The spatial structure and condition of *Lycopodium clavatum* L. in the Zrębice Forestry

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ABSTRACT: The aim of the study was to estimate the condition of *Lycopodium clavatum* stands. The biggest area of 67m^2 occupied by the club moss was located in the *Calamagrostio arundinaceae-Quercetum petraeae* (Hartm. 1934) Scam. et. Pass. 1959 association. The contribution of living vertical shoots was much higher than the dead ones. Horizontal shoots were strongly branched. In the *Leucobryo-Pinetum* W. Mat. (1962) 1973 association club mosses occupied the area of 28m^2 in one stand, and in two others, 5 m^2 each. These stands were characterized by the high average number of dead shoots. Horizontal shoots occupied small parts of individual squares. In 2007, club moss stands in the *Leucobryo-Pinetum* were destroyed as a result of procedures of forest managing. Also, there were only dead shoots present in the stand localized in the *Calamagrostio arundinaceae-Quercetum*. We can assume that illegal collection of club moss shoots additionally results in deceasing of the stand and population numbers.

ABSTRAKT: Celem badań była ocena kondycji stanowisk *Lycopodium clavatum*. Największą powierzchnię – 67m^2, widłak zajmował w zespole *Calamagrostio arundinaceae-Quercetum petraeae* (Hartm. 1934) Scam. et. Pass. 1959. Udział żywych pędów pionowych był znacznie wyższy niż udział pędów martwych. Pędy poziome były silnie rozgałęzione. Na stanowiskach zlokalizowanych w zespole *Leucobryo-Pinetum* W. Mat. (1962) 1973 widłak zajmował powierzchnię 28 m^2 na jednym z nich, a na dwóch pozostałych po 5 m^2. Stanowiska te charakteryzowały się wysoką średnią liczbą martwych pędów. Pędy poziome zajmowały małe fragmenty pojedynczych poletek. Do roku 2007 stanowiska widłaka w zespole *Leucobryo-Pinetum* zostały zniszczone na skutek zabiegów gospodarczych. Także na stanowisku zlokalizowanym w zespole *Calamagrostio arundinaceae-Quercetum* nie odnaleziono pędów żywych, a jedynie martwe. Zmniejszanie się liczby stanowisk oraz liczby populacji może wynikać z nielegalnego pozyskiwania pędów widłaka.

KEY WORDS: *Lycopodium clavatum*, horizontal shoots, vertical shoots, spatial structure, condition, polycormons

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Introduction

Data on the stands of rare species and the size of their populations is an important element of species protection (Kapuściński 2006). The disappearance of club moss stands and the necessity of their protection were mentioned at the beginning of the 20th century (Chmielińska 1938). Despite that club moss species in Poland are under legal protection at present, the number of their stands is still decreasing (Juchacz *et al*. 1993). The pace of this phenomenon is quicker than the time needed for a new specimen to appear. Therefore it is important to conduct studies about the size and condition of existing populations and to determine their reproductive capacities. The aim of this study was to estimate the condition of *Lycopodium clavatum* L. stands in a managed forest of the Zrębice Forestry.

L. clavatum is a clonal plant with crawling shoots. Vertical forked shoots grow out of horizontal shoots. Vertical shoots have usually one or two strobili placed at a long stalk. *L. clavatum* reproduces generatively and vegetatively. The entire development from a ripe spore to the gametophyte producing sexual organs can last from 6 to 15 years (Grochowski 1956; Podbielkowski *et al*. 1986). Because of that club moss coenopopulations much quicker enlarge their cover by vegetative reproduction.

1. Material and methods

The study was conducted on the grounds of the Zrębice Forestry belonging to the Złoty Potok Forestry Management in the northern part of the Częstochowska Upland. In the whole forestry *L. clavatum* is recognized as a rare species (www.katowice.lasy.gov.pl). In the area of the Zrębice Forestry, club moss stands were localized only in two units: 352g and 330n. There were four study plots established altogether:

Leucobryo-Pinetum 1, 2 and 3 (abbreviations: LP1, LP2, LP3): three parts of the unit 352g designed for thinning in fresh pine coniferous forest referring to *Leucobryo-Pinetum*;

Calamagrostio arundinaceae-Quercetum 1 (abbreviations CaQ1): a part of the unit 330n; acidophilous oak forest referring to *Calamagrostio arundinaceae-Quercetum petraeae*.

The study was conducted in July and August 2005 and additionally in July 2007. The size of established plots was fitted to the club moss population and occupied the whole cover of its occurrence. The plots LP1 and CaQ1 were of the size of 10×10m, and the plots LP2 and 3 of the size of 5×5m. Each square was divided into smaller squares of 1×1m using Greig-Smith grating (Falińska

2002). Within each square living shoots with and without strobili, and dead shoots were counted. Every living vertical shoot without strobili was recognized and counted, and every shoot with at least one strobili was classified as such. Neither the actual number of shoot forks nor the number of strobili were taken into consideration. Shoots with and without strobili were summed. Distribution of horizontal shoots visible on the surface was mapped within the stand. Average and standard deviations of individual shoot densities in 1 m^2 were calculated for squares, where club moss occurred.

2. Results

The smallest area occupied by club moss was 5m^2 (LP2 and 3), and the biggest 67m^2 (CaQ1). In LP1 club moss occupied 28m^2. The highest number of polycormons was observed in LP1 (24) and in CaQ1 (20 – Fig. 1). Polycormons in LP1 were mainly small and poorly branched. Among 23 found, 13 were of a small size (about 1m – Fig. 1). Among others, more branched, the biggest

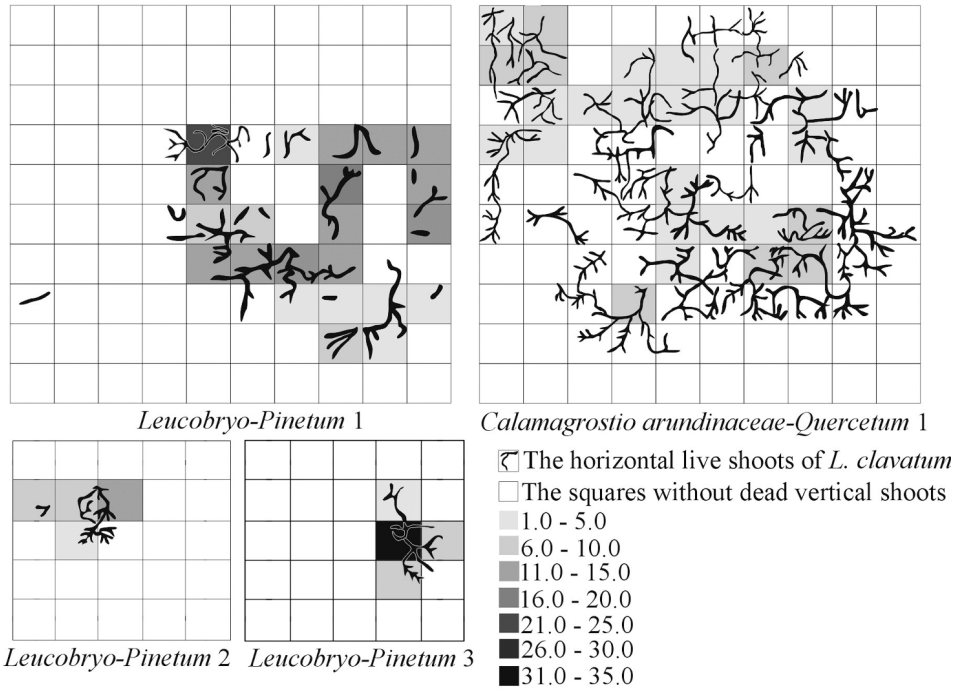

Fig. 1. The occurrence of living horizontal shoots and the number of dead vertical shoots at study plots

Ryc. 1. Występowanie żywych pędów poziomych i zróżnicowanie liczby martwych pędów pionowych na badanych powierzchniach

one spread over the area of six squares. Stands of LP2 and LP3 were formed by the smallest number of polycormons (Fig. 1). The most complicated structure was that of polycormons in CaQ1. The biggest of them spread over the area of 18 squares. Polycormons occurring within only one square were sporadic (Fig. 1). Detailed data on the number of living and dead shoots as well as the number of strobili produced are shown in Table 1.

In 2007 the *L. clavatum* stands occurring in *Leucobryo-Pinetum* were destroyed during cutting the trees. In LP1 we managed to find only remnants of 7 polycormons with 55 dead shoots. The whole coenopopulation in *Calamagrostio arundinaceae-Quercetum* was destroyed too. We found only a small (1m^2) patch of dry shoots. They were not counted because of signifi-

Tab. 1. Detailed results of research
Tab. 1. Szczegółowe wyniki badań

	LP1	LP2	LP3	CaQ1
Size of research area (m^2) (Wielkość badanej powierzchni)	100	25	25	100
Number of plots occupied by *L .annotinum* (Liczba powierzchni z *L. annotinum*	28	5	5	67
Total number of living branches* (Całkowita liczba żywych pędów)	692	170	228	3060
Percentage participation of living branches* (Udział procentowy żywych pędów)	77.3	85.42	82.3	97
Average number of living branches* per plot ± s.d. (Średnia liczba żywych pędów na powierzchni ± s.d.)	24.7±22.1	34.6±22.8	45.6±33	45.6±34.9
Maximum number of living branches* per plot (Maksymalna liczba żywych pędów na powierzchni)	97	58	95	157
Total number of branches with strobili (Całkowita liczba pędów ze strobilami)	111	3	0	556
Percentage participation of branches with strobili (Procentowy udział pędów ze strobilami)	16.0	1.76	0	18.1
Average number of branches with strobili per plot ± s.d. (Średnia liczba pędów ze strobilami na powierzchni ± s.d.)	3.96±5.54	0.6±0.54	0±0	8.32±11.3
Maximum number of branches with strobili per plot (Maksymalna liczba pędów ze strobilami na powierzchni)	22	1	0	73
Total number of dead branches (Całkowita liczba martwych pędów)	203	29	49	92
Percentage participation of dead branches (Udział procentowy martwych pędów)	22.6	14.5	17.6	2.91
Average number of dead branches per plot ± s.d. (Średnia liczba martwych pędów na powierzchni ± s.d.)	7.25±5.7	5.8±4.9	9.8±11.,7	1.37±2.20
Maximum number of dead branches per plot (Maksymalna liczba martwych pędów na powierzchni)	22	12	30	8

LP1, 2, 3 – *Leucobryo-Pinetum* 1, 2, 3; CaQ1 – *Calamagrostio arundinaceae-Quercetum* 1
*The term "living branches" means a sum of branches with and without strobili
*określenie „żywe pędy" oznacza sumę pędów płonnych i wywarzających kłosy

cant destruction and fragility. Places, in which club moss shoots grew before, were visible on the soil surface, however in most cases dead shoots were not present there.

3. Discussion

One of the reasons of the shrinking number of the club moss stands is the record in the law, which does not prevent destroying their habitats, during forest managing (Minister of Environment 2004). Also drying out of the forest habitats and collecting *L. clavatum* by people contribute to disappearance of its stands (Piękoś-Mirkowa, Mirek 2003).

Data on the club moss stands appear sporadically in publications and do not include information about the size and condition of populations. Studies on some aspects of the club moss spatial structure come from the literature and refers mainly to *Lycopodium annotinum*. Studies concerning the spatial structure of Lycopodiophyta populations in Poland are scarce (Cieszko 1999; Rudak 2002; Śliwińska-Wyrzychowska, Bogdanowicz 2008; Śliwińska-Wyrzychowska, Książczyk 2008), especially on *L. clavatum* (Juchacz *et al.* 1993).

The population of *L. clavatum* studied by Juchacz *et al.* (1993) in the Wielkopolski National Park formed a thick patch of 20.77m^2, which however was smaller than the area of the two, studied by us, stands LP1 and CaQ1, but bigger than LP2 and LP3. The authors did not give information about the number of living shoots. Producing shoots with strobili is essential for survival of club mosses as they can spread out for further distances using spores (Cieszko 1999). In Juchacz *et al*. studies (1993) the number of shoots with strobili in two consecutive years was much higher than in our study. Since there is no data on shoots with and without strobili in Juchacz *et al*. (1993), it becomes impossible to compare their results with those obtained and presented in this study. The number of club moss shoots with strobili was the biggest in the *Calamagrostio arundinaceae-Quercetum* stand and significantly lower in *Leucobryo-Pinetum* stands. The reason for this may be the fact that *Leucobryo-Pinetum* stands were situated at the forest edge and exposed to the strong insolation. According to Grime (1985), reproduction by spores, which is the popular method in pteridophytes, is not effective in expansion of club mosses to new habitats. Long duration of each developmental stage lessens the speed of inhabiting of an area, especially in *L. clavatum*, in which development of gametophyte lasts several years. Thus, the area is much quicker occupied by vegetative shoots, whose enlargement is observed within a year, than by new specimens produced from gametophytes. Such a phenomenon was studied by Callaghan *et al*. (1986a) for *L. annotinum* and according to our unpublished

observations an analogical process occurs in the discussed species. Juchacz *et al*. (1993) stated that patches of dry shoots bigger than 2m^2 disturbed the development of club mosses but they did not explain the reasons of this phenomenon, stressing that it required further observations. Callaghan *et al*. (1986a) suggested that the probability of the death of each horizontal shoot increased with the age whereas the opposite relationship was observed in vertical shoots, where the youngest ones were the most vulnerable. However, these observations were not confirmed for *L. clavatum* in the study from the Wielkopolski National Park (Juchacz *et al*. 1993) nor in the present one. In our study dead shoots did not form thick patches but they were dispersed. Their biggest number was noted in LP1, and it could not be ruled out that it was the result of the strong insolation causing the drying of habitat. The similar relationship was observed by Juchacz *et al*. (1993).

The analysis of the type and number of vertical shoots gives information about the condition of studied populations. According to the previous assessment, the presence of many branched polycormons spreading over the area of at least three squares can suggest the viability of the population (Śliwinska-Wyrzychowska, Bogdanowicz 2008) and its quick expansion to a new area (Cieszko 1999). The occurrence of numerous living vertical shoots, many of them bearing strobili, suggests the proper conditions for the population development. The presence of long, poorly branched horizontal shoots, which occupy only parts of single squares as in studied LP1 may suggest that the population became older because of habitat conditions changed. Relatively big contribution of dead shoots may support this interpretation.

In the present study, the number of living shoots in CaQ1 was bigger than in LP1–3, what may be explain by the higher humidity of *Calamagrostio arundinaceae-Quercetum* habitat. The small contribution of dead shoots in CaQ1 seemed to confirm this assumption. According to Sutherland and Stillman (1998) production of long horizontal shoots increases the probability for ramets to reach a habitat suitable for further development and to effectively use it due to the big number of branches. According to Callaghan *et al*. (1986), however, when a horizontal shoot is in unfavorable microhabitat, other shoot meristems activate to change the direction of growth and to avoid such conditions. It is so-called an opportunistic run away (Callaghan *et al*. 1986a,b). In the *Calamagrostio arundinaceae-Quercetum* stand, the club moss started dying and in places, where previously were numerous shoots with strobili, after two years dead specimens were found. It can suggest, similarly to Sutherland and Stillman (1988), that the club moss did not find suitable conditions.

It is important to stress the fact of the occurrence of pulled out polycormons in the area of *Calamagrostio arundinaceae-Quercetum*. Existing traces and the lack of dry shoots suggest the human interference that can be the cause

of population destruction due to illegal collection of club moss shoots (Piękoś-Mirkowa, Mirek 2003). Pulling out fragments of polycormons could disturb the structure of the coenopopulation and lead to its dying out. Thus, it is impossible to put forward an unambiguous conclusion about the habitat influence on the studied population because the human activity could be here an additional interfering factor.

3. Summary

The stands of club mosses localized in the *Leucobryo-Pinetum* grew in worse conditions than those localized in the *Calamagrostio arundinaceae-Quercetum*. More humid habitats promote development of *L. clavatum* as in the area of CaQ1. However, further studies on the population are necessary to verify the influence of the habitat condition on the club mosses.

Intensive forest management not only leads to the direct mechanical destruction of *L. clavatum* population but also affects it indirectly by changing microclimatic conditions in the habitat. *L. clavatum* can grow at the edges of forests in light places (Piękoś-Mirkowa, Mirek 2003) of insolation higher than inside the forest. However, the change of light and humidity regimes after cutting the trees is too drastic for *L. clavatum* and it leads to dying of the specimens. The forecast for surviving of the species would be appalling, if the procedure of cutting down the trees in economic forests is so intensive in other forestries as in Zrębice. One of the solutions to this problem would be leaving the intact part of the forest surrounding the club moss stand, which would protect it from unfavorable conditions. Besides, the problem of illegal collection of *L. clavatum*, which significantly contribute to decreasing of the species, is still unsolved.

References

Callaghan T.V., Headley A.D., Svensson B.M., Li Lixian, Lee J.A., Lindley D.K. 1986a. Modular growth and function in the vascular cryptogram *Lycopodium annotinum*. – Proc. R. Soc. Lond. B **228**: 195–206.

Callaghan T.V., Svensson B.M., Headley A.D. 1986b. The modular growth of *Lycopodium annotinum.* – Fern Gaz. **13**: 65–67.

Chmielińska M. 1938. Widłak Babimór (*Lycopodium clavatum* L.). – Wyd. Polskiego Komitetu Zielarskiego **54**: 1–9, Warszawa.

Cieszko J. 1999. Ekologia populacji paprotników (Pteridophyta). – Wiadomości Botaniczne **43**(3/4): 7–17.

Falińska K. 2002. Przewodnik do badań biologii populacji roślin. – PWN, Warszawa, 587 pp.

Grime J. P. 1985. Factors limiting the contribution of pteridophytes to a local flora. – Proc. Roy. Soc. Edinb. **86B**: 403–421.

Grochowski W. 1956. Chrońmy widłaki. – Państwowa Rada Ochrony Przyrody,PWN, Warszawa, 96 pp.

Juchacz A., Lembicz M., Zątek W.S. 1992–1993. Stan populacji *Lycopodium annotinum* L. i *L. clavatum* L. w Wielkopolskim Parku Narodowym w latach 1992–1993. – Prace i materiały Muzeum im. Prof. Władysława Szafera, p. 71–76.

Kapuściński R. 2006. Ochrona przyrody w lasach. – Państwowe Wydawnictwo Rolnicze i Leśne, Warszawa, 448 pp.

Minister of Environment 2004. Rozporządzenie z dnia 9 lipca 2004 r. w sprawie gatunków dziko występujących roślin objętych ochroną. – Dz. Ust. Nr 168, poz. 1764, z dnia 28 lipca 2004.

Piękoś-Mirkowa H., Mirek Z. 2003. Flora Polski. Atlas roślin chronionych. – Wydawnictwo Mulico, Oficyna Wydawnicza, Warszawa, 584 pp.

Podbielkowski Z., Rejment-Grochowska I., Skrigiełło A. 1986. Rośliny zarodnikowe, Wyd. 4. – PWN, Warszawa, 857 pp.

Rudak M. 2002. Badania populacji *Diphasiastrum complanatum* (L.) Holub. na terenie Sulejowskiego Parku Krajobrazowego. – In: Kurowski J.K., Witosławski P. (eds), Funkcjonowanie Parków Krajobrazowych. – Wyd. Katedra Geobotaniki i Ekologii Roślin UŁ, p. 127–129.

Sutherland W.J., Stillman R.A. 1988. The foraging tactics of plants. – Oikos **52**: 239–244.

Śliwińska-Wyrzychowska A., Bogdanowicz M. 2008. The spatial structure and condition of *Lycopodium annotinum* populations in the "Sokole Góry" Reserve and managed forest in Zrębice Forest Division (Częstochowa Upland, Southern Poland). – Scripta Facultatis Rerum Naturalium Universitatis Ostraviensis **186**: 315–318.

Śliwińska-Wyrzychowska A., Książczyk P. 2008 (in press). Występowanie i wielkość cenopopulacji widłaków (*Lycopodium clavatum* L. oraz *Lycopodium annotinum* L.) na terenie Nadleśnictwa Smardzewice (Sulejowski Park Krajobrazowy). – Chemia i Ochrona Środowiska.

www.katowice.lasy.gov.pl/strony/1/i/37005.php, 25.10.2008 r. – Web-site PGL LP Złoty Potok Forest District.

Struktura przestrzenna i kondycja *Lycopodium clavatum* L. na terenie leśnictwa Zrębice

Badania struktury przestrzennej stanowisk *L. clavatum* pozwalają monitorować kondycję jego cenopopulacji, dla których zagrożeniem jest przede wszystkim człowiek. Rozwój gametofitu *L. clavatum* może trwać wiele lat, dlatego gatunek ten zasiedla terytorium głównie poprzez namnażanie wegetatywne. Badania pozwoliły określić aktualny stan cenopopulacji *L. clavatum* w zespołach należących do *Leucobryo-Pinetum* oraz *Calamagrostio arundinaceae-Quercetum* na terenie Leśnictwa Zrębice. W celu przeprowadzenia badań założono 4 powierzchnie badawcze podzielone na poletka o wymiarze 1×1m. W roku 2005 na każdej z nich policzono liczbę pędów pionowych: żywych (płonne + zarodnionośne) i martwych oraz wykonano mapy rozmieszczenia pędów poziomych. Najwięcej silnie rozgałęzionych pędów poziomych (20), odnotowano na powierzchni należącej do zespołu *Calamagrostio arundinaceae-Quercetum*, gdzie zajmowały one do kilkunastu poletek. Niski udział pędów martwych (2,9%) sugerował, iż kondycja populacji jest dobra. Na powierzchniach należących do zespołu *Leucobryo-Pinetum* kondycja cenopopulacji widłaka była słabsza. Pędy poziome były słabiej rozgałęzione i zajmowały mniejszy obszar. Udział pędów martwych wynosił nawet do 22,6%. W roku 2007 stanowiska należące do tego zespołu zostały zniszczone na skutek prowadzonych zabiegów gospodarczych. W tym samym roku w zespole *Calamagrostio arundinaceae-Quercetum* nie odnaleziono pędów żywych. Przyczyną tego zjawiska mogło być nielegalne pozyskiwanie widłaka przez ludzi, jak również niekorzystne dla dalszego rozwoju gatunku warunki siedliskowe.