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The development of tree species composition in the Rachel–Lusen region of the Bavarian Forest National Park

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Abstract
About 4,500 years ago, at a time when the human influence on the landscape was still negligible, the silver fir (*Abies alba*) spread over the area of the Bohemian Forest mountain range. While the proportion of European beech (*Fagus sylvatica*) remained relatively stable, Norway spruce (*Picea abies*) was gradually displaced and beech-fir forests became predominant. Other tree species played a much less significant role. Over the centuries, there was a growing human influence on the composition of the forest. By the 16th century, glass manufacturing had become an important industry. It required firewood to run the furnaces and potash to reduce the melting point of quartz. Selective cutting was the practised method of forest use. By the end of this period, Norway spruce had become the most common tree species, followed by European beech and silver fir. The age of planned forestry began in the first half of the 19th century when ownership of the forests in the National Park area was transferred to the Kingdom of Bavaria. At first, forestry practices were based on shelterwood cutting (until 1880) and later, on the Bavarian "femelschlag" technique (expanding gap management). As a result of these types of forest management, the proportion of spruce in relation to silver fir increased even further, while the European beech component remained constant. This development continued in the 20th century. The introduction of the principle of land rent theory led to an intensification of forestry practices. As a consequence of World War I and II, the tree harvest reached a peak level. At the time of the establishment of the Bavarian Forest National Park in 1970, the proportion of spruce had increased to 72%, silver fir had decreased to only 3.2%, and European beech was still very stable at about 25%. During the first 20 years after establishment of the Bavarian Forest National Park, the tree composition changed only very little, while the tendency for spruce to increase and silver fir to decrease continued. A break in this longstanding trend did not occur until 1992–2002. Due to a spruce bark beetle infestation, the proportion of spruce decreased, while that of silver fir increased – in absolute numbers as well – for the first time. The proportion of other tree species also increased. In the meantime, mountain ash has become the third common species.

Key words: silver fir, European beech, Norway spruce, Moutain ash, forest history, forest ecology, Bavarian Forest National Park, Bohemian Forest

Introduction

The main goal of national parks is the protection of natural processes that are not influenced by human activity. This is known as "ecological process management", and means that ecological processes, such as nutrient cycles, disturbance, natural succession, decay, competition, predation, symbiosis, birth, and death are allowed to take place without human intervention. The formula "leave nature to itself" was characterised as the goal of environmental protection in national parks. An additional purpose also designated by the IUCN as a priority goal of national parks is the preservation of biodiversity and, consequently, species protection (IUCN 1994).

One of the prerequisites for the success of species and process protection is that the carriers of the process, i.e., the flora and fauna, are able to exist in viable populations. Only under such conditions process protection can be implied to essentially include the aspect of species protection. For this reason, information on the tree species composition before human intervention and on the effects of human activity on the forest composition provides a significant foundation for national park management.

Analysis of the history of the vegetation cover in the post-glacial period can be studied by means of pollen analysis – the investigation of the various trees based on pollen that have been preserved in raised bogs. This instrument is too imprecise for determining the exact details of forest development in the more recent past (since the Middle Ages). From this time on, historical accounts of the forest condition appear at shorter time intervals and with increasing density of information.

The mountain range called the Bohemian Forest was settled relatively late in history and was more or less neglected by chroniclers, the range of early sources on the situation here is quite limited. Comprehensive descriptions of the forests – their tree composition, age and stand structure – do not appear until about the middle of the 18th century. More detailed information is not available until the 19th century. Among the useful sources are forestry documents, natural history accounts, literary works, and early travel guides.

The goal of this paper study, therefore, is to reconstruct the history of the tree species distribution in the Rachel–Lusen region, the south-eastern and oldest part of the Bavarian Forest National Park, based on both pollen analysis and historic sources. In addition, an attempt will be made to explain the reasons behind the changes in the tree species composition.

Study area

The Rachel–Lusen region (RLR) of the Bavarian Forest National Park (BFNP) is located in south-eastern Bavaria along the German–Czech frontier and encompasses an area of 13,300 ha (Fig. 1). The area includes the south-west declivity of the central part of the Bohemian Forest between the Grosser Rachel Mt. in the north-west and the villages of Mauth and Finsterau in the south-east. It extends from the valley of the Grosse Ohe stream at 650 m a.s.l. to the mountain ridges, where the highest peaks are the Grosser Rachel Mt. (1452 m a.s.l.) and the Lusen Mt. (1373 m a.s.l.). The area is protected as the National Park since 1970. Detailed descriptions of the geology, soils, climate, and vegetation were published eslewhere (Baumgartner 1970; Petermann & Seibert 1979; Hauner 1980; Elling et al. 1987; Rall 1995; Heurich & Neufanger 2005).

Biographic research of historical documents and literature review

Tree species composition before the onset of human intervention

Our knowledge of the forest structure before the first historical accounts is derived from bogs and lakes, in which the pollen of the tree species has been preserved over millennia. The pollen analyses by Stalling (1987) indicate that about 4,500 years ago (during the transition between the warm, moist Atlantic period to the cold, moist Subatlantic period), the silver fir (*Abies alba*) spread over the area of the Bohemian Forest mountaine range, which was practically free of human influences. This was coupled with a decrease in the distribution of the Norway spruce (*Picea abies*), while the relative proportion of European beech (*Fagus sylvatica*) remained unchanged. The silver fir, which grows in almost any location

Fig. 1. Situation of the Rachel–Lusen region (RLR) in the Bohemian Forest.

with the exception of particularly wet and extremely poor soils, was able to occupy the entire range of altitudes. Below 950 m a.s.l., beech-fir forests developed, in which Norway spruce only played a subordinate role, being restricted to extreme locations, such as talus fields and organic soils (Table 1). At the time, spruce-fir-beech forests existed even in the high-altitude ranges. Competition between the main tree species resulted in dense stands, which left only few sites for other species, such as mountain ash (*Sorbus aucuparia*), white birch (*Betula pendula*), downy birch (*Betula pubescens*), wych elm (*Ulmus glabra*), large-leaved lime (*Tilia platyphyllos*), small-leaved lime (*Tilia cordata*), European ash (Fraxinus excelsior), sycamore maple (*Acer pseudoplatanus*), Norway maple (*Acer platanoides*), black alder (Alnus glutinosa), grey alder (*Alnus incana*), wild cherry (*Prunus avium*), European yew (*Taxus baccata*), eurasian aspen (*Populus tremula*), scots pine (*Pinus sylvestris*), and the various willows (*Salix* spp.). Many of these tree species were only able to establish themselves in sites with certain stages of forest succession or in highly specific locations, such as gravel stream banks, which serve as habitat for grey alder.

Table 1. Development of pollen frequencies (as percent of the total sum of pollen) of Norway spruce, European beech, and silver fir in different layers of peat-bog sediment from the Bavarian Forest, representing a zone between 750 and 950 m a.s.l. (modified according to Stalling 1987). For the interpretation one has to consider that beech and fir pollen is underrepresented in comparison to the real vegetation (as in the sample from surface).

Period	Norway spruce	European beech	Silver fir
Recent time	90.8	8.2	0.9
Beginning of the 19th century	73.4	15.9	7.9
16th–17th century	43.9	38.3	17.8
12th–13th century	30.2	48.6	21.2
3000 years before present	19.1	49.1	31.7

Forest development in the historic period

First settlements

Due to the harsh climate and the impenetrable forests, the central Bavarian Forest was avoided by humans for a long time. Until the early Middle Ages, it was an almost undisturbed forest wilderness. Abbey documents speak of the "eremus Nortwald", the "uninhabited northern forest" (Pfister 1979).

To promote the settlement and cultivation of this "Northern Forest", the abbeys of Niederaltaich (741), Rinchnach (1011), and St. Oswald (1396) were founded. The salt trade between Reichenhall and Bohemia played an important role for the frontier region, and the first settlements were founded along the old trade routes (i.e., Mauth in 1698, Finsterau in 1704) and were accompanied by the infrastructure required by the traders, such as inns, saddlerys, and farriers (Haug & Strobl 1993).

For the first settlements, clearings were created in the continous forest, but these were not large enough to alter its substance and composition. The sporadic requirements for firewood, construction lumber, and wooden articles for living and agricultural needs barely touched the huge timber supply of the primeval forests, even in areas close to the few established settlements. Due to the lack of transportation alternatives, it was impossible to find other uses for the wood.

The period of glass manufacture – description of forest use by the glassworks

The wood in the extended forests was put to use by the introduction of glass manufacturing. In the Bavarian Forest, the required raw materials existed in abundance. In addition to the virtually "endless" supply of wood, there was also a large amount of quartz. In the 16th century, glassworks became an important element in the area of the present national park (Haug & Strobl 1993). Over the course of time, permanent settlements were established in the vicinity of the earliest glassworks (Hütten in German). Many settlements in the today's National Park region date back to the founding or growth of these glassworks (i.e., Riedhütte (1450), Neuschönau (1417), and Weidhütte Spiegelau (1521)).

With the onset of glass manufacturing, a new era began: the large-scale utilisation of the wood resources. The glasswork forests were divided into the nearby logging forests (Scheiterwald), which provided firewood for the kilns, and the more distant, often less accessible "ash forests", in which potash (K_2CO_3) was produced by burning wood.

To keep transportation distances short, firewood was produced as close to the glassworks as possible. The practised method for wood production was the so-called selective cutting (Plenter) method, according to which only the largest trees of a stand were extracted. These were felled, cut and split as firewood, and then transported to the glassworks. The remaining trees were left standing and continued to grow. The intensity of this form of intervention varied considerably. If the smaller trees were harvested as well, the selective use often turned into an exploitive use. But even heavy use never resulted in clear cuts since at least the smaller and medium silver firs and European beech were left standing. Once the available wood supply in the vicinity of a glassworks was depleted, the glassworks was relocated to a new site. This is indicated by such village names as Althütte and Neuhütte.

In addition to firewood, potash was required as an agent to reduce the melting point of quartz. Since potash is easier to transport, it was produced by burning wood at the harvest site. Especially larger trees were used for this purpose, whether dead or alive. The production of potash required much more wood (approximately twice as much) than the amount needed for firing the kilns. For this reason, the more distant forests, beyond the immediate vicinity of the glassworks, usually served as the so-called "ash forests"". Because of their high potassium content, the preferred tree species were silver fir, European beech, the valuable hardwoods, and to a lesser extent, willows.

The influence of the glass industry on forest structure

The influence of the former glass industry on the forests can only be roughly estimated. Detailed accounts or planning documents are not available. The following sources provide a descriptive picture of the structure of the forests towards the end of the glass manufacturing period.

The general situation was described in the "Erinnerungen des königlichen Ministerial-Forsteinrichtungsbureaus" (Memoirs from the Royal Ministerial Forest Management Planning Office), which was completed as a part of the primitive operates in 1847: "As a natural result, only the best wood was used in the more distant locations … in spite of the large quantities exploited by the potash makers, who felled many a pasture forest this use remained well below the sustainable harvest. Even though the enterprises run by the 'glassworks masters' were carried out without planning, one thing is certain: they left us forests with plentiful timber. The stands from the selective harvests are not among the worst in this complex. It is due to this selection forest cutting system that fir and beech have been preserved in such abundance." (Plochmann 1961).

The forest management planning report for the forestry office in Zwiesel from 1838 provides a relatively vivid description of the situation: "The general character of the forests that have always been subject to expanding gap management is such that the harvestable age class, including some very old individual trees, is distributed throughout the entire area of the forest districts. With the exception of the most recent cuttings, large scale regeneration has not yet been undertaken in the cut-over areas. There are no large contiguous areas of intermediate timber or timber approaching harvestable dimensions. These are only found scattered in over-aged stands that have become more or less sparse. Only in the forest in the valley bottoms and the lower altitude spruce-fir forests, which according to traditional accounts have already been totally rejuvenated, do we find complete, excellent stands of evenaged, partially harvestable, partially nearly harvestable sawtimber trees." (Plochmann 1961).

At the end of this period, the high altitude ranges and the more inaccessible locations on the slopes and in the valleys between the mounts Rachel and Lusen still consisted of stands of practically undisturbed primeval forest. This is reflected in the forest descriptions of the Court Treasury official (Hofkammerrat) Utzschneider in 1788: "between the Rachel Mt., Waldhäuser, St. Oswald, Riedhütten, and Klingenbrunn, all of the forested parcels are located in several small valleys where the wood is now used very little and where there are many windthrown trees, which cannot be extracted individually to any advantage; this huge area of forest cannot be left in such a desolate state forever, …" (Seyfert 1996).

The condition of the forests used by the individual glassworks must have varied considerably, based on the characteristics of their respective locations and the ways in which they were used. The description of the glasswork forests by the forester Johann Georg Forster in 1788 emphasised the difference between the forests of the glassworks of Frauenau and Klingelbrunn: the Klingenbrunn Forest consisted of "beech, maple, and fir", while the Frauenau Forest consisted mostly of "silver fir and Norway spruce" (Friedl 1954).

The account of the Munich botany professor Otto Sendtner in 1855 gives a descriptive portrayal of the forests: "…We had never seen such firs, such beeches, in our entire lives; their majesty cannot be described adequately with numbers. Even more venerable is their history. These 300–400-year-old trees originated in the age of the primeval forest; for the forest itself is nothing other than a thinned, tidied up primeval forest. It is composed of

0.7 fir, 0.2 beech, and 0.1 spruce. The beeches are surpassed in height by the fir, and their trunks, having grown in the shade, rise as straight as gigantic columns, the first 70 feet (1 Bavarian foot = 0.292 m) without branches. High above, they spread their gracious, leafy crowns. The firs grow beyond the peaks of the beeches and provide the forest with a uniform dark appearance when viewed from the outside. At a healthy age of 300–400 years, each fir reaches a height of 200 feet and a diameter of 4–7 feet. Older trees are subject to breakage. Such stands are not rare, and the average timber volume is 115 fathoms (1 Klafter = 3.13 m^3) per Bavarian acre (1 Tagwerk = 3,408 m^2); there are even some that contain 130 fathoms. In addition to this live timber inventory, these forests also contain a supply of deadwood. In the mountains lie the dead trunks of fallen trees, which are known here as 'Rannen'." (Pfiigersdorffer 1977).

At the end of the glass manufacturing period, the forest in the RLR were composed of large areas with stands of irregular selection forest. The tree composition included nearly equal amounts of Norway spruce, silver fir, and European beech with a large overall timber inventory and impressive individual ancient trees. Since even the forests at more distant locations from the glassworks had eventually been used for the production of potash, albeit less intensively, they cannot be designated as old-growth forest a strict sense. However, the designation primeval-like is certainly justifiable. Because of the selective harvest for potash production, it may be assumed that glass manufacturing promoted an increase in the proportion of Norway spruce at the cost of European beech, silver fir, and the valuable hardwoods (Elling et al. 1987). Pollen analyses also support this hypothesis (Stalling 1987).

The period of regulated forestry

Between 1786 and 1834, most of the rights of the glassworks operators to use the state-owned forests in the central Bavarian Forest were rescinded (Plochmann 1961). This was the end of almost 400 years of irregular, selective forest use that had been characteristic of the glass manufacturing industry.

After transferral of the rights of use to the Kingdom of Bavaria in the first half of the 19th century, forest inventories for the purpose of determining harvest rates were carried out in the central Bavarian Forest. This data laid the foundation for the so-called "primitive" forest stand operatives – that is, the first forest organisation plans (= management plans). The undertaking began in 1837 in the district of the upper Ilz catchment (corresponding roughly to the area of RLR west of the Sagwasser stream), and extended over a period of 10 years. By 1857, they had been completed for the entire area of the central Bavarian Forest.

The following are descriptions of the forest stands of the Bavarian Forest from its Forest management rules of 1849: "The most prevalent are the mixed stands of beech, fir, and spruce (partly pure stands of beech or spruce) on the mostly gently inclined mountain slopes… In suitable locations, beeches also attain unusual magnitude and perfect shafts. The mixture of the mentioned tree species depends on the previous types of use and the respective altitude. In regard to total mass, beech is less often the dominant species except in areas where conifers had previously been removed. The present, almost pure beech stands are derived from this type of selective use. At lower altitudes, fir is more common than spruce unless the former was already heavily exploited by the activity of the potash makers. Stands growing out of the clear-cut areas are composed mostly of spruce, but individual beech trees or groups there have remained and can become numerous in the resulting mixed stands. With increasing altitude, beech and fir eventually no longer occur…" (Kgl. Ministerial-Forsteinrichtungs-Bureau 1849).

The forest inventories carried out at the time allow the first numerical estimates of tree species composition. According to the tree species composition that was registered in the slope and valley locations during the first inventory in 1850, there was a relatively even mixture of European beech (33%), Norway spruce (41%), and silver fir (25%). Other deciduous species were of completely subordinate significance, with a proportion of only 1%. In the **valley bottoms**, Norway spruce was the most common species (52%), followed by silver fir (26%) and European beech (22%). On the **slopes**, the proportion of Norway spruce decreased (42%) to the advantage of European beech (34%); silver fir was only slightly less common than in the valley bottoms (23%). Together, all other tree species on the slopes made up about one percent. They also comprised about 1% in the valley bottoms, where the stands were only up to 40 years old.

It can be assumed that, from the present perspective, the 120-year-old stands existing in 1850 were in a relatively near-natural state. In the **valley bottoms**, the most common species was silver fir (37%), followed by Norway spruce (35%) and European beech (28%). On the **slopes**, European beech was the most common species with 37%. The percentage of Norway spruce increased with increasing altitude and averaged on 31%. The opposite trend held true for silver fir; its percentage decreased with increasing altitude and averaged on 32% (Plochmann 1961). The high-altitude forests were almost exclusively pure stands of Norway spruce, with mountain ash and sycamore maple mixed in at only few locations (Zierl 1972).

At the time of the first operates, the auxiliary tree species contributed only a few percentage points to the total composition of the stands. As stated in the Forest management rules (Kgl. Ministerial-Forsteinrichtungs-Bureau 1849), “scattered, individually or in clusters, are maple (*Acer pseudoplatanus* more common than *A. platanoides*), mountain ash, elm, ash, birch, alder, aspen, goat willow, and yew (very rare), and in the more proximate forests, pine”. The proportions of the auxiliary species was influenced in the preceding centuries, as mentioned above, by the potash makers from the glassworks and by specific needs for certain types of wood for manufacturing of certain equipment and tools. In spite of this, the proportion of auxiliary species in the total forest composition at the time of the first operates was large enough to be mentioned in many contemporary forest descriptions. During his tour of the Bavarian Forest, the botanist Otto Sendtner (1855) noted: “…What we see at first, at approximately 2,800 to 3,000 feet above sea level, are numerous maples (sycamore maple is the most common, but Norway maple is also seen…)”.

Goals of the first forestry management plans

The onset of regular forest management included remarkably progressive approaches for forest planning. The first guidelines for management of the forest were published in 1849 under the title “Forest management rules for the Bavarian Forest” (Kgl. Ministerial-Forsteinrichtungs-Bureau 1849).

“The experience that mixed stands of spruce, fir, and beech help to preserve the higher productivity of the soils and are more capable of successfully withstanding the disadvantageous influences of the elements than pure stands of spruce or fir … demands that everywhere … the primary and utmost priority must be to preserve and promote mixed stands” (Forstwirtschaftliche Mitteilungen, Vol. 3, cited in Plochmann 1961). In spite of this stated goal to preserve the mixture of Norway spruce, silver fir, and European beech, which was a common factor in all of the forestry management plans since the first “primitive operates”, foresters were not able to maintain the proportion of silver fir. The reasons for this were likely due to the practiced forestry methods as explained in following chapters.

The Norway spruce forests in the valley bottoms were to be clear cut and replaced with even-aged stands. This was usually followed by drainage of the wet soils. The associated drop in the water table facilitated the subsequent Norway spruce plantings. These efforts were not always crowned with success. Extremely early and late frosts often killed the plantings.

According to the Forest management rules (Kgl. Ministerial-Forsteinrichtungs-Bureau 1849), the high-altitude forests were to be managed by selective harvesting so that the area would "continue to remain in a forested state".

The period of shelterwood cutting

At the time, shelterwood cutting (Burschel & Huss 1997), carried out over entire forest parcels (ca. 80 ha), was considered an appropriate method for the regeneration of montane mixed forests (Hartig's "dark felling" method). First, a preparatory cut was carried out with the goal of creating an evenly distributed, "dark", shading canopy. The older trees were removed approximately 10 years later.

Plochmann (1961) analysed the tree species composition of stands derived from the shelterwood cutting method. Since the cover existed only for a short period, Norway spruce was able to become the dominant species, reaching proportions of 80–95% in the resulting stands. Correspondingly, the other mixed tree species played an insignificant role. The percentage of European beech lay between 5 and 15%, and silver fir accounted for only 3–10% of the total. Besides the decline in silver fir, this type of forest management also induced a reduction in the amount of European beech. While before the introduction of regular management, the European beech component on the slopes had been as much as 30–45%, it decreased to 25% by 1890.

The causes that led to the "unmixing" of the stands were recognised at an early stage. With the aid of the shelterwood cutting method, it was possible to achieve an adequate level of regeneration, but Norway spruce had a decisive competitive advantage in the rapidly cleared areas. In the forest organisation plan of 1881 for the Wolfsteiner complex (the areas east of the Sagwasser stream), it had already been recognised that "in the Bavarian Forest, Norway spruce in the young growth stage is a very aggressive tree species in its environment. Presently, it enjoys such an advantage here in the constant soil moisture and humidity that, even in shelterwood situations with less light, it quickly surpasses European beech and silver fir, whether they are of equal age or older, and completely suppresses them within a period of 20 years." In addition to these failures, the windthrow catastrophes of 1868 and 1870, which especially affected stands in the shelterwood areas, led to the abandonment of this method of forest management. In 1880, it was replaced by the Bavarian expanding gap management method (Femelschlag) (Plochmann 1961).

The period of expanding gap management

The goal of the expanding gap management method was to start with preparatory cuts in order to promote European beech seed germination (Burschel & Huss 1997). From this situation, groups and clusters of trees were gradually thinned and cleared with the intention of giving European beech a lead of about 15 years. The same was supposed to be done analogously for silver fir. Afterwards, the old stands were to be cleared over large areas and regeneration with Norway spruce was to follow (Plochmann 1961).

During this phase, foresters seem to have recognised the significance of the supplementary stock of silver fir. In the course of the preselection process for the preparatory cut, however, the requirements for the quality of silver fir trees to be left standing were so high that adhering to the criteria meant that almost all of the predominant trees had to be harvested (Plochmann 1961). Because the Forest management rules of 1849 had already required removal of silver fir in the understorey during cleaning and regeneration cuts, this measure was obviously greatly responsible for the decline of silver fir. The preselection process was instrumental to the fact that the expanding gap management method did not result in the desired tree species composition.

While the regeneration of European beech was adequate, the natural regeneration of Norway spruce was unsuccessful. In a Swiss journal for forestry Engler (1905) wrote about the regeneration in expanding gap managed areas of the forest districts Wolfstein and Bischofsreuth: "…it (Norway spruce) has to be planted in the bare, weed-covered areas between clusters of beech. Fir will be completely absent in the future stands since, due to the type of management cuts, it is given no opportunity for regeneration. In neither forest district was I able to find a single cluster of fir, although, in the older stands, fir is numerous and is represented by impressive individuals capable of producing seed." A further result was an overall decrease in the natural regeneration component, which only reached a level of 11% in the upper Ilz catchment complex between 1903 and 1927. As a result, the percentage of European beech, which had originally been reduced by introduction of the shelterwood cutting method, increased again. It even reached a level that was approximately equal to the situation before the commencement of regular forest management. Due to these experiences with the expanding gap management method, forestry experts came to fear that European beech would become overly predominant, and they began to use the term "green hells" for stands with competitive European beech regeneration (Klotz 1959).

Excessive exploitation in the 20th century

At the beginning of the 20th century, the central Bavarian Forest still included 14,000 ha of old selection forest stands (Plochmann 1961). In the sense of the emerging land rent theory (Bodenreinertragslehre), these old primeval-like forest stands were considered excess inventory, which, due to their growth characteristics, had been unproductive for a long time. The goal of an economic management method based on maximum yield was to make use of such stands as soon as possible and to replace them with stands of rapidly growing Norway spruce with shorter turnover rates. Based on this idea, Graf Toerring-Jettenbach ordered a drastic increase in the harvest rate in the Bavarian state forests in 1908. The order went into effect in 1910. Immediately afterward, harvesting of the old stands in the RLR of the current National Park was increased. As a result, the expanding gap management system, which had been planned as a long-term management system, went out of control. Due to the rapid advancement of the strip femel system, it turned into more of a clear strip system that resembled clear cutting. Between 1910 and 1913, 96,000 m^3 were cut annually in the RLR (Haug & Strobl 1993). In the following years, regular management of the forests was disrupted by the both World Wars and their consequences. Exploitation continued at the same order of magnitude and was accelerated by windthrow, snow breakage, and bark beetle infestations. During the occupation in the years following the World War II, clear cutting of the last remnants of the old stands continued. In order to supply the cities, refugee and prisoner camps with firewood, the occupying powers directed large-scale exploitation of the forests in the absence of any management goals.

Due to the large expanses and rapid acceleration of the cutting, the cut-over areas were no longer capable of natural regeneration. Large-scale plantings became necessary. The chance for silver fir to become established in these areas was only slight, and as a result, its proportion decreased even further.

After the World War II, exploitation of the old stands finally reached a peak level. By 1949, only 21.6% of the area supported forest older than 100 years. Only 100 years earlier, when the planned forest management practices were first introduced, that figure was 55% (Vangerow et al. 1979).

The return to regular management did not occur until the early 1950s. The group cut

Table 2. Development of tree species composition in the Mittelsteighütte old-growth forest (modified according to Löfflmann 1987).

Year	Norway spruce	European beech	Silver fir	Annual decrease in silver fir
1856	10	30	60	not determined
1892	10	40	50	$-0.27\%.\text{year}^{-1}$
1930	15	40	45	$-0.13\%.\text{year}^{-1}$
1939	20	40	40	$-0.55\%.\text{year}^{-1}$
1987	20	75	5	$-0.73\%.\text{year}^{-1}$

system, which was re-introduced as the Bavarian combined method (Burschel & Huss 1997), became the standard forest management tool. The average annual harvest rate before establishment of the National Park was approximately 68,000 m^3.

By 1970, the year of the founding of the National Park and 120 years after the first forest descriptions, the forests were changed significantly. After periods of planned management and unplanned use, the character of the forests of the National Park area had been determined to a great degree by forest management practices: they had been converted to large-scale, even-aged, and structurally poor high forests (Rall 1995). While silver fir had been able to survive the type of forest use practised by the glassworks, the period of shelterwood and expanding gap management systems led to a near complete elimination of this tree species. At the founding of the National Park, silver fir made up only 3.2% of the forest. In contrast, the effects of shelterwood management, as well as windthrow, bark beetle calamities, and the increased harvest after the two wars promoted the spread of Norway spruce. By 1970, 72% of the National Park area was covered with Norway spruce. The proportion of European beech had changed very little. Although it had decreased during the shelterwood management period, Europeean beech was able to recover the losses incurred during the period of expanding gap management. The proportion of the other tree species also remained almost unchanged. In contrast to the tree species composition on the slopes, the composition at high altitudes was practically unaltered.

Decline of the silver fir in the areas of old-growth forests

The most conspicuous development in the forests, however, was the decline of the silver fir, a fate that was not restricted to forests managed for timber production. Even in the old protected areas, such as the so-called Mittelsteighütte old-growth forest, in which was no significant forestry use, the development of the tree species composition was similar to that observed in the economically managed forests (Table 2). Since the Josefin demarcation of 1761–1850, this stand had been designated as a so-called protected forest (Bannwald), in which any type of use was forbidden (Köstler & Seibert 1970). There was a small amount of use between 1850 and 1914 in the form of cleaning cuts, single tree extraction, and harvest of individual trees for potash production. In 1914, the area was declared a forest sanctuary, and use was restricted to purposes of forest protection. Also hunting was no longer allowed.

If inappropriate forest management practices had been the only reason for the decline of silver fir, it might be assumed that the silver fir component in this area would have remained more or less stable. The development of the tree species composition in the old-growth forest areas, however, took an unexpected course: while initially the proportion of silver fir receded only slightly, the decreasing trend has been accelerating since 1930.

This observation has also been confirmed for other areas. For the Kubany (Boubín) old-growth forest in the Czech Bohemian Forest, Seibert & Vogel (1982) calculated that the annual decline of fir was 0.05% in the period between 1851 and 1954. In this area as well, the decline of fir accelerated between 1954 and 1962, finally reaching an annual rate of 1.7%. After evaluation of additional sources, they concluded that the annual decline of the fir component in other regions of central Europe also lay between 1.7 and 5.8%. Also in other European regions like the Carparthians or the Alps a decrease in silver fire has been observed in natural forest reserves (Motta & Garbarino 2003; Senn & Suter 2003; Vrška et al. 2009).

Köstler & Seibert (1970) assumed that heavy browsing damage was a significant factor for the decline of silver fir in the Mittelsteighütte old-growth forest area. Also Löffimann (1987) stressed this point. He counted 4,500 silver firs per ha in the height class of trees up to 65 cm, but found only two per ha in the height class between 65 and 130 cm. Furthermore, in the long term survey plots, he estimated browsing damage rates between 50% and almost 70% for both European beech and mountain ash. This rate of browsing damage, which is extreme compared to that of the entire Zwiesel forest district, is explained by the use of the area by roe deer as an overwintering area, the high availability of forage, and the lack of hunting activity, which in turn, promotes further concentration of roe deers. Mayer (1975) also found that silver fir regeneration in the Kubany old-growth forest did not proceed beyond a tree height of 10 cm. Even if evidence for the strong impact of ungulate herbivory on silver fir is overwhelming the interactions between ungulates and the forest dynamic are not fully understood (Senn & Suter 2003).

Significance of wild ungulates and forest grazing

There are no reports from the 19th century of ungulates causing damage to trees. Red deer had been absent from the RLR since the early 19th century. Roe deer were present only in low densities. This observation was supported by the hunting statistics of the forest district Bodenmais between 1850 and 1869. During this period, 108 roe deers were harvested per year in an area of 3,200 ha, an annual yield of <0.2 roe deer per 100 ha. After the effects of the hunting regulations of 1852 began to take hold, the number of roe deer in the central Bavarian Forest increased. Between 1880 and 1889, the annual yield in the forest district Bodenmais, which then comprised an area of 4,800 ha, had increased to 203 roe deer (0.5 per 100 ha.year^{-1}). The results of this wildlife management system were soon witnessed. Abele (1909) for the first time referred roe deer as serious vermin. The large storm catastrophes of 1868 and 1870 and the subsequent bark beetle calamity resulted in excellent habitats and probably helped to increase the number of roe deer. Later, the populations fluctuated due to the effects of the wars in the first half of the 20th century – with alternating periods of illegal hunting and population management. After the World War II, the numbers increased again significantly. Although the influence of roe and red deers on forest regeneration was well-known, the yield was at first kept too low to allow for natural regeneration of silver fir (Schwarz 1978). According to the forest inventory within the RLR in 1981, browsing damage affected 5.9% of the Norway spruce, 16.2% of the European beech, and 33.4% of the silver fir. For silver fir regeneration stages between 50 and 100 cm, the proportion of trees damaged by browsing increased to 50%.

In addition to grazing by wild animals, large portions of the forests of the National Park had been subjected to varying intensities of grazing by domestic animals, especially cattle. Forest grazing remained in practice from the time of the earliest settlements until the mid-20th century and was carried out from the beginning of June to the end of September. The effects of grazing on the forest were controversial. However, the heavy grazing cattle

Table 3. Development of tree species composition in the Rachel–Lusen region (RLR) of the Bavarian Forest National Park (modified according to RALL 1995).

Year	Norway spruce	European beech	Silver fir	Other tree species
1971	72.2	23.5	3.2	1.1
1981	70.6	23.4	3.0	3.0
1991	73.5	20.6	2.8	3.1
2002	65.9	23.6	3.2	7.1

certainly must have caused damage to the juvenile trees by trampling and by browsing leaves in summer. For example, a grazing intensity of the grazing community Lindberg, which practised forest grazing on an allotted area of 3,000 ha (slope, valley bottom, high altitude), is available for comparison. The main grazing area was a high altitude forest. Between 1755 and 1958, herds in the range of 62 to 363 heads, on average of 200–300 cattle, were driven to this area annually. It is difficult to quantify the effects on the forest after this use. It is conspicuous, however, that the old grazing areas within these Norway spruce forests, the so-called Schachten, have got relatively high densities of sycamore maple that originated from the primeval forest stands, which existed before the areas were cleared (SEYFERT 1975). This may be interpreted as an indication that these Norway spruce forests originally contained a much higher proportion of sycamore maple, which probably felt victim to the potash makers working for the glassworks. Regeneration of sycamore maple, however, was probably significantly inhibited by the practice of forest grazing in the high altitude forests over hundreds of years. But on the other hand, regeneration of silver fir might be promoted by forest grazing (VRŠKA et al. 2009).

Forest development since the establishment of the National Park

On 11 June 1970, the Bavarian Parliament decreed the establishment of the first German National Park. During the period of its foundation, the concept of a naturally developing National Park had not yet been clearly formulated, as there was no other example for a forest national park in central Europe. A natural forest was not the original goal of the parliamentary decree. Primarily, the forest was to be managed to maintain near-natural conditions and for the production of timber. The forest management principles were to create and preserve a forest appropriate to the location, with a stable, preferably multiple-layered structure, and to convert all non-native, labile, and inappropriate sections of the forest (BAYERISCHE STAATSFORSTVERWALTUNG 1972). One condition of this forest management mandate was that all practices were to be subordinate to the requirements of the National Park. In this respect, opinions varied widely. While one group saw little contradiction between the goals of a national park and timber production, the proponents for the greatest possible degree of natural development considered these goals irreconcilable. Table 3 illustrates the development of the tree species composition in the area of the National Park between 1970 and 2002.

The first forest management plans for the National Park

A seminal decision for the further development in this factional dispute was made by the former Minister of Agriculture, Dr. Hans EISEMANN who, in advance of the forest management plan, declared that the timber harvest would be discontinued on 2,500 ha in the high altitude range. In addition, the accessibility of the stands in these reserves was no longer to be improved. This meant cancellation of the planned construction of 115 km of additional forest access roads.

Furthermore, the forest management plan, composed under the direction of the State Ministry and completed on 1. January 1972, was extremely important for the future development of the forest. The following statements are found in the Principles for future management: "…management of the forests in the territory of the National Park as high forest system is to be continued. For the upcoming forest inventory period, almost all stands are to be subjected to successive cutting; however, this is to be modified by extending the regeneration period. Only a few stands satisfy the requirements for selective cutting." (Bayerische Staatsforstverwaltung 1972). The "general economic goal", as was expressly stated, was directed primarily towards realisation of the goals of the Bavarian Forest National Park. For the forests, this meant (i) preservation of primeval-like forest stands and (ii) conversion of the remaining stands into mixed forests with near-natural structure.

In terms of forest management, this implied: regeneration and development to produce multi-layered stands; promotion of endangered accessory species, especially silver fir, in regeneration and maintenance practices; conversion of large and heavily damaged stands; and keeping to a harvest age that is not oriented toward maximum profit, but that considers the physical age maximum and health of the trees (Bayerische Staatsforstverwaltung 1972). Extensive measures were planned to help realising these forestry objectives. The goal was an annual harvest of 55,000 m^3. Between 1972 and 1982, however, an average of only 42,000 m^3 was achieved.

"New forest damage" leads to the die-off of the old silver fir trees

Although, after establishment of the National Park, forest management practices were initiated to increase the proportion of silver fir, this tree species faced further decline. Due to the sensitivity of silver fir to airborne pollutants, especially sulphur dioxide, significant damage began to be noticed in the mid 1960s, which even in the Bavarian Forest led to the die-off of old silver fir trees. The damage increased significantly after the drought year of 1976. The forest inventory in the original National Park territory in 1982 led to much concern over the health of the silver fir. The deadwood inventory contained a disproportionate amount of silver fir. In relative terms, the greatest decrease in dead wood of fir was among the 80–120-year-old stands (Bayerische Staatsforstverwaltung 1982).

Tree ring studies on silver fir from the Bavarian Forest reveal noticeably depressed growth rates between 1965 and 1982 (Hofherr & Poost 1996, Strunz et al. 1999). During that period, the future of the silver fir was viewed with scepticism (Wagner 1981). However, the ordinance released in 1983 for the regulation of large power plants led to a drastic reduction in sulphur dioxide emissions nationwide. As a result, the air concentrations and the deposition of sulphur oxides and free acid radicals in the forest ecosystems decreased. In the area of the National Park, the observed reduction of sulphur deposition by 61% resulted in an improvement of the soil chemistry (Beudert & Breit 2004).

Due to this relief, the growth rate of silver fir began to increase again over the course of the 1980s (Elling 2004). Another positive aspect was that the tree rings and the associated vitality of the trees have increased since 1990 to the level of the 1950s (Strunz et al. 1999; Elling et al. 2008).

The inclusion of an ecological value analysis in forest management planning

During preparation of the forest management plan in 1980, the general intention was to build upon the forestry objectives from the 1972 plan. The designation of stands to be excluded from harvests was to be decided upon with the aid of an ecological value analysis. The goal was to examine the stands in the National Park according to their near-natural status, rarity, and structural variety (Ammer & Utschik 1984). As a result, many old stands were granted reservation status and were thereby excluded from any mode of forest management. Furthermore, several variants were devised for future forest management practices. After consultation on the plans presented in spring 1983, the Bavarian parliament decided on the proposed variant with a management yield of 28,000 m^3 per year. At the same time, 6,400 ha of the forest, which amounted to approximately half of the total forest area within the former National Park boundary, were strictly protected in reservations.

The windthrow damage of 1983–1984

Soon thereafter, the decision to designate and resolutely protect the reservations was put to a test: on 1 August 1983, a thunderstorm blew down trees with a total timber volume of 31,000 m^3. Approximately 20,000 m^3 of the total were situated within the reserves. After long consultations with the experts in the National Park Advisory Committee, Dr. Hans Eisenmann made another groundbreaking decision for the future development of the National Park, which was not to interfere with the natural process. The goal was "an old-growth forest for our children and children's children". After this unequivocal "yes" to allow nature for taking its free course, extreme events, such as windthrow, would continue to determine the natural development in the reservations.

In the period between 1971 and 1991, only small changes in the tree species composition were observed. While Norway spruce and other tree species increased somewhat, the proportion of European beech decreased. Silver fir continued to decline, especially because of the high numbers of wild ungulates and anthropogenically produced pollutants. This happened in spite of concerted support and management measures. A detailed account of the history of the National Park presented Rall (1995) and Haug & Strobl (1993).

Massive bark beetle infestations have determined the forest development since the 1990s

In the early 1990s, the timber yield outside of the reservations was further reduced as well. Significant reasons for this were the two heavy storms: Vivian and Wiebke (on 27. February and 1. March 1990, respectively). The directive to discontinue harvests in the Bavarian state forests in general was decisive in leading to the end of regular timber harvests in the National Park. Based on the forest inventory and the National Park ordinance of 1992, the current zoning system was established. This resulted in the designation of a Natural Zone and a 500-m-wide Management Zone, in which certain management measures, such as bark beetle control, are allowed. The regular annual timber yield decreased accordingly: from 15,000 $m^3.year^{-1}$ between 1986 and 1992 to <1,000 $m^3.year^{-1}$.

Since 1992, forest development within the RLR has been influenced significantly by mass reproduction of the spruce bark beetle. While the newly infested areas after the storm damage of 1983 and 1984 covered only a relatively small area of 5 ha in 1991, the infestation increased considerably afterward, reaching a peak of 827 ha in 1996. In subsequent years, the infestation decreased and by 2000 it stabilised at a high niveau. In 2001, the newly affected area decreased from 605 ha to 55 ha and levelled off at approximately 100 ha in the two following years (Fig. 2; Heurich et al. 2001).

Since the extreme summer of 2003, the bark beetle infestation has again been increasing rapidly. In order to prevent encroachment of the beetle infestation into neighbouring, privately owned forest parcels, the timber yield in the National Park Management Zone was increased. The maximum level of these compulsory fellings within the RLR reached 38,400 m^3 in 1998 (Fig. 3).

As a consequence of the bark beetle development, the tree species composition in the RLR has changed considerably since 1991 (Table 4). Stands of old Norway spruce were reduced by 3,000 ha. Because of the resulting near treelessness of these areas, Norway spruce was

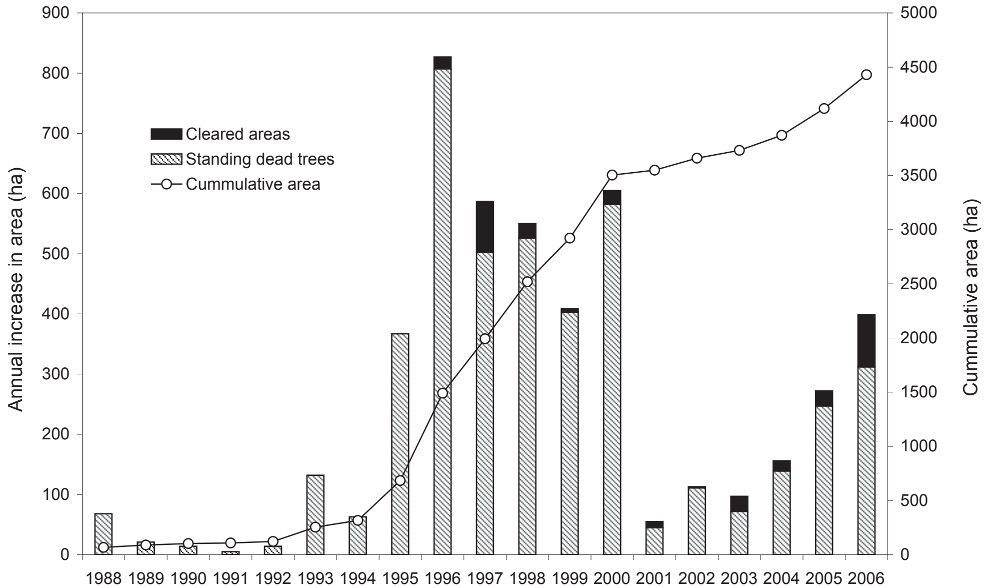

Fig. 2. Dead spruce stands in the Rachel–Lusen region (RLR); stacked bars show total annual areas (left ordinate); line with symbols respresents the cumulative area (right ordinate).

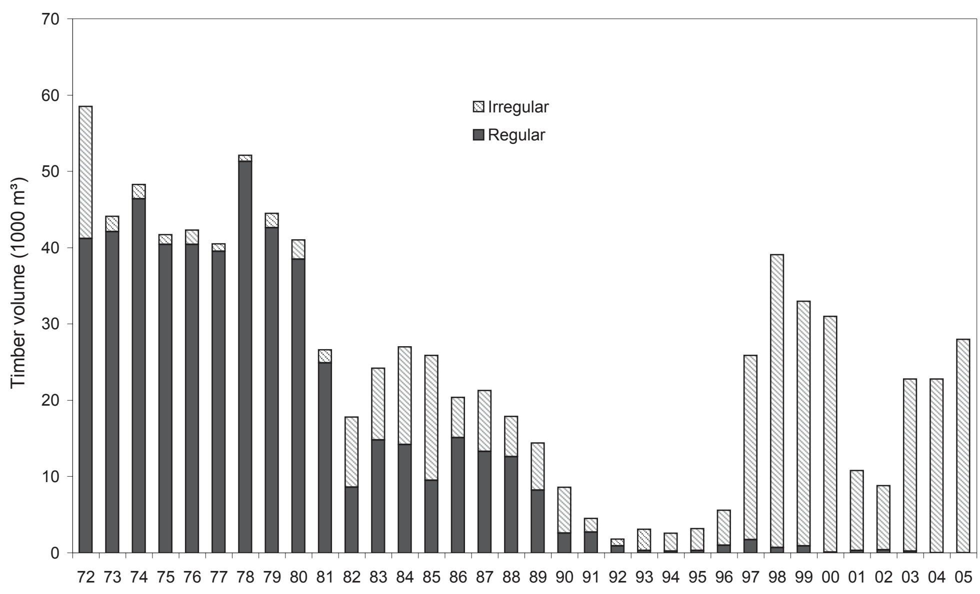

Fig. 3. Annual wood felling in the Rachel–Lusen region (RLR); regular: planned wood harvest; irregular: wood felling in the Management Zone of the National Park because of bark beetle infestation, snow break, and wind throw.

Table 4. Detailed comparison of tree species composition by age classes between 1991 and 2002 in the Rachel–Lusen region (RLR) (Heurich & Neufanger 2005).

Tree age:	**until 20 years**				**20 to 100 years**				**more than 100 years**				**Sum of all trees**			
	1991		**2002**		**1991**		**2002**		**1991**		**2002**		**1991**		**2002**	
Tree species	ha	%	ha	%	ha	%	ha	%	ha	%	ha	%	ha	%	ha	%
Norway spruce	305.5	68.1	2677.5	75.1	4440.7	75.7	3988.7	74.4	4582.5	71.5	1641.6	44.6	9328.7	73.3	8307.8	65.9
Pine & larch	0.5	0.1	0.0	0.0	20.1	0.3	15.6	0.3	3.9	0.1	6.9	0.2	24.5	0.2	22.5	0.2
Silver fir	16.9	3.8	45.6	1.3	62.6	1.1	63.7	1.2	277.1	4.3	297.5	8.1	356.6	2.8	406.8	3.2
Douglas fir	0.0	0.0	0.0	0.0	1.5	0.0	1.4	0.0	0.0	0.0	0.0	0.0	1.5	0.0	1.4	0.0
All coniferous species	322.9	72.0	2723.1	76.3	4524.9	77.1	4069.4	75.9	4863.5	75.9	1946.0	52.9	9711.3	76.3	8738.5	69.3
European beech	34.4	7.7	263.3	7.4	1122.8	19.1	1040.0	19.4	1467.2	22.9	1668.8	45.3	2624.4	20.6	2972.1	23.6
Hardwoods*	7.2	1.6	17.5	0.5	95.4	1.6	74.1	1.4	60.5	0.9	52.7	1.4	163.1	1.3	144.3	1.1
Other deciduous tr.	84.0	18.7	563.5	15.8	126.5	2.2	178.8	3.3	14.1	0.2	12.5	0.3	224.6	1.8	754.8	6.0
All deciduous species	125.6	28.0	844.3	23.7	1344.7	22.9	1292.9	24.1	1541.8	24.1	1734.0	47.1	3012.1	23.7	3871.2	30.7
Total species	448.5	100	3567.4	100	5869.6	100	5362.3	100	6405.3	100	3680.0	100	12723.4	100	12609.7	100

* deciduous trees like maple, ash, cherry

able to become well established again and the area covered by stands less than 20 years old has increased by 2,300 ha. All in all, the balance for Norway spruce is negative. Its area was decreased by nearly 1,000 ha and its proportion decreased from 73 to 66%. In the initial regeneration stage, the proportion of Norway spruce remained nearly constant at 57%.

Larch and Douglass fir, which are not native to the area, are practically insignificant in the RLR; they make up only 0.1% of the forest.

European beech was able to increase its proportion in the old stands from 23 to 45%. However, the ecological conditions in the treeless areas are not conducive to this species. In these areas, European beech only increased from 21 to 24%. In the advanced regeneration, it continues to gain importance (from 22 to 28%; HEURICH & NEUFANGER 2005).

The development of silver fir was similar to that of European beech. In the old stands, its proportion doubled from 4 to 8%. In all, the area covered by silver fir within the RLR had increased by 50 ha since the last inventory. This corresponds to an overall increase from 2.8 to 3.2%. Even more positive in respect to the natural tree species composition is the development of the advanced regeneration. The percentage of silver fir increased to 9.1%. On the other hand the spruce bark beetle infestation had a negative effect on silver fir regeneration: the proportion of silver fir in the areas of young growth was only 1.6%. Also important is that the distribution of silver fir over the RLR is still favourable despite its low numbers (Fig. 4).

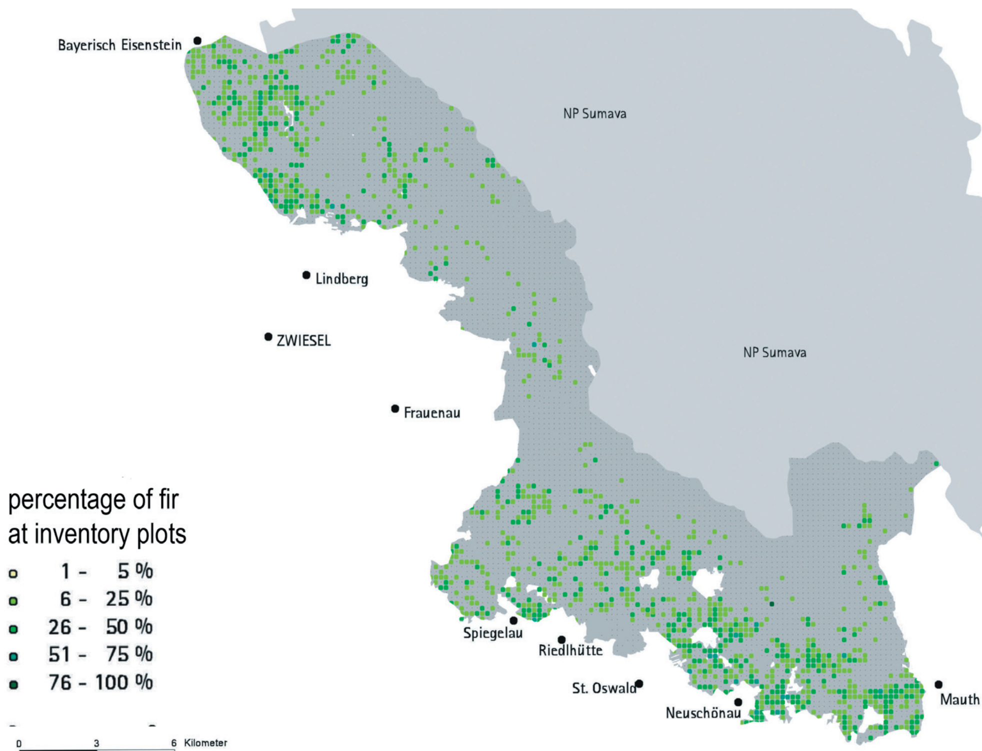

Fig. 4. Distribution of silver fir in the Bavarian Forest National Park (data source: Inventory 2002).

The proportion of the other deciduous tree species increased from 1.8 to 6%, which corresponds to an increase of 530 ha. This group of tree species was able to become well established in the newly created treeless areas. They also increased their percentage in the advanced regeneration to 6.5%. The proportion of the valuable hardwoods decreased from 1.3 to 1.1%. This was especially apparent in the 20–100-year-old stands, where this group of species lost approximately 22% of its area. Its proportion in the young stands is only 0.5%. Even in the advanced regeneration, its proportion is only slightly higher at 1% (Heurich & Neufanger 2005).

Concluding discussion

In essence, the results of the pollen analyses and the evaluation of the historical sources lead to the following conclusions:

- The forests in the RLR were originally dominated by European beech and silver fir. Norway spruce was less significant and was limited to specific locations like peat bogs, rocky areas, or the higher elevations.
- Silver fir has undergone a drastic decline in the valley bottoms and on slopes, a trend that extends to the present time. Both results of pollen analyses and historical descriptions indicate a decline by at least 90%.
- The original area of silver fir is today more or less covered by Norway spruce. This species at least doubled its range since the beginning of modern forestry.
- The area of European beech did not change much since the beginning of modern forestry, but dropped significantly in comparison to the results of pollen analysis.
- It appears that the proportion of other tree species has always been relatively low. Due to their low significance and the poor quality of the information, it is impossible to discern tendencies in their development. As a result of the current bark beetle outbreak the area of these species increased significantly.
- The role of non-native tree species in the National Park is almost negligible.
- After the founding of the BFNP, tree species composition was relatively stable until the major bark beetle outbreak lead to a decrease in Norway spruce and an increase in auxiliary tree species.

Descriptions from central and eastern European old-growth forests of the mixed montane zone support these results concerning the original tree species composition. The structure of the reservations investigated in these areas is usually very uniform and characteristic in spite of the highly varied geographic locations. The most important tree species is silver fir, the proportion of which is usually more than 50%. The second most common species is European beech, followed by Norway spruce. Other species make up less than 5% (Leibundgut 1982; Korpel 1995).

Concerning the results of the pollen analysis, it must be considered that it might be quite difficult to arrive at an analytical interpretation of the historic development of the less common mixed tree species. It is known, for example, that the pollen of the yew is difficult to diagnose and that it is often missing or mistaken in pollen diagrams. Furthermore, since several of the accompanying species, such as lime, maple, and cherry are pollinated by insects, their respective contents in pollen deposits might provide inaccurate information. To cope with this it is suggested to multipy the pollen data of these species by correction factors whit values between 2 and 4 (Faegri & Iversen 1950; Andersen 1970; Lang 1994).

The early historic records from the Bavarian Forest, an area that was settled late in history and long neglected, are meagre. Comprehensive descriptions of the forests – tree species composition, age, and stand structure – are not available before the mid-18th century. More detailed accounts were not given until the 19th century. Among the available sources are forestry documents, natural history and literary descriptions, as well as the first travel guides, which were the harbingers of early tourism. A problem with the historic sources is that the condition of the forest was usually only described, but not quantified. In addition, the sources are mostly very subjective and, in some cases, contradictory. The unregulated use by the glassworks, for example, was always judged very critically by forestry officials. At the time, the complete harvest of small sections of stands in "orderly cuts" was considered an advanced method that was to be striven for. In contrary to this view, naturalists draw a more positive image of these glasswork forests.

What are the primary reasons for the decline of the silver fir and the increase of Norway spruce? Pollen analyses from the RLR indicate a significant decrease of silver fir and European beech in the pollen count immediately after the silver fir optimum in the subatlantic period. This trend accelerated in the beginning of the 19th century. It would seem appropriate to attribute the shift in tree species composition to the increasing influence on forest structure by human activity. However, diagrams from lower elevation mires indicate that the increase in the Norway spruce component was lower than in mires situated on the slopes and at high altitudes. The increased human influence, however, would be expected to have been greater in the lower altitude areas. Stalling (1987) concluded that the spread of Norway spruce was not solely due to the influences of man, but that it also had natural causes. The most plausible explanations are those based on climatic fluctuations. Indeed, at around 1300, after one of the periods with the warmest winters in the millennium, there was an abrupt switched to a period with very cold winters. This drastic temperature drop marked the beginning of the Little Ice Age (Pfister 1998). These climatic conditions, which were less advantageous for silver fir and European beech, may have assisted the spread of Norway spruce. Superimposed over this natural component was the influence of man, which later became the predominant factor. A use-determined decrease in silver fir probably took place as early as during the glass manufacturing period. This was accelerated by the introduction of regulated forest management. The formulated goal of retaining a high proportion of silver fir could never have been achieved through implementation of the chosen forest management methods. The heavy use resulting from the effects of the wars exacerbated the situation and lead to a strog increase of Norway spruce. After the World Wars the felling had already decreased considerably, the management of the roe and red deer populations led to greater increases in browsing damage. Because of this, too few silver fir trees were able to grow into the forest stands. On top of this, the "new forest damage" caused a noticeable decline in the number of old silver firs.

The results from the forest inventory of 2002 indicated the first increase in area covered by silver fir since preparation of the first primitive operates. Silver fir trees are still well distributed throughout the area. Whether or not this is truly a turn-around cannot be determined at this point in time. At present, the development of silver fir is affected by positive, as well as negative factors. Positive factors are: the currently observed increasing of temperatures, which is more accommodating to silver fir than to Norway spruce; the fact that forest management measures are no longer carried out in the National Park; the recent recovery from acid stress and the diminished influence of the wild ungulate population on the regeneration of this tree species. The latter was accomplished by a significant reduction in numbers, abandonment of winter feeding (and establishment of winter enclosures), and the return of the lynx. Disadvantageous, however, is the spruce bark beetle infestation. Because of its ecological requirements, silver fir is at a competitive disadvantage in the treeless areas, especially in comparison to Norway spruce. Correspondingly, its proportion in these areas is only 1.3% in comparison to areas with advanced regeneration where its proportion is 9.1%.

The presented results show that the tree species composition has undergone significant changes due to natural causes since the last Ice Age. Starting in the Middle Ages, human activity increased as a significant driving force influencing the development and composition of the forest in the study area. Based on the available information, it is only possible to roughly estimate the past development of the tree species over time. But even this somewhat scant information provides important information for consideration in National Park management.

The management goal for national parks is the preservation of natural processes and all naturally occurring tree species with their inherent genetic variability (IUCN 1994). Accordingly, the BFNP concept is not directed toward achieving a particular condition by means of forest management (as for example, restoration of forest conditions as they would have been at the onset of regulated forest management or adjustment of the tree species composition according to predetermined proportions). Instead, the central theme of the National Park concept is to allow and to revive the development of natural processes. It is only their formative strength that will create natural conditions over the course of time. Due to the relatively natural species composition of the forests and the adequate size of the Natural Zone of the RLR, there is no need for active implementation of forest management practices to promote the supplemental tree species. In the Natural Zone, as well as in the Management Zone, no such measures are planned. The only exceptions are for the preservation of rare tree species in sustainable populations, such as yew, and for the removal of non-native tree species, such as Douglas fir and larch.

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