coenological study of club moss populations in western Hungary. Abstracta Botanica 20(1): 47–54.

POWO. 2022. Plants of the World Online. Facilitated by the Royal Botanic Gardens, Kew. Accessed March 9, 2022 at http://www.plantsoftheworldonline.org/

Primack, Richard B. 1973. Growth patterns of five species of *Lycopodium*. American Fern Journal 63(1): 3–7.

Raven, Peter H., Ray F. Evert and Susan E. Eichhorn. 1986. Biology of Plants. Worth Publishers, New York, NY. 775 pp.

Rhoads, Ann Fowler and Timothy A. Block. 2007. The Plants of Pennsylvania. University of Pennsylvania Press, Philadelphia, PA. 1042 pp.

Rimgailė-Voicik, Radvilė and Jonas Remigijus Naujalis. 2022. Techniques for locating and analyzing subterranean *Lycopodium* and *Diphasiastrum* gametophytes in the field. Applications in Plant Sciences 10(2): e11458. Available at https://doi.org/10.1002/aps3.11458

Śliwińska-Wyrzychowska, Anna and Monika Bogdanowicz. 2008. Sporulation of *Lycopodium annotinum* L. in winter. Available at https://www.researchgate.net/profile/Anna-Sliwinska-Wyrzychowska/publication/259620191_Sporulation_of_Lycopodium_annotinum_L_in_winter/links/0deec52ceaad10b825000000/Sporulation-of-Lycopodium-annotinum-L-in-winter.pdf

Śliwińska-Wyrzychowska, Anna and Monika Bogdanowicz. 2012. Selected aspects of *Lycopodium annotinum* L. sporulation. Ecological Questions 16: 51–58.

Snyder, David. 2000. One hundred lost plants found. Bartonia 60: 1–22.

Soltis, Pamela S. and Douglas E. Soltis. 1988. Estimated rates of intragametophytic selfing in lycopods. American Journal of Botany 75(2): 248–256.

Spessard, Earle Augustus. 1917. Prothallia of *Lycopodium* in America. Botanical Gazette 63: 66–76.

Sutherland, William J. and Richard A. Stillman. 1988. The foraging tactics of plants. Oikos 52(3): 239–244.

Svensson, Brita M. and Terry V. Callaghan. 1988. Apical dominance and the simulation of metapopulation dynamics in *Lycopodium annotinum*. Oikos 51(3): 331–342.

Svensson, Brita, Britt Floderus, and Terry V. Callaghan. 1994. *Lycopodium annotinum* and light quality: Growth responses under canopies of two *Vaccinium* species. Folia Geobotanica et Phytotaxonomica 29: 159–166.

talaakso. 2017. *Lycopodium annotinum* image. Tero Laakso, CC BY 2.0 https://creativecommons.org/licenses/by/2.0 via Creative Commons.

U. S. Army Corps of Engineers. 2020. National Wetland Plant List, version 3.5. https://cwbi-app.sec.usace.army.mil/nwpl_static/v34/home/home.html U. S. Army Corps of Engineers Research and Development Center, Cold Regions Research and Engineering Laboratory, Hanover, NH.

USDA, NRCS (U. S. Dept. of Agriculture, Natural Resources Conservation Service). 2022a. *Lycopodium annotinum* illustration from Britton, N. L. and A. Brown, 1913, An illustrated flora of the northern United States, Canada and the British Possessions, 3 vols., Kentucky Native Plant Society, New York, Scanned By Omnitek Inc. Image courtesy of The PLANTS Database (http://plants.usda.gov). National Plant Data Team, Greensboro, NC.

USDA, NRCS (U. S. Dept. of Agriculture, Natural Resources Conservation Service). 2022b. PLANTS profile for *Lycopodium annotinum (Stiff Clubmoss).* The PLANTS Database, National Plant Data Team, Greensboro, NC. Accessed March 9, 2022 at http://plants.usda.gov

Wagner, Warren H. Jr. and Joseph M. Beitel. Page updated February 22, 2022. *Lycopodium annotinum* Linnaeus. In: Flora of North America Editorial Committee, eds. 1993+. Flora of North America North of Mexico [Online]. 22+ vols. New York and Oxford. Accessed March 9, 2022 at http://floranorthamerica.org/Lycopodium_annotinum

Walz, Kathleen S., Linda Kelly, Karl Anderson and Jason L. Hafstad. 2018. Floristic Quality Assessment Index for Vascular Plants of New Jersey: Coefficient of Conservativism (CoC) Values for Species and Genera. New Jersey Department of Environmental Protection, New Jersey Forest Service, Office of Natural Lands Management, Trenton, NJ. Submitted to United States Environmental Protection Agency, Region 2, for State Wetlands Protection Development Grant, Section 104(B)(3); CFDA No. 66.461, CD97225809.

Wang, B., and Y. L. Qiu. 2006. Phylogenetic distribution and evolution of mycorrhizas in land plants. Mycorrhiza 16(5): 299–363.

Weakley, A. S. 2015. Flora of the southern and mid-Atlantic states, working draft of May 2015. University of North Carolina Herbarium, North Carolina Botanical Garden, Chapel Hill, NC.

Wilce, J. H. 1972. Lycopod spores, I. General spore patterns and the generic segregates of *Lycopodium*. American Fern Journal 62: 65–79.

Wittig, Rudiger, Ruth Jungmann, and Hans-Joachim Ballach. 2007. The extent of clonality in large stands of *Lycopodium annotinum* L. Flora 202(2): 98–105.