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Successful transplantation of a hart's tongue fern population (*Asplenium scolopendrium* L.) with ten years of monitoring

– Thomas Becker and Ute Becker –

Abstract

At the edge of the Harz Mountains in Lower Saxony a population of the hart's tongue fern (*Asplenium scolopendrium*) threatened by destruction by a gypsum quarry were transplanted into a dolina which was not populated by the species at that time, and the new population was followed over ten years. 90% of the 59 transplanted plants survived this period and grew larger during the first six years after transplantation. Progenies appeared in the third year after transplantation. Nowadays, in the tenth year after transplantation, there are 1110 progenies, 171 of which are reproducing. Overall, the population increased by 1781% in the ten years. Plants that were planted on a rocky slope or a boulder heap in the new habitat, where soil was available, grew better than plants in rock faces without soil. In contrast, in the rock faces, where substrate was not covered with autumn foliage, more juveniles established. The distance between juveniles and mother plants rarely exceeded three meters, which indicates a limited dispersal potential of the hart's tongue fern and may explain together with low diaspore pressure as a result of local rarity of the species that the dolina had not been colonized spontaneously. We conclude that transplantations of adult plants or introduction of spores are a suitable measure for preserving hart's tongue fern populations that are endangered by destruction. In the long run, however, such measures cannot compensate for ongoing destruction of natural habitats by mining activities in the gypsum karst region at the southern edge of the Harz Mountains.

Zusammenfassung: Umsiedlung einer Population des Hirschzungenfarns (*Asplenium scolopendrium* L.) mit zehnjährigem Monitoring

Am Harzrand in Südniedersachsen wurde eine Population des Hirschzungenfarns (*Asplenium scolopendrium*), die durch einen Gipssteinbruch zerstört worden wäre, in eine Doline, in der die Art bis dahin nicht vorkam, umgesiedelt, und die Entwicklung der neuen Population wurde zehn Jahre lang verfolgt. 90% der 59 umgesiedelten Pflanzen überlebten in dieser Zeit und wurden bis zum sechsten Jahr nach der Umsiedlung kontinuierlich größer. Im dritten Jahr nach der Umsiedlung traten erste Jungpflanzen auf. Mittlerweile, im zehnten Jahr der Untersuchung, gibt es 1110 Nachkommen, von denen 171 selbst reproduzieren. Damit wuchs die Population in den zehn Jahren um 1781%. Pflanzen, die an einen felsigen Hang oder auf eine Blockhalde mit Feinboden in dem neuen Habitat gepflanzt worden waren, wuchsen besser als Pflanzen in Felswänden, wo kein Feinboden vorhanden war. Dafür konnten sich in den Felswänden, wo kein Falllaub den Boden bedeckte, erheblich mehr Jungpflanzen etablieren. Der Abstand der Jungpflanzen zu den Mutterpflanzen betrug selten über drei Meter. Dies deutet auf ein begrenztes Ausbreitungspotential des Hirschzungenfarns hin, das zusammen mit einer geringen Sporendichte infolge der Seltenheit der Art im Gebiet die ausgebliebene natürliche Besiedlung der Doline erklären kann. Wir schlussfolgern, dass Umsiedlungen eine geeignete Maßnahme zur Rettung unmittelbar von Zerstörung bedrohter Populationen der Hirschzunge sind. Langfristig können solche Maßnahmen jedoch die anhaltende Zerstörung der natürlichen Lebensräume durch Gipsabbau am südlichen Harzrand nicht kompensieren.

Keywords: Habitat destruction, *Phyllitis scolopendrium*, population foundation, rare species, reintroduction.

1. Introduction

In 1993 it was announced that the company "HeidelbergCement AG" was planning an extension of a gypsum quarry in ravine forests with a hart's tongue fern population (*Asplenium scolopendrium*) at the Lichtenstein Mountain nearby Osterode at the south-western edge of the Harz Mountains. This rare fern is considered "endangered" in Lower Saxony and is "particularly protected" according to the German Federal Species Protection Ordinance (Korneck et al. 1996, Garve 2007). In addition, the ravine forest concerned belongs to the priority habitat type *9180 "*Tilio-Acerion* forests of slopes, screes and ravines" (European Union 1992, Ssymank et al. 1998) and was hence "particularly protected" at the time of its destruction. After the plans of the gypsum industry had been unveiled, the former "Initiative Naturschutzstudium" at the University of Göttingen and the "Naturfreunde Göttingen e. V." protested against them, e.g. with spectacular actions in Goslar and in front of the state parliament of Lower Saxony in Hanover. Among others, these activities stopped the planned quarrying of gypsum in the nature reserve "Lichtenstein", but the destruction of the adjacent ravine forests with the hart's tongue fern population in question went on. In summer 1997 the area was deforested, and soon afterwards the exploitation started. In early summer 1998, just before the quarrying would have reached the fern population, we decided to transplant parts of the population into a dolina that is situated 4 km southeast at the Blossenberg Mountain south of Osterode (Fig. 1). This dolina was not populated by the hart's tongue fern at that time, but we considered it a suitable habitat. Here, we describe the performance of the transplanted fern individuals and of the whole population over the past ten years.

Reintroduction measures and the establishment of new populations are a central part of the "Global Strategy for Plant Conservation" and contribute to the implementation of the "Convention on Biological Diversity" adopted at the Earth Summit in Rio de Janeiro in 1992 (United Nations 1993). Reintroductions and new establishment of plant populations may aim at different targets in nature conservation: Firstly, the biodiversity of degraded habitats can be restored (e.g. Hölzel et al. 2002 for floodplain meadows, Kiehl et al. 2006 for nutrient-poor grasslands, or Mottl et al. 2006 for forests). Secondly, specific vegetation types, which are important for the ecosystem, might be (re-)established by reintroducing respective key species e.g. *Calluna vulgaris* (Mitchell et al. 2008), or *Sphagnum* species (Graf & Rochefort 2010). Thirdly, rare species or species that are extinct in a specific area can be reintroduced as species conservation measure, e.g. *Vitis vinifera* subsp. *sylvestris* in the Rhine Valley (Arnold et al. 2005), *Pulsatilla patens* in a gravel plain near Munich (Röder & Kiehl 2008), or *Gladiolus imbricatus* in Estonian (Jõgar & Moora 2008) and *Scorzonera humilis* in Luxembourgian (Reckinger et al. 2010) flood plains.

In general, reintroductions and new establishments of populations are broadly accepted and increasingly practiced measures of nature conservation. However, these measures have rarely been practiced in Central Europe so far (but see Arnold et al. 2005, Kiehl & Pfadenhauer 2007, Reckinger et al. 2010), with the exception of restoration measures involving whole habitats, e.g. by transfer of hay or of diaspores of typical sets of species (Donath et al. 2006, Hölzel et al. 2006, Kiehl et al. 2006). In contrast, reintroduction or establishment measures of single species are rare and have even more rarely been monitored so far (but see Colas et al. 2008, Jõgar & Moora 2008, Röder & Kiehl 2008). Very recently, however, reintroduction projects with rare species were started in Central Europe indicating a trend reversal, e.g. with *Apium repens*, *Oenanthe conioides*, *Luronium natans*, and *Pulsatilla pratensis* in Schleswig-Holstein (Lütt 2009, Rickert & Drews 2009) and with *Pinguicula vulgaris* in Thuringia (Ebel 2006).

Reintroduction measures need not necessarily be successful (Arnold et al. 2005), but they often are (Hölzel & Otte 2003, Ebel 2006, Maschinski & Duquesnel 2006). In some cases, established populations perform even better than (Colas et al. 2008) or similar to (Morgan 2000, Marrero-Gómez 2007) existing ones.

In contrast to experiments that mainly focus on technical questions or that study the success of re-established populations in the short term, long-term studies of reintroduction measures are missing (but see Cully 1996, Bottin et al. 2007, Colas et al. 2008).

Reintroduction and establishing of populations should comply with several conditions, e.g. the use of autochthonal plant material from populations nearby (if possible) and of a mix of genotypes, which is important for the adaptive potential of populations (Heinken 2009); furthermore, all reintroduction measures should be properly documented (Pegtel 1998, van Groenendael et al. 1998). Such documentation is also part of our study, which is obviously the first (published) study on transplantation or introduction of a fern population. At least a search in the Web of Science (THOMSON REUTERS 2008) using the search terms "reintroduction" or "reestablishment" or "transplantation" and "fern" did not produce any hits.

The main questions of our study are: (i) How did the transplanted individuals or the new population, respectively, perform over the last ten years? (ii) How does the micro habitat affect the success of the transplantation?

2. The species *Asplenium scolopendrium*

The hart's tongue fern (*Asplenium scolopendrium* L.; synonym: *Phyllitis scolopendrium* (L.) Newm.) (Fig. 2 and 3) is a hemicryptophyte of the Polypodiaceae family. The in Europe diploid species is distributed from Western Europe and Great-Britain, southwards to the edge of the Alps (here normally not higher than 1700 m a.s.l.) and the northern Mediterranean, and eastwards to the Carpathians and to Crimea (SEBALD et al. 1993). A triploid tribe is distributed in Japan and in east North America. The species distribution pattern is considered to be submediterranean-temperate-subatlantic (OBERDORFER 2001). In Germany, the hart's tongue fern mainly occurs in low mountain ranges in the southwest and at the edge of the Alps. Large populations can still be found in the low-mountain range of north-western Germany, where the species reaches its northern range margin; however, many local populations went extinct here (BUNDESAMT FÜR NATURSCHUTZ 2009). In the study region at the south-western edge of the Harz Mountains, the hart's tongue fern still

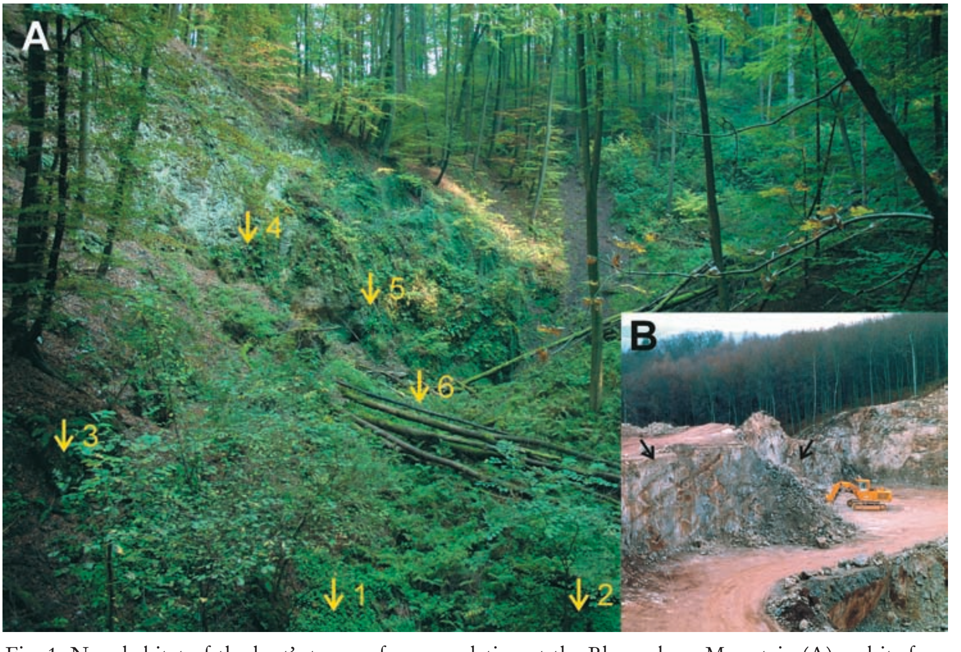

Fig. 1: New habitat of the hart's tongue fern population at the Blossenberg Mountain (A) and its former "habitat" at the Lichtenstein Mountain (B). Yellow arrows in "A" indicate localities of the six planting groups (planting groups 1–4 in the rock face, group 5 on the slope, and group 6 on the boulder heap; 15.10.2005; T. Becker). Black arrows in "B" indicate the former locality of the population at the Lichtenstein Mountain (19.11.1997; G. Ellwanger).

Abb. 1: Neues Habitat der umgesiedelten Hirschzungenpopulation am Blossenberg (A) und ihr früheres „Habitat" am Lichtenstein (B). Die gelben Pfeile in „A" zeigen die Lage der sechs Pflanzgruppen an (Pflanzgruppen 1–4 in den Felswänden, Gruppe 5 am Hang und Gruppe 6 auf der Blockhalde). Die schwarzen Pfeile in „B" zeigen den ehemaligen Wuchsort am Lichtenstein an.

Fig. 2: Well-developed individual of the hart's tongue fern (planting group 4) ten years after transplantation (31.10.2009; T. Becker).

Abb. 2: Üppig entwickelter Hirschzungenfarn aus Pflanzgruppe 4 zehn Jahre nach der Umsiedlung.

occurs in the nature reserves "Hainholz" and "Lichtenstein". It mainly grows in shady sites, on calcareous (sulphate) soils (often on rocks), in areas with high air humidity and mild winter climate, mainly in ravine forests of the *Fraxino-Aceretum pseudoplatani* W. Koch ex Tx. 1937 (alliance *Tilio platyphylli-Acerion pseudoplatani* Klika 1955) (Hettwer 1999, Oberdorfer 2001). The leaves of the hart's tongue fern are wintergreen (life span: 13 months and more) and unable to endure desiccation. In contrast to other species of the genus *Asplenium* (*A. trichomanes*, *A. ruta-muraria*) that are able to persist frost by desiccation (poikilohydry), the hart's tongue fern tolerates freeze and winter drought due to osmotic regulation and thickened cell walls. Frost hardiness of the species is recorded up to –14 °C and –19 °C, respectively (Kappen 1964, Lösch et al. 2007).

3. Methods

3.1. Transplantation of the plants

In June 1998, 59 individuals of the hart's tongue fern were removed from their natural habitat at the Lichtenstein Mountain near Osterode (ordinance survey map no. 4227/33; Gauß-Krüger coordinates 358216/573257; 10°11'25" E, 51°43'30" N; 225 m a.s.l.). At first, the plants were cultivated in a bright grove in the New Botanical Garden Göttingen. In March 1999, they were transplanted into the dolina 3 km south of Osterode at the Blossenberg Mountain (260 m a.s.l.; ordinance survey map no. 4227/34; Gauß-Krüger coordinates 3585122/5730328; 10°13'48,7" E, 51°42'03,9" N), which we considered a suitable habitat for the hart's tongue fern. This dolina is located in a north-facing uvala valley covered with forests at about 4 km distance from the original habitat at the Lichtenstein Mountain. The northeast part of the dolina is formed by gypsum from the Zechstone period and the southwest part by argillaceous shale. At the border of the two strata percolating water caused dissolution of gypsum leading to a subsidence of ground and formation of the dolina. This process is still ongoing. The dolina has a size of 45 m × 45 m and a depth of ca. 10 m. Steep

Fig. 3: Juveniles of *Asplenium scolopendrium* in the rock face habitat of planting group 2 (31.10.2009; T. Becker).

Abb. 3: Jungpflanzen von *Asplenium scolopendrium* in der Felswand im Bereich von Pflanzgruppe 2.

gypsum rocks, which tower the dolina in the east (Fig. 1, back left), form its northern and eastern boundary. The foot of the gypsum rock is covered by a boulder heap, and between gypsum rocks a rocky slope extends to the base of the dolina (Fig. 1, front and centre left). The western part of the dolina consists of clay layers which form a less steep slope (Fig. 1, back right). The area close to the dolina is dominated by European beech forest, whereas the dolina itself is covered by ravine forest with *Acer pseudoplatanus* and *Ulmus glabra* (*Fraxino-Aceretum*) belonging to the priority habitat type *9180 "*Tilio-Acerion* forests of slopes, screes and ravines" (EUROPEAN UNION 1992, SSYMANK et al. 1998). On the percolated wet soils in the western part of the dolina, common ash trees are growing with *Carex remota* in the field layer. During the last ten years, several old trees slipped down the slope leading to increased gaps in the canopy. The well-developed field layer mainly consists of ferns: *Athyrium filix-femina*, *Dryopteris filix-mas*, *D. dilatata*, on the rocky faces also *Polystichum aculeatum*, *Asplenium trichomanes,* and *Cystopteris fragilis*. *Impatiens noli-tangere*, *Urtica dioica*, *Geranium robertianum,* and in wet areas *Chrysosplenium oppositifolium* represent herbs and herbaceous perennials.

We planted the individuals into six groups referred to a "planting groups" in the following, containing 7–12 individuals each. Four of them were in rock faces (planting groups 1, 2, 4), and one group each on a rocky slope (group 3), a ledge (group 5), and a boulder heap at the basis of the dolina (group 6). The position of the plants within each of the planting groups was recorded to enable individual monitoring. In the rock face habitats of planting groups 1 and 2 slope was steep (about 85° inclination), while it was less steep (about 40° inclination) in the non-rock face habitats i.e. the ledge, bolder heap, and rocky slope.

3.2. Monitoring of the plants, estimation of dispersal distance and studying environmental variables

In late summer or early autumn the fate, number of leaves, and, since 2000, length of the longest leaf of each of the transplanted individuals were recorded annually until 2003 and biennially between 2003 and 2009. Only leaves of the respective year were counted and measured. In addition, the presence or absence of spores was recorded for each individual. If present, juveniles were counted and assigned to the nearest planting group. Prothallia were not recorded because species could not be identified. In 2009 the size (length of the longest leaf) of each of the 265 juveniles (43–73 in each planting group) was recorded. To study the dispersal potential of the species, the mean and the maximum distance of the established juveniles to the next transplanted (adult) individual was estimated in each planting group. The inclination of the slope was recorded at five positions in each of the six planting groups using a compass with clinometer (Recta DP 6), and light intensity was measured with a luxmeter (Elvos LM-1010) above each adult plant (15–23 measurements in each of the six planting groups).

3.3. Data analysis

Prior to analysis, variables describing the plant growth were averaged over the six planting groups. The changes of the growth variables over time were analysed using univariate analysis of variance (ANOVA) and repeated measurement ANOVA. Differences in the size of the juveniles and the relative growth rate of the plants between habitats (rock faces vs. non-rock faces) were analysed with simple ANOVA. The relative growth rate of the transplanted individuals was calculated as: RGR = [(# $leaves_{2009}$ × length longest $leaf_{2009}$) – (# $leaves_{2000}$ × length longest $leaf_{2000}$) / (# $leaves_{2000}$ × length longest $leaf_{2000}$)] × 100.

Statistical analyses were performed using the SPSS version 15.0 (SPSS Inc., Chicago, Illinois, USA).

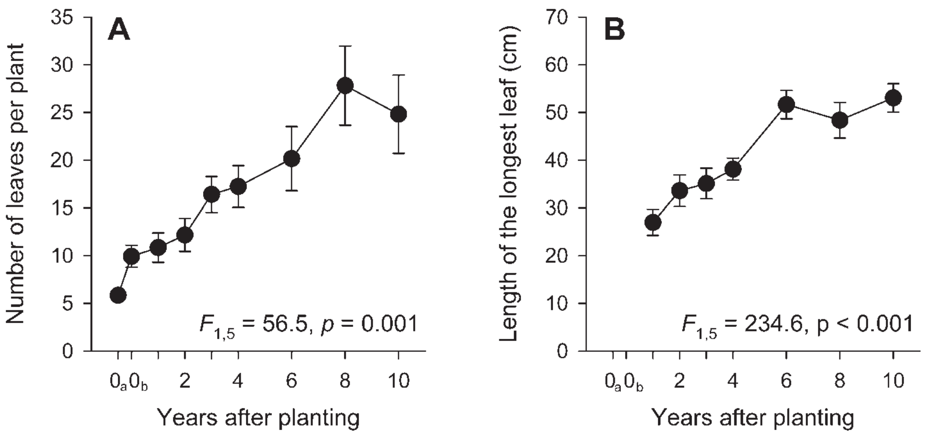

Fig. 4: Development of (A) the number of leafs, and (B) the length of the longest leaf of transplanted hart's tongue fern plants over a time span of ten years. Mean values and + 1 standard errors are shown. Repeated measurement ANOVA. 0_a = spring 1999 (date of planting), 0_b = summer 1999.

Abb. 4: Entwicklung (A) der Anzahl der Blätter und (B) der Länge des längsten Blattes pro umgesiedelte Hirschzungenpflanze über den Zeitraum von zehn Jahren. Dargestellt sind Mittelwerte und + 1 Standardfehler. ANOVA mit Messwiederholung. 0_a = Frühjahr 1999 (Pflanzdatum), 0_b = Sommer 1999.

4. Results

4.1. Fate and growth of the transplanted individuals

52 of the 59 transplanted individuals (88%) survived the study period of ten years. Seven individuals (12%) died during this period because they were slipped out of the rock face (three individuals), buried by beech autumn foliage (one individual), and because of unknown reasons (three individuals).

The average number of leaves per plant significantly increased from ten in the first year to 26 after eight years ($F_{1,5} = 56.5$, $p = 0.001$) (Fig. 4A). At the same time, the variability of the number of leaves increased significantly ($F_{1,5} = 31.3$, $p = 0.003$, $r^2 = 0.94$, $p < 0.001$) (see error bars in Fig. 4A). The length of the longest leaf per each plant doubled from about 25 cm to 50 cm within the first six years ($F_{1,5} = 234.7$, $p < 0.001$) (Fig. 4B). The size of plants that were planted on the rocky slope, the boulder heap, or the rock ledge increased during the study period by 679% ± 291%, whereas plants that were planted into rock faces increased only by 396% ± 205%.

4.2. Population dynamics

At the time of transplanting, none of the plants contained spores. Already one year later, 68.4% of the plants had sporulated, and in the fourth year, almost all plants were fertile ($F_{1,5} = 735.7$, $p < 0.001$) (Fig. 5A). Two years after the first plants had developed spores, the first juveniles emerged. At first, the number of offspring increased slowly up to 50 in the fourth year; later on, the reproduction rate increased faster and faster up to 1110 offspring ten years after transplanting, 171 offspring were reproducing that time ($F_{1,5} = 12.1$, $p = 0.018$) (Fig. 5B and Fig. 6). Each of the 59 transplanted individuals produced 18.6 established juveniles as a result of sexual reproduction, i.e. clonal offshoots were never observed. All in all the population increased by 1781% within the 10 years.

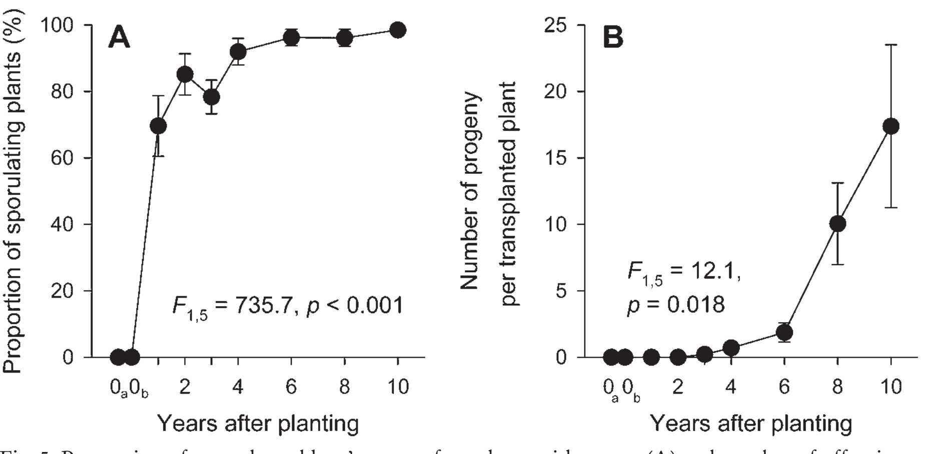

Fig. 5: Proportion of transplanted hart's tongue fern plants with spores (A) and number of offspring per transplanted plant (B) over a time span of ten years. Mean values and + 1 standard errors are shown. Repeated measurement ANOVA. 0_a = spring 1999 (date of planting), 0_b = summer 1999.

Abb. 5: Anteil der umgesiedelten Hirschzungenpflanzen mit Sporen (A) und Anzahl der Nachkommen pro umgesiedelte Pflanze (B) über den Zeitraum von zehn Jahren. Dargestellt sind Mittelwerte und + 1 Standardfehler. ANOVA mit Messwiederholung. 0_a = Frühjahr 1999 (Pflanzdatum), 0_b = Sommer 1999.

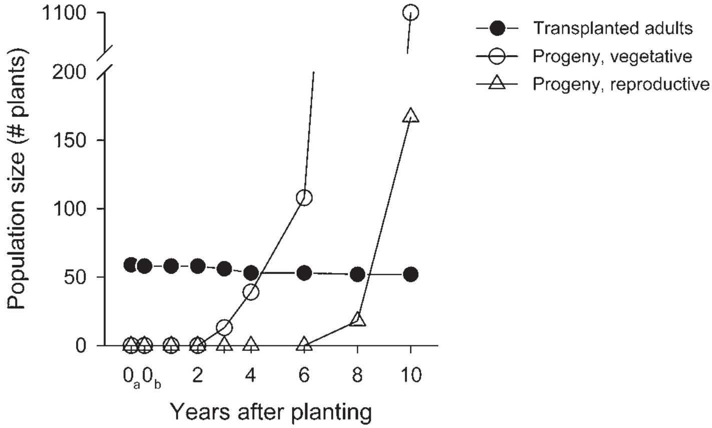

Fig. 6: Development of population size of transplanted adults, juveniles, and adult offspring over a time span of ten years. 630 vegetative progeny were counted in the eighth year of the study (value not shown). 0_a = spring 1999 (date of planting), 0_b = summer 1999.

Abb. 6: Entwicklung der Populationsgröße unterschieden nach umgesiedelten Pflanzen, und juvenilen und adulten Nachkommen über den Zeitraum von zehn Jahren. Im achten Jahr gab es 630 vegetative Nachkommen (Wert nicht angezeigt). 0_a = Frühjahr 1999 (Pflanzdatum), 0_b = Sommer 1999.

4.3. Effects of the micro habitat on offspring performance

On average, each adult plant in rock faces had produced 24.9 offspring after 10 years, whereas plants on the rocky slope, the ledge, and the boulder heap had produced only 8.9 offspring ($F = 1.7_{1,5}$, $p < 0.261$). After ten years, the mean length of the longest leaf per plant was 18.3 ± 5.1 cm on the rocky slope, the ledge, and the boulder heap, but only 3.9 ± 0.1 cm in the rock faces ($F = 3.5_{1,5}$, $p < 0.134$). The number of spore-producing progenies was also lower on the rocky slope, the ledge, and the boulder heap compared to progeny in the rock faces (24 vs. 32 progenies). However, due to low statistic power these differences were not significant.

Light intensity differed significantly between planting groups, i.e. conditions were darker in groups 1 and 5 (366–498 lux) and more bright in the other groups (654–772 lux) ($F_{1,5} = 16.7$, $p < 0.001$). However, light intensity did not differ significantly between rock face and non-rock face habitats (619 vs. 637 lux, $F_{1,5} = 0.18$, $p = 0.669$).

5. Discussion

The results of our study show that the dolina at the Blossenberg Mountain is a suitable habitat for the hart's tongue fern, which raises the question why the species did not establish spontaneously in the dolina, particularly since the closest populations of the hart's tongue fern, which could have served as potential diaspore sources, grow less than 4 km away and one would expect that the diaspores are well-dispersed because they are very light. However, the short distances between juveniles and adults recorded in our study as well as the main dispersal direction (which is down slope) indicate that the dispersal potential of the species is indeed restricted. Obviously, most of the spores fall directly to the ground without being dispersed by wind, which, however, might also be attributed to the sheltered position of the dolina. On the other hand 13 juveniles were found outside the dolina (in about 10 m distance to and about 5 m above the next mother plant), indicating that wind dispersal is nevertheless possible. Long distance dispersal in *Asplenium scolopendrium* is also indicated by the fact that synanthropic habitats such as stone walls and fountain shafts even in cities are colonised by the species (SEBALD et al. 1993; pers. observation). In total, the fact that the species did not colonise the dolina spontaneously can best be explained by a function of dispersal limitation and low diaspore pressure due to overall rarity of the species at the south-western edge of the Harz Mountains.

Several authors emphasize that the hart's tongue fern is restricted to moist air conditions (e.g. OBERDORFER 2001) and that it is sensitive to changes in the humidity conditions of the habitat (KELSALL et al. 2004). At the south-western edge of the Harz Mountains, high air humidity also occurs in other dolinas and on the north facing side of gypsum rocks that are not occupied by the hart's tongue fern indicating that the species does not fill its potential niche. However, overall these habitats are relatively rare. Nevertheless, in these habitats the establishment of further populations of the hart's tongue fern could be possible, e.g. by attaching leaves with spores from neighbouring populations on rock faces, thus enhancing a dispersal of spores onto the rocks. This measure could increase the frequency of the species in the area and thus enable its spontaneous further dispersal.

In our study, the increasing variability in the number of leaves among the six planting groups with time might be explained with differences in nutrient, but also in light conditions. Overall, the plants grew better in places with accumulated fine earth, i.e. they grew better on the rocky slope, ledge, and boulder heap than on rock faces without fine earth. Furthermore, the planting groups 1 and 2 (at the rock faces) were overgrown with high spruces until the winter 2005/06 when the spruces were overthrown by a storm; therefore, light was very likely also a limiting factor here until winter 2005/06.

The enhanced reproduction of the species in rock faces is probably due to better germination and recruitment conditions because these areas are not covered with beech autumn foliage. Mainly on the rocky slope, but also on the larger ledges, prothallia and juveniles are covered with fallen beech leaves in autumn, decreasing their survival probability. However, on rock faces competition with the liverwort *Conocephalum conicum*, which often forms a dense cover, can adversely affect germination and recruitment of prothallia and juveniles. This assumption is supported by the fact that a high number of juveniles established on the root plate of a beech that was overthrown in 2004 (Fig. 1, centre), providing open soil without moss competition, although this root plate was relatively far from the nearest mother plants. In contrast light conditions did not differ between rock face and non-rock face habitats and therefore cannot explain the differences in the number of juveniles between the two habitat types.

Furthermore, gypsum boulders at the base of the dolina are obviously a suitable habitat. These gypsum boulders have open rock at their edges, which enables germination and recruitment of the plants, while soil accumulations between and on top of the boulders provide nutrients; moreover, on top of the boulders there is less accumulation of slowly decomposable beech foliage because maple and elm are the dominant species here. In any case, the boulder heap was colonized not only by many, but also by conspicuously large and fertile offsprings. In total, the results of our study indicate the importance of micro-habitats for establishment success. The importance of open soil for the recruitment was also shown by FLINN (2007) for fern species in North America, and by SCHWARZBERG (2008) for the reintroduction success of *Pinguicula vulgaris* in gypsum rock faces at the southern edge of the Harz Mountains close to the study area.

The transplantation in our study cannot compensate for the loss of ravine forests at the Lichtenstein Mountain. However, habitat conservation is only possible if no further mining permits will be issued for valuable habitats in the karst landscape of the southern edge of the Harz Mountains and if mining can be stopped in particularly sensitive areas. The former condition may be fulfilled soon: since 2004, 10.88 km² of the karst landscape south of Osterode, including the forests at the Blossenberg Mountain and "our" dolina, are accepted as Natura 2000 site "Gipskarstgebiet bei Osterode" (EU-4226-301) (for designation and significance of the Natura 2000 site see ELLWANGER 1999a,b). However, the protected area has gaps in the form of existing active (Lichtenstein Mountain) or planned quarries; two of those, 8 ha and 6 ha in size, respectively, are located in only 150 m and 450 m distance of "our" dolina, respectively – as shown by a map of the Ministry for Environment and Climate Protection of Lower Saxony (NMUK 2009).

In the long run, one can only hope that gypsum products like wallboards will be replaced by alternative products and that, until then, consumers will stop using them because companies still focus on mining of gypsum as shown by recent purchases of deposits in the Thuringian gypsum karst and mining applications made even in Natura 2000 sites.

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