Lycopodium: Growth Form, Morphology, and Sustainability of a Non-timber Forest Product

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Abstract.—Several species of *Lycopodium* or clubmoss belong in the category of non-timber forest products and are often gathered for a variety of traditional uses. It is important to evaluate baseline information for these species, such as abundance and frequency of occurrence, before making any management decision. In addition, understanding the biology of the *Lycopodium* group as a whole, including growth form and morphology, may enable us to make better decisions about forest management practices used and harvesting quotas allowed for sustaining these species.

INTRODUCTION

Several *Lycopodium* or clubmoss species are extensively collected as non-timber forest products and are marketed to industries for production of seasonal and traditional decorations and for floral and horticulture uses. In addition, medicinal (Aboriginal and homeopathic), native folklore, and theatrical uses exist for various *Lycopodium* species (Johnson *et al.* 1995; Shakhashiri 1983; Ullman 1992, 1997). *Lycopodium* species are considered to be fern-allies. In temperate forests they are vascular, terrestrial, evergreen, perennial, rhizomatous, and clonal in nature. This group of species has been around a long time, with ancestors that date back to the Tertiary period (Lellinger 1985). Few studies have been done to determine how these species can be regenerated and how fast they recover after harvesting (Matula 1995, Primack 1973). Although some of the *Lycopodium* species are common in northern hardwood forests, the impacts of forest management practices on populations of these species are not well understood.

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SPECIES DESCRIPTIONS AND USES

Following is a brief description of each of the six *Lycopodium* species discussed in this paper. The descriptions are compiled from personal observations, as well as information referenced from the literature (Cody and Britton 1989; Flora of North America 1993; Johnson *et al.* 1995; Lellinger 1985; Meeker *et al.* 1993; Primack 1973; Turner *et al.* 1983; Ullman 1992, 1997).

Lycopodium species vary in growth form and morphology. The mature aerial stems of a plant photosynthesize. They may be either non-branching or treelike in form. When mature, the aerial stems often have cones (strobili) or sporangia that produce the spores necessary for sexual reproduction. Spores mature and are released in the late fall, even as late as November. In general, *Lycopodium* aerial stems reach maturity and begin to produce spores at from 4 to 6 years of age, depending on the species and local growing conditions. *Lycopodium* species have either aboveground or belowground running rhizomes or lateral branches. The rhizomes have the ability to produce adventitious roots and are used for photosynthate, water, and nutrient transport. The rhizomatous nature of these species may add to the photosynthesis capacity of the plant as a whole and may affect the plant's ability to get around vegetatively. A typical *Lycopodium* patch can have multiple-aged lateral branches or rhizomes, and each rhizome may have ramets that vary in age from 1 to 6 years. In general, the

bigger and more branching the patch, the older it is.

The aerial stems of *Lycopodium dendroideum* and *L. obscurum* are frequently harvested and used for decorative greens. Although commonly found in aspen-birch forests, these two species are also found in moist rich woods and along edges of bogs. The branching aerial stems resemble small pine trees: hence the common name of princess pine or ground pine. Only the individual mature aerial stems should be harvested, and this should be done after prime spore release in late fall. The spores of these two species are flammable when mature and have been used historically for theatrical and pyrotechnical purposes. In addition, the ground pines have belowground rhizomes running between 2 and 6 inches below the soil surface (Nauertz and Zasada, personal observations); consequently, a new aerial stem may not appear above the soil surface until sometime in the second year of growth.

Lycopodium complanatum, also known as ground cedar, is most commonly found in pine forest communities, typically grows in clumps, and can cover large areas. It has tree-like, branching aerial stems with adpressed and tightly packed microphylls or leaves that strongly resemble cedar boughs. When mature, the aerial stems host a "candelabra" of cones for spore production. This species of *Lycopodium* differs from the ground pines *L. dendroideum* and *L. obscurum*, in that it has aboveground running rhizomes growing through the litter layer on the forest floor. *Lycopodium complanatum* is also harvested for decorative greens and has some homeopathic and Aboriginal medicinal uses. Harvesting for greens is different for this plant in that the entire aboveground runner, or rhizome, is yanked from the surface of the soil; hence, the entire plant or section of a clone is harvested, rather than just the mature aerial stems as done for the ground pines. Optimal lateral extention or growth for each rhizome has been recorded to occur in year 1 (most recent year growing tip) to year 6, with maximum extension reaching 400 to 600 cm. Greatest aerial stem mass was recorded in years 3 to 6, with peak weights reaching 13 to 25 grams (Nauertz and Zasada, unpublished data).

Running clubmoss, Wolf's paw, or *Lycopodium clavatum* also has aboveground running rhizomes and is harvested for decorative greens in the same manner as the ground cedar. Traditional Aboriginal and homeopathic remedies are concocted from the dried plant parts of this species. *L. clavatum* has forking, non-branching aerial stems that typically bear one to two cones when mature. The aerial stems are often tightly packed along the aboveground running rhizomes. In Canada, Aboriginal peoples on Vancouver Island, located in British Columbia, believed the plant should be left alone. It is said that clubmoss should be left because it is "something that gets you confused in the woods" or "confused and uncertain about orientation" (Turner *et al.* 1983). Perhaps this belief stemmed from the random pattern of branching that is common for this species.

Lycopodium annotinum or stiff clubmoss is not traditionally gathered or harvested. Although considered evergreen, this species tends to dry out quickly and does not remain green and pliable, as do the other species harvested for decorative greens. *Lycopodium annotinum* has forking, non-branching aerial stems that produce a single strobilus, or cone, when mature. The stems are typically densely packed along aboveground running rhizomes.

Shining clubmoss or *Lycopodium lucidulum* is most common to northern mesic forests dominated by sugar maple, preferring the embedded acid, wet woods or rocky areas. Native Americans traditionally gathered it for use as padding for cradleboards. *L. lucidulum* does have some features that are unique to this group of clubmoss species. It has forking, non-branching aerial stems that, when mature at around 6 years of age, produce sporangia that contain spores in the leaf axils. In addition, gemmae or bulblets may be produced in the upper leaf axils. They mature usually in late summer or early fall, and when bumped will catapult off the aerial stem and, upon landing in proper growing media and conditions, have the potential for growing into a new, genetically identical plant. This is a means of vegetatively increasing plant frequency, but not genetic variation. *Lycopodium lucidulum* does not technically form rhizomes; instead the aerial stems tend to layer, and then branch and fork. Each fall the leaf litter from the overstory canopy falls, anchoring the layered aerial stems to the surface of the forest floor. Adventitious roots for water and nutrient uptake will form along the layered aerial stems.

LYCOPODIUM REPRODUCTIVE CHARACTERISTICS

Reproduction method, both sexual and asexual, may help explain the frequency and cover patterns of individual *Lycopodium* species. All ferns and fern-allies produce spores and experience an alternation in generations, which is a means of dividing, segregating, and re-combining chromosomes. This allows for genetic variability to occur and for evolution to proceed (Lellinger 1985). Spores vary in where they germinate within the soil surface layers and were found to germinate at deeper depths as well as on the soil surface (Cobb 1963, Freeberg 1962). The spores produced by fern-allies such as *Lycopodium* may remain viable for many years and could take up to 7 or more years to develop into a gametophyte (Cobb 1963). Gametophytes may remain alive from only a few weeks or months (Lellinger 1985) to as long as 10 or more years (Cobb 1963). A gametophyte bears the sexual mechanisms for reproduction and, given optimal conditions, may result in a new, genetically unique sporophyte or plant that would be recognized as *Lycopodium*. A complete life cycle from spore to gametophyte to sporophyte may take up to 20 years.

Spore development may potentially lead to a new patch and an increase in frequency. Rhizome growth and expansion will increase the overall area covered by an individual patch. For *Lycopodium*, as well as for other rhizomatous species, a major portion of the expansion of cover is created by the growth and branching of the lateral branches or rhizomes. Rhizomes are a plant's mechanism for getting around, exploring new territory, and foraging for new resources. At some point, if new resources are not discovered and exploited, that section of the plant will be cut off physiologically and another section of the plant will begin to grow and explore for new resources. In general, both methods of reproduction, sexual and asexual, help to explain *Lycopodium* distribution.

LYCOPODIUM DISTRIBUTION

The distribution of *Lycopodium* in northern forests tends to vary. These clumps or colonies are so well distributed throughout the forest that they have a certain amount of randomness in their distribution (Curtis 1959). A patch may be very dense and vast, or it may be thin and sparse. Patches of *Lycopodium* may be located near each other and occur frequently within an area, or there may be large areas where no *Lycopodium* occurs at all.

Lycopodium, especially ground pine, is often found in northern hardwood forests in Michigan's Upper Peninsula. Nauertz (1999) conducted a study in these forests to gain insight on the species biology and presence in managed and unmanaged forests. In addition, as part of a larger study (USDA, FS, NCRS, NC-4153-94-03), basal area was measured and recorded in all of these stands in 1995-1996. Four forest types were studied: (1) Unmanaged old-growth forest with trees as old as 250+ years that have not been disturbed by logging. Basal area was 23 - 47 m^2/ha. (2) Unmanaged second-growth forest that was clearcut in the 1910s and now remains unmanaged with trees that are primarily of second-growth origin. Basal area was 26 - 37 m^2/ha. (3) Managed uneven-aged forest that is of old-growth origin and is managed to have an all-age size distribution using selection cuts and group cuts. Basal area was 20 - 27 m^2/ha. (4) Managed even-aged forest that is also of second-growth origin and was clearcut around the turn of the century. Crop tree release and thinning have been performed at routine intervals to convert the even-aged stands to an uneven-aged distribution. Basal area was 21 - 30 m^2/ha.

Nauertz (1999) found that *Lycopodium* species occurred in 10 - 67 percent of the 130 plots sampled in the study. Two-thirds of the *Lycopodium* present was found in the managed even-aged and unmanaged old-growth stands used for this study. Highest *Lycopodium* frequency of occurrence and percent cover values existed in the unmanaged old-growth, managed even-aged, and unmanaged second-growth stands, respectively. *Lycopodium* percent cover under these three management regimes was not statistically different. *Lycopodium dendroideum*, *L. lucidulum*, and *L. annotinum* occurred most often across management regimes, with high and statistically similar cover values existing in the unmanaged old-growth, managed even-age, and unmanaged second-growth stands. *Lycopodium dendroideum* cover ($r^2 = 0.75$; $P < 0.01$), *L. annotinum* cover ($r^2 = 0.66$; $P < 0.01$), and *L. lucidulum* cover ($r^2 = 0.49$; $P < 0.01$) were correlated to total *Lycopodium* cover. Highest

Lycopodium frequency and percent cover occurred under the management regimes with the highest measured basal area.

FOREST MANAGEMENT AND *LYCOPODIUM*

The basic growth form or morphology of individual clonal species may offer different advantages under different environments. According to Doust (1981), most clonal species are categorized as having either a "guerilla" or a "phalanx" strategy. Species that have widely spaced individual aerial stems or ramets (guerilla strategy) explore a wide area, are successful in discovering and occupying gaps, are usually better competitors at low densities, and are more common in early successional habitats (Doust 1981). This strategy may be applied to the tree-like branching *Lycopodium* species such as *L. dendroideum*, *L. obscurum*, and *L. complanatum*. Species with densely packed individual aerial stems or ramets (phalanx strategy) expand slowly; form large clumps; are most successful in close, competitive environments; and predominate in late successional stages where competition is most severe (Doust 1981). This strategy, in turn, may be applied to the non-branching aerial stem species of *Lycopodium*, such as *L. annotinum*, *L. clavatum*, and *L. lucidulum*.

In Nauertz' (1999) study, *Lycopodium dendroideum* (ground pine) percent cover was highest and statistically similar in managed even-aged, unmanaged old-growth, and unmanaged second-growth forests. Mean percent cover of all *Lycopodium* species combined was greater in unmanaged forest than in managed forest; however, significant differences were noted, with the highest mean percent cover of *L. dendroideum* occurring in unmanaged forest. Mean percent cover of all *Lycopodium* species combined was significantly greater in second-growth forest than in old-growth forest; the highest *L. dendroideum* mean percent cover occurred in the second-growth forests. In addition, the highest *Lycopodium* frequency and percent cover occurred under the management regimes with the highest measured basal area. Considering these points, it is apparent from this study that a combination of disturbance and time following disturbance may be required to allow for adequate levels of *Lycopodium* frequency and cover to develop.

Another factor to consider is the evergreen nature of *Lycopodium* species. Regardless of the forest overstory management regime used, this evergreen characteristic should allow the clubmosses to take advantage of the spring and fall light windows that are known to exist in general and that have been recorded in these forest stands (Nauertz *et al.*, unpublished data). Temperatures near the forest floor respond to the increased light during these times and become warm enough to support biological processes relatively early and late in the growing season (Nauertz *et al.*, unpublished data). These "windows of opportunity" may be important times for photosynthate production and storage for the *Lycopodium* clone.

At various times during their life cycle, certain *Lycopodium* species may or may not turn out to be able to adapt to excessive changes in their environment. Much of their adaptive success will need to be attributed to the "individuality" of each species. In areas with dense *Lycopodium* populations, using forest management practices that consider the group as a whole will certainly add to their sustainability and overall success.

DISTURBANCE AND COMPACTION OF THE FOREST FLOOR

Soil surface disturbance is a side effect of logging operations in forest overstory management. On one hand, exposed mineral soil is a result of these operations and may provide good conditions for spore germination and gametophyte development and, if successful, a pathway for genetic variation. On the other hand, intensive soil disturbance reaching well below the soil surface and excessive soil compaction may both result when frequent entries are made into managed areas or when logging is done when soils are wet and more likely to compact. Consequently, intensive and excessive conditions may not offer the best habitat for survival of newly formed gametophytes or production of a new sporophyte. Considering the length of the life cyle for *Lycopodium* in general, fewer management entries and less excessive and intensive soil disturbance and compaction would be beneficial. Compact soils also make it difficult for species with belowground running rhizomes to expand vegetatively. Soil compaction will also alter the hydrology, often causing wetland-like conditions. Without optimal resources for success,

the *Lycopodium* clone may not be able to sustain itself or reproduce either sexually or vegetatively.

In forests of old-growth origin, the pit and mound topography is better defined and more variable than in the managed forests of second-growth origin. This variable topography offers a variety of microhabitats and resources of which *Lycopodium*, as well as other rhizomatous plants, may take advantage. In general, species with aboveground rhizomes such as *Lycopodium annotinum*, *L. clavatum*, and *L. complanatum*, as well as the layering species such as *L. lucidulum*, would have the advantage in wet, rocky areas with compact soil, whereas species with belowground rhizomes like the ground pines, *L. dendroideum* and *L. obscurum*, would have the advantage in areas where pit and mound topography exists, where the soil is well aerated and of low bulk density.

LYCOPODIUM HARVESTING GUIDELINES AND RECOMMENDATIONS

In the northern forests of Wisconsin, Michigan, and Minnesota, the ground pines are the most heavily harvested group of *Lycopodium* species. Typically you will need a permit if you plan to harvest ground pine on public land and only the mature aerial stems of the ground pine are considered to be valuable economically for decorative purposes (Wenger 1995). The most efficient and least destructive way to harvest ground pine is by clipping the mature aerial stem or tree-like portion of the plant near the base of the stem at ground level. It is less stressful for the plant if you cut it with a sharp instrument instead of ripping or tearing it away. Cutting lessens the impact the aerial stem harvest will have on the belowground rhizome, allowing it to remain stable in position within the soil below. Matula (1995) reported that disturbances such as harvesting of individual, mature aerial stems in such a way as not to disturb the underground rhizome may enhance the survival of the plant by increasing belowground rhizome branching. Taking only the mature or oldest aerial stems and leaving the younger immature stems will ensure future harvest opportunities. In addition, skipping a year or two between harvests will allow time without disturbance for possible spore germination and new plant development. A year or two between harvests within a ground pine patch will also ensure enough time for an increase in vegetative expansion and future harvest potential.

Lycopodium complanatum (ground cedar) and *L. clavatum* (running clubmoss) are two species with aboveground rhizomes that are often used when making wreaths. Harvest on public land is not allowed, but these two species are often gatherered on private land with the permission of the landowner. They are commonly harvested by grabbing an end of a rhizome and yanking it, pulling the aerial stems, rhizome, and roots all out of the forest floor litter layer. However, gathering an entire ground cedar or running clubmoss patch would prevent any surviving rhizomes from expanding vegetatively, and would consequently eliminate future harvest opportunities. Selective gathering from a dense patch is recommended, leaving plants or parts of the patch to branch and expand. In addition, some disturbance from the yanking of rhizomes during harvest exposes mineral soil and hence creates good conditions for spore germination.

Time of harvest of *Lycopodium* should also be considered for two reasons. First, *Lycopodium* species are evergreen perennials that process and store photosynthate primarily in the spring before leaf-out of the forest canopy. Since the greatest quantities of *Lycopodium* are used for traditional seasonal holiday decorations, it would not make sense to gather large quantities of them in the spring. Second, the *Lycopodium* do not produce spores until the fall, usually sometime between October and mid-November (Nauertz, personal observations), and it is important to consider whether the spores are mature and ready to be released or dispersed before the harvest. This timeline may vary slightly from year to year and can easily be tested by flicking the cone or strobili with a finger to see if the yellow dust-like spores escape.

In general, *Lycopodium* species are considered to be a rather slow growing group. A word of caution—it is not known how overharvesting will affect the growth rate of an individual plant, patch, or clone over time. Allowing a patch to recover for a few years after a harvest would ensure future harvest opportunities. Any abrupt and intensive alteration of growing conditions could make it difficult for any type

of existing ground vegetation to survive. When considering whether to gather any forest products, whether for timber or non-timber use, it is important to consider taking them in moderate quantities. The First Nation native tribal elders speak wise words: "Take what you need. Pay your respects. Leave the rest."

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