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Long term monitoring of natural regeneration in natural forest reserves in Austria

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Abstract

Research in natural forest reserves provides insights about the natural dynamics that can serve as basis for sustainable forest management. The research project ELENA studied the natural regeneration in unmanaged mountain forests in six natural reserves (Goldeck, Laaser Berg, Schiffwald, Hutterwald I and II, Kronawettgrube) in Austria. The study design and results of a comparative analysis of the regeneration on 197 long-term monitoring plots allows drawing conclusions on natural regeneration processes of Homogyno alpinae-, Athyrio alpestris- and Adenostylo glabrae-Piceetum mountain forests. The first investigation of the natural regeneration processes in natural forest reserves allow an evaluation of the forest dynamics and the identification of the driving factors for successful establishment of natural regeneration. It was found that the numbers of individuals in the natural regeneration and their distribution among different categories vary greatly between the natural forest reserves (between 766 n*ha-1 in Hutterwald and 15869 n*ha-1 in Krimpenbachkessel). The growing stock lies between 334 and 725 m³*ha-1 and the coarse woody debris volume (lying and standing dead wood) summaries up to 44.2 and 120.2 m³*ha-1 (10-26% of the growing stock). The analysis focuses on the relation between the occurrence of natural regeneration and the availability of coarse woody debris. It is shown that the number of seedlings established and saplings depend on the amount, type and distribution of coarse woody debris strongly.

Keywords

natural regeneration, natural forest reserves, Norway-spruce, long-term monitoring, coarse woody debris

Introduction

Undisturbed forests are valuable objects to study vegetation structure and dynamics (MAYER et al. 1987; LEIBUNDGUT 1982). The Austrian 'Natural Forest Reserves Program' was launched in 1995 to support the in-situ conservation of rare and endangered forest types and the study of natural dynamic processes, including the effect of natural disturbances and catastrophes (FRANK & MÜLLER 2003). The natural forest reserves also serve as references for biodiversity assessments and ecological monitoring, as they are not subject to any human activities (FRANK & KOCH 1999; FRANK et al. 2005).

The primary target of natural forest reserves, where the forests are excluded from active management, is the maintenance of the biological diversity being characteristic for the different forest communities in Austria. No particular forest conditions shall be conserved, but the dynamics of natural processes shall develop without intervention (FRANK & KOCH 1999). The majority of the natural reserves cannot be seen as true remnants of virgin forests, but most of them had a very less intensive management over the past decades or even centuries. This was mostly caused by the inaccessibility or bad suitability for timber production due to difficult terrain and soil conditions. The historical land use patterns explain why most of the reserves were formerly established in the montane and subalpine belts of the Austrian Alps (FRANK & KOCH 1999). The minor anthropogenic interferences in these areas enable however promising research studies on natural forest structure and undisturbed forest development.

The University of Natural Resources and Life Sciences, Vienna started in 2008 in cooperation with the Austrian Federal Research and Training Centre for Forests, Natural Hazards and Landscape (BFW) the ELENA project (in German: 'Empfehlungen für die Naturverjüngung von Gebirgswäldern') to address the above mentioned aspects and to develop recommendations for natural regeneration of mountain forests. The research project aimed to study the dynamics of natural regeneration on the basis of unmanaged mountain forests and to apply the findings subsequently for the development of guidelines for concepts focusing on minimal intervention silviculture. Light ecology, competitive factors, site and stand conditions as well as the degree of human influence was analysed for the phases of germination, seedling establishment and sapling growth. Additionally the role of deadwood and woody debris, which has been proved to be of special importance for the natural regeneration in some forest communities already in several studies (e.g., STÖCKLI 1995), was considered within the study.

This contribution presents the study design and results of a comparative analysis of the regeneration on 197 long-term monitoring plots of in total six natural reserves to draw conclusions on natural regeneration processes of Homogyno alpinae-, Athyrio alpestris- and Adenostylo glabrae-Piceetum mountain forests. The objectives were to identify the primary influencing factors for the initiation of natural regeneration seedlings and saplings in the forest communities.

Methods

For the long term monitoring circular permanent sample plots, 300m² in size, were established systematically on a 100x100m grid in each of the natural reserves (RUPRECHT et al. 2012). Trees taller than 1.3m were documented on the whole 300m² plot measuring their position, DBH, tree height, crown height and size. Additionally, damages were accessed. Standing and lying deadwood >10cm DBH/mid diameter was recorded through full enumeration on the study plot. For lying deadwood (<10cm in mid diameter) the total dominance was estimated for the sample plot. In addition, general characteristics as altitude, aspect, slope gradient, geology, micro and meso relief and dominance of the tree layers have been assessed on each of the plots. To assess the tree age of the different layers within the plot increment cores (Ø 5mm) were taken from 1-3 trees of different diameter classes of the main tree species spruce, fir and larch if present on the study plot. No cores were taken from trees with a DBH < 15cm.

Within each of the circular sample plots 16 subplots (category A), 0.25m2 in size (0.5x0.5m), were placed systematically, with clusters of four subplots in 4m distance of the plot center all four main directions. Within these subplots the tree regeneration was counted (seedlings and saplings) separately for the different tree species. For the saplings >15cm in height the tree height, height increment of the preceding year and diameter at root collar were measured. Additionally the vitality, damages and micro relief of the sapling position was accessed. The clusters of small subplots were surrounded by three 1m² large subplots (category B) in 3, 5 and 6m distance of the plot center. In the subplots of category B no seedlings were counted, but saplings and measured if larger than 15cm (Fig. 1).

Tree regeneration with heights larger than 30cm was measured within the whole sample plot and their approximate location was documented on a sketch. The positions of the subplots were marked permanently with a stick at 5m distance from the plot center in each of the four directions. Additionally the plot center was marked the same way and the closest large tree from the center was labelled with the plot number.

Additionally site parameters were investigated on each circular plot. Within each of the subplots of category A and B - no matter seedlings or saplings have been found on the subplots or not - the site parameters aspect, slope gradient and microclimate (e.g., cold or humid air, exposure to wind or snow accumulation) have been recorded. To deduct the area not suited for regeneration (e.g., stones, living trees) and to record the dominance of the ground vegetation, the ground cover was estimated by a frame (0.5x0.5m) with a rectangular grid for each of the subplots. The ground coverage (%) was recorded separately for vascular plants, mosses, lichens, deadwood (>10cm mid diameter), branches, living trees, litter, mineral soil, boulders and rocks. Additionally the mean height (cm) of the dominating ground vegetation was noted. The humus type, the mean thickness of the organic layer and the soil depth were measured and type, texture, hydrology and humidity of the soil have been assessed. To measure the direct and indirect radiation available for germination and growth of the natural regeneration hemisphere photos were taken with a single lens reflex camera (SLR) during homogenously covered sky, in 0.9m height over the category A subplot cluster and in 1.3m height at the plot center.

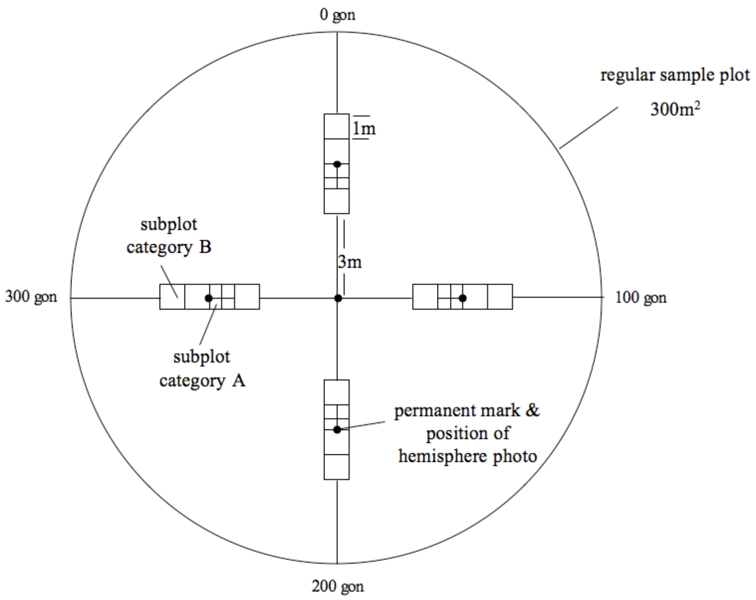

Figure 1: Sampling design on the permanent sample plots in the natural reserves (RUPRECHT et al. 2012).

Results

Natural Regeneration

It was found that the numbers of individuals in the natural regeneration and their distribution among different categories vary greatly between the natural forest reserves. The number of seedlings varies between 6574 n/ha in Schiffwald and 661531 n/ha in Hutterwald. For the saplings the numbers vary between 766 n/ha in the Hutterwald and 12288 n/ha in Goldeck. Norway Spruce is the dominating species in all reserves in the height category '30.0-129.9cm', other tree species play only a minor role. Details are given in Tab. 1.

The browsing impacts vary as well. The highest percentage of browsed individuals in the height category 15.0-129.9cm was found in the Goldeck natural forest reserve (75%), followed by Hutterwald and Kronawettgrube with 48%, Schiffwald with 19% and Laaserberg with 12%. The broadleaves are the most affected species. In the Goldeck natural forest reserve, damages caused by inter- and intraspecific competition as well as insects and mites were observed; in Hutterwald, damages from fungi and the competition with the herb and shrub layers are more frequent.

Natural reserve	Tree species	Natural regeneration category							
		seedlings		saplings		15.0-29.9cm		30.0-129.9cm	
		n/ha	%	n/ha	%	n/ha	%	n/ha	%
Goldeck	Spr.	15612 ±15707	95.9	10834 ±22740	88.1	196 ±794	64.7	369 ±745	93.6
	Con.	590 ±2051	3.6	228 ±573	1.9	-	0.0	22 ±69	5.6
	Brl.	84 ±456	0.5	1226 ±1544	10.0	107 ±365	35.3	3 ±10	0.8
	Σ	16286 ±16270	100	12288 ±23208	100	303 ±862	100	394 ±778	100
Hutterwald	Spr.	661444 ±876460	100.0	322 ±1045	42.0	227 ±1083	33.2	463 ±970	85.3
	Con.	-	0.0	-	0.0	25 ±133	3.7	22 ±49	4.0
	Brl.	87 ±464	>0.1	444 ±981	57.0	431 ±1065	63.1	58 ±127	10.7
	Σ	661531 ±876772	100	766 ±1377	100	683 ±1544	100	543 ±1075	100
Schiffwald	Spr.	5034 ±13168	76.6	1045 ±1817	15.1	211 ±630	48.4	461 ±668	78.5
	Con.	643 ±1776	9.8	134 ±646	1.9	11 ±61	2.5	111 ±213	18.9
	Brl.	897 ±2942	13.6	5732 ±9060	83.0	214 ±761	49.1	15 ±32	2.6
	Σ	6574 ±14383	100	6911 ±9524	100	436 ±979	100	587 ±788	100
Laaser Berg	Spr.	17702 ±19956	45.1	994 ±1366	80.0	232 ±693	97.5	360 ±373	87.2
	Con.	21519 ±17005	54.9	248 ±909	20.0	6 ±19	2.5	53 ±111	12.8
	Brl.	-	0.0	-	0.0	-	0.0	-	0.0
	Σ	39221 ±28515	100	1242 ±1694	100	238 ±693	100	413 ±431	100
Kronawettgrube	Spr.	139315 ±94175	100.0	7623 ±9294	93.8	55 ±130	100.0	183 ±275	100.0
	Con.	-	0.0	-	0.0	-	0.0	-	0.0
	Brl.	250 ±770	>0.1	500 ±1173	6.2	-	0.0	-	0.0
	Σ	139565 ±94233	100	8123 ±9325	100	55 ±130	100	183 ±275	100

Table 1: Amount of natural regeneration in the natural reserves

Deadwood

The amount of dead wood found in the natural reserves varies between 73.2 m³ / ha (Hutterwald) and 44.2 m³/ha (Schiffwald). The share of deadwood in relation to the amount of the living growing stock is between 10 and 20% (Tab. 2). Norway Spruce has the highest share (72-100%) of the total volume of deadwood, except in the Laaserberg Nature Reserve (were 48% of the deadwood was not able to clearly assigned to a certain species). The proportion of stumps (tree stumps below 1.30 cm height and ≥5.0 cm diameter) of the deadwood volume is between 1-18%. The standing deadwood (≥5.0 cm dbh) has the largest share of the deadwood volume (82% and 64% respectively) in the reserves of Schiffwald and Kronawettgrube, for the three other natural forest reserves the share of deadwood is lower (56-67%).

Natural reserve	**Tree species**	**standing deadwood [≥5.0cm]**	**lying deadwood [≥10.0cm]**	**stumps [≥5.0cm]**	**∑ deadwood**	**Growing stock volume**	**share of deadwood of volumen**
		m³/ha	m³/ha	m³/ha	m³/ha	m³/ha	%
		%	%	%	%		
Goldeck	Spr.	14.2 ±48.5	32.5 ±37.1	3.1 ±4.7	49.8 ±66.8	573.1 ±310.4	**9**
	Con.	3.5 ±9.5	3.6 ±7.4	0.3 ±0.6	7.4 ±12.2	148.9 ±193.8	**5**
	Brl.	0.2 ±0.5	0.3 ±1.1	>0.1	0.5 ±1.2	2.8 ±6.6	**18**
	ot.	0.4 ±2.2	10.1 ±27.8	1.1 ±2.0	11.6 ±27.5	-	**-**
	∑	18.3 ±51.6	46.5 ±52.4	4.5 ±5.1	69.3 ±79.5	724.8 ±311.0	**10**
Hutterwald	Spr.	21.6 ±29.5	39.1 ±81.9	1.9 ±3.6	62.6 ±89.0	265.4 ±207.1	**24**
	Con.	1.5 ±4.8	4.8 ±18.6	-	6.3 ±19.0	96.2 ±90.5	**7**
	Brl.	>0.1	-	-	>0.1	0.1 ±0.5	**20**
	ot.	-	0.6 ±1.9	3.7 ±5.2	4.3 ±6.1	-	**-**
	∑	23.1 ±29.4	44.5 ±98.0	5.6 ±6.3	73.2 ±104.3	361.7 ±216.8	**20**
Schiffwald	Spr.	27.8 ±62.3	6.2 ±12.5	0.7 ±5.6	34.7 ±64.2	288.2 ±157.3	**12**
	Con.	8.5 ±15.3	0.4 ±2.2	-	8.9 ±15.4	55.9 ±63.8	**16**
	Brl.	-	-	-	-	1.1 ±4.8	**0**
	ot.	-	0.5 ±3.5	0.1 ±0.6	0.6 ±3.5	-	**-**
	∑	36.3 ±63.8	7.1 ±13.2	0.8 ±5.6	44.2 ±66.1	345.2 ±170.7	**13**
Laaser Berg	Spr.	11.1 ±16.4	7.0 ±11.8	0.7 ±2.3	18.8 ±24.2	402.0 ±205.3	**5**
	Con.	4.3 ±10.7	6.1 ±18.2	1.3 ±2.5	11.7 ±20.4	135.7 ±144.9	**9**
	Brl.	0.2 ±0.9	0.1 ±0.2	-	0.3 ±1.1	-	**-**
	ot.	-	20.0 ±20.9	8.4 ±16.2	28.4 ±26.5	-	**-**
	∑	15.6 ±22.0	33.2 ±28.3	10.4 ±16.0	59.2 ±38.0	537.7 ±301.4	**11**
Kronawett-grube	Spr.	45.2 ±47.5	24.5 ±61.8	0.4 ±1.6	70.1 ±87.9	477.4 ±199.6	**15**
	Brl.	0.1 ±0.6	-	-	0.1 ±0.6	0.5 ±1.7	**20**
	∑	45.3 ±47.4	24.5 ±61.8	0.4 ±1.6	70.2 ±87.8	477.9 ±199.7	**15**

Table 2: Stumps, standing and lying deadwood in the natural reserves (Spr. – Norway Spruce, Con. – coniferous tree species; Brl. – broadleaves; oth. – other species, unidentified)

Discussion and Conclusion

In general, the numbers in the natural regeneration are in the range or above those of other spruce-dominated natural forest reserves and virgin forests. It is striking that the figures calculated by BACHOFEN (2009) are reached up to a height category of <20cm in all examined natural forest reserves. From a height class about 20cm the Kronawettgrube reserve is the only one below the formulated target numbers from Switzerland. In general, the number of individuals in the natural regeneration for this study is lower at these high-altitudinal grades compared to lower elevations (KORPEL 1995 and BACHOFEN 2009).

Based on the analysis the most important success factors for the establishment and early growth of the seedlings and saplings in the natural regeneration have been studied. The examination of the light ecology and intraspecific competition, the role of site and stand factors, the importance of coarse woody debris as well as the human influence allowed drawing conclusions on natural regeneration planning. The parameters to be significant (e.g. indirect and direct site factor, herbaceous ground vegetation, ground cover, slope factor, moisture) differentiated between the forest associations and the natural reserves. Single parameters have a high significance, although the interrelations are sometimes contrary. As a consequence no unique guideline for regeneration planning in mountain forests can be proposed. However, it can be assumed that a variety of site factors and forest structures will lead to the most promising results. The standardized concept for the data investigation will support the long term monitoring with the Austrian natural reserve program as well.

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