A CENTURY LONG DYNAMICS OF SILVER FIR POPULATION IN MIXED SILVER FIR-EUROPEAN BEECH FORESTS

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Abstract
The long-term dynamics of silver fir in mixed silver fir-European beech forests in Slovenia was studied in three geographically dislocated study areas, i.e. Leskova dolina, Trnovo and Jelovica. In the study, archival data on forest stands for the past century were used to create the GIS database, which included data for the periods 1912-2004 for the Leskova dolina study area, 1897-2003 for the Trnovo study area, and 1899-2002 for the Jelovica study area. In the observed period, substantial changes in diameter structure of silver fir and its proportion in stand volume were recognized. In Leskova dolina and Trnovo, the silver fir population was ageing, while in Jelovica it rejuvenated. In Leskova dolina and Trnovo, the silver fir proportion in stand volume decreased in the observed period, indicating its reciprocal replacement with European beech. The analyses of regeneration and recruitment designated different future potential of silver fir in the study areas. The found dynamics of silver fir is underpinned by a complex array of influential factors, notably past forest use, the impact of large ungulates, and site conditions.

Key words: Abies alba, forest management plans, diameter structure, tree species composition, recruitment, regeneration, forest management, large ungulates

INTRODUCTION

Silver fir (Abies alba Mill.) is the third most abundant tree species in Slovenia. It is currently present in 30% of forests, but it occurs abundantly only in 8% of forest cover (Poljanec et al., 2009). Silver fir (hereinafter fir) is naturally admixed to forest stands on approximately one third of forest sites in Slovenia (Dakskobler and Marinšek, 2009) from the colline to the subalpine altitudinal belts, but it finds its optimum in the montane and altimontane altitudinal belts (Ficko and Bončina, 2006). It most often forms mixed stands with European beech (Fagus sylvatica L.) or Norway spruce (Picea abies Karst.), sometimes also with other species like sycamore maple (Acer pseudoplatanus L.), larch (Larix decidua Mill.), wych elm (Ulmus glabra Huds.), common hornbeam (Carpinus betulus L.) or hop hornbeam (Ostrya carpinifolia Scop.); pure fir stands are rare. It is a typical shade-tolerant species, enduring frequent and long-lasting canopy shading, but on the other hand it is one of the most demanding and sensitive species in terms of other ecological demands (Prpić, 2001).

In the past, fir was given particular attention in research and forest management (e.g. Brinar, 1964; Levanič, 1997; Diaci, 2009; Ficko et al., 2011). Its proportion in stand volume decreased noticeably after the first national forest inventory in 1947, but the decrease was even more pronounced after 1970. During this period, its proportion more than halved, fir population became older, which was indicated by a strong increase in large-sized trees’ proportion and a concurrent decrease of small-sized trees’ proportion (Poljanec et al., 2009). In 1970-2008, the area of...
forest stands with more than 25% of fir in stand volume diminished from 18.9% to 9.5% of forest cover in Slovenia (Ficko et al., 2011). These facts indicate that fir is in regression in Slovenia, which is, however, a common feature of central-European forests (e.g. Eckstein et al., 1983; Senn and Suter, 2003). Some analyses showed that the dynamics of fir population may differ at the regional spatial level, but also between different forest types (Poljanec et al., 2009); on certain sites, even its progression was documented (Simončič and Bončina, 2010). In the past, climate and pollution were exposed as the most important factors of fir regression (Brinar, 1964; Levanič, 1997; Prpić, 2001; Elling et al., 2009; Diaci et al., 2010), but the impact of large ungulates, in particular red deer (*Cervus elaphus* L.), needs to be highlighted as well, since fir was often recognized as one of the most palatable and exposed tree species (Motta, 1996; Senn and Suter, 2003; Jarnič et al., 2004).

In the last decades, a particularly pronounced fir regression was identified in the Dinaric fir-beech forests (Levanič, 1997; Poljanec et al., 2009; Ficko et al., 2011), where fir is among the main tree species (Kordić, 1993). Fir-beech forests were recognized as a late-successional forest type, in which fir and beech have been continuously present for the last seven thousand years (Šercelj, 1996; Wick and Möhl, 2006). Fir is an important ingredient of these forests, since its proportion in their «natural» tree species composition would range from 20% to 40% of stand volume (Veselič and Robič, 2001).

In Slovenia, long-term dynamics of fir has not been very thoroughly studied so far (e.g. Gašperšič, 1967; Bončina et al., 2003; Firm et al., 2009; Diaci et al., 2010) and there is no study that would comparatively investigate long-term dynamics of fir on a regional spatial scale within the same forest type. The presented study was part of doctoral dissertation of the first author (Klopčič, 2011). The main aims of this study were 1) to explore long-term dynamics of fir in spatially dislocated study objects of fir-beech forest type, and 2) to evaluate its potential in study objects. We additionally analysed the impact of large ungulates on regeneration of fir and other tree species in Dinaric fir-beech forests in the Leskova dolina study area.

**STUDY AREA AND METHODS**

**OBJEKT IN METODE DELA**

Fir dynamics was explored in three study areas of fir-beech forests: Leskova dolina in the Notranjski Snežnik region, Trnovo on the Trmovski gozd plateau, and Jelovica in the Ju-

![Fig. 1: The locations of study areas, the spread of silver fir-European beech forests in Slovenia, and silver fir proportion in stand volume in compartments within study areas (data source: ZGS, 2010).](image)

**Slika 1: Lokacija raziskovalnih objektov, razširjenost jelovo-bukovih gozdov v Sloveniji in delež jelke v lesni zalogi v raziskovalnih objektih (vir podatkov: ZGS, 2010).**
The long-term dynamics of fir in fir-beech forests was examined by evaluation of changes in its diameter structure and its proportion in stand volume, while its future potential was investigated with the analyses of its regeneration and recruitment in the last inventory period. Obtained results were compared with the values of the same parameters for beech and spruce (regeneration also with sycamore). Diameter structures of the main tree species were calculated from basic data gathered in full calliperising or on permanent sampling plots, and presented in 10 cm diameter classes to unify the data in different inventories. Stand volume and volume of a particular tree species were calculated from diameter structure and standard Bolley’s tariffs. Recruitment (i.e. the ingrowth of trees above the measurement threshold of 10 cm in dbh) was calculated from the data on the last two measurements on permanent sampling plots (sampling grid 250×500 m: \( N_{\text{Leskova dolina}} = 488 \), \( N_{\text{Trnovo}} = 543 \); sampling grid 200×200 m: \( N_{\text{Jelovica}} = 1654 \)). Additionally, recruitment rate index RRI (Yoshida et al., 2006) was calculated for each main tree species (Equation 1):

\[
RRI_i = \left( \frac{N_{\text{yold}} + N_{\text{rec}}}{N_{\text{yold}}} \right)^{0.1} - 1
\]  

where \( i \) means tree species, \( N_{\text{yold}} \) number of trees on a plot at the first inventory, and \( N_{\text{rec}} \) number of recruited trees on a plot at the second inventory. RRI index designates the proportion of recruited trees in total number of trees at the first inventory (or how much a total number of trees increased due to recruitment with the presumption that there was no mortality). Regeneration was analysed using the regeneration inventory data (ZGS, 2004). Inventory plots were 5 m × 5 m large and distributed on a 2 km × 2 km grid. On each plot, seedlings and saplings 15-150 cm tall were tallied by tree species and by damage classes. Our sample contained 43 plots, 10 of them being in Leskova dolina, 8 in Trnovo, and 25 in Jelovica. In Leskova dolina (sub-compartments 38A and 39C), browsing on regeneration was additionally examined in 2008. On 33 plots sized 4 m × 4 m placed in fenced areas and on 33 plots of the same size placed in non-fenced areas, regeneration was surveyed by tree species, by height classes and by damage classes (Klopčič et al., 2010).
Statistical differences in diameter distributions of tree species between study areas in observation periods were examined using $\chi^2$-tests. Additionally, differences between study areas in means of tree species proportions, recruitment, RRI, abundance and proportion of tree species in regeneration were analysed by the non-parametric Kruskal-Wallis test, while differences in the number of seedlings and saplings in fenced and non-fenced areas were analysed by the non-parametric Mann-Whitney U test (Zar, 2010).

RESULTS

During the last century, the diameter structure of fir has changed noticeably in all study areas, but the dynamics differed between them (Figure 2). In Leskova dolina and Trnovo, stand density significantly decreased. In Leskova dolina, the total number of fir decreased for 68/ha in 1912-2004, while in Trnovo the reduction was even larger, amounting to 217/ha in 1897-2003. In Trnovo, the number of fir decreased in all diameter classes, but the proportion of large trees (dbh≥50 cm) in stand volume increased noticeably. Similarly, in Leskova dolina the number of fir in diameter classes of up to 50 cm decreased, while the number of large fir (and its proportion in stand volume) increased. In both study areas, the processes in the fir diameter structure may be described as “population ageing”, since the absolute number and proportion of large fir were obviously higher at the end of observation period than at its beginning. On the contrary, in Jelovica the total number of fir noticeably increased in the last century (from 42/ha in 1899 to 58/ha in 2002). In 1899-1973, the number of thin fir (dbh=10-19 cm) increased from 8/ha to 34/ha, while after 1973 this number fluctuated within the 26-32/ha interval. The number of large fir remained practically at the same level. In comparison to fir population, the populations of beech and spruce were noticeably “younger”, which is indicated by a larger proportion of thin trees in the total number of beech or spruce in forest stands.

The dynamics of diameter structure was followed by the changes in tree species composition. After 1960, the propor-

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**Fig. 2**: Diameter structure of silver fir (upper row), European beech (middle row), and Norway spruce (bottom row) in the Leskova dolina, Trnovo and Jelovica study areas (columns).

**Slika 2**: Debelinska struktura jelke (zgornja vrsta), bukve (srednja vrsta) in smreke (spodnja vrsta) v objektih Leskova dolina, Trnovo in Jelovica (stolpci).
tion of fir in stand volume started to decrease in all study areas (Figure 3). The highest decrease of fir proportion was observed in Trnovo; in 1963-2003, it decreased from 54% to 18%. In the same time period, a fluctuation in dominance between fir and beech was noticed. According to Josephinian land register, the proportion of fir in Leskova dolina in the mid-18th century was noticeably lower (24%) than its current proportion, the dominant species at that time was beech. Until the mid-19th century, the proportion of fir rose to around a half of stand volume, while in 1912 its proportion already reached 68%. During the past century, fir was the dominant tree species at any given time, but in its second half, a decrease in its proportion, similar to that in Trnovo, was detected (from 69% in 1964 to 53% in 2004). By contrast, the proportion of fir in Jelovica was significantly lower than in the other study areas throughout the entire observation period. However, even there a decrease in fir proportion has been registered during the past century (from 16% to 9% in 1899-2002).

Simultaneously with changes in fir proportion, changes in proportion of beech occurred in Leskova dolina and Trnovo. The observed increase in fir proportion was mainly due to a reduced proportion of beech. When fir proportion culminated in the mid-20th century and then began to drop, it resulted in increased proportion of beech, but also spruce, which has been replacing fir on some sites. In Jelovica, on the contrary, spruce was the dominant species in the entire observation period, while proportions of fir and beech fluctuated between 8% and 17% of stand volume.

Recruitment of fir was generally low in the last inventory period (on the average 13.5 recruited fir/ha/10 years) and significantly lower than recruitment of beech (37.3 recruited beech/ha/10 years) and spruce (87.2 recruited spruce/ha/10 years). Total recruitment and recruitment per tree species (absolute values and RRI values) significantly differed between study areas (all p<0.000; Figure 4). Recruitment was the highest in Jelovica (190.2/ha/10 years), followed by Trnovo (94.2/ha/10 years), and Leskova dolina (61.3/ha/10 years). Recruitment of fir reached the highest value in Jelovica; on the average, there were 21.8 recruited fir/ha/10 years in 1992-2002, representing 11.5% of total recruitment. In Leskova dolina, recruitment of fir averaged 3.1/ha/10 years in 1994-2004 (5.1% of total recruitment), while in Trnovo only 0.7 fir/ha/10

![Fig. 3: The dynamics of silver fir, European beech and Norway spruce proportions in total stand volume in the observation period.](image-url)

**Slika 3: Dinamika deležev jelke, bukve in smreke v skupni lesni zalogi v preučevanem obdobju.**
years was recruited in 1993-2003 (0.8% of total recruitment). If compared, beech and spruce represented significantly higher proportions in total recruitment in all study areas (Leskova dolina 32.8% and 61.7%, Trnovo 45.4% and 43.0%, Jelovica 21.3% and 61.5%, respectively).

Similarly as the analysis of recruitment, the analysis of regeneration showed a very low proportion of fir in the total number of seedlings and saplings (Figure 5). The lowest proportion of fir was found in Trnovo (2.3%), while slightly higher proportions were registered in Leskova dolina (4.8%) and Jelovica (7.6%). In Trnovo, beech and sycamore were most abundantly present in the regeneration, with the proportion of spruce reaching only 0.5%. In Leskova dolina, beech and sycamore prevailed in the regeneration, while spruce was present in similar proportion as fir. In contrast, in Jelovica spruce strongly prevailed in the regeneration, but beech and sycamore were abundantly registered as well.

The regeneration and recruitment success of individual tree species may be importantly influenced by large ungulate impact. The overall browsing rate on regeneration was the highest in Leskova dolina (29%), slightly lower in Trnovo (26%), and the lowest in Jelovica (16%). The data on browsing rate per individual tree species were not available; such data would give a more detailed insight in the potential of fir and other species in the study areas.

The analysis of regeneration in fenced and non-fenced areas in Leskova dolina showed that no statistically significant differences existed in total number of seedlings and saplings between fenced and non-fenced areas (p=0.078), whilst differences in their numbers per height classes and per tree species were statistically significant (Figure 6). In fenced areas, all tree species successfully recruited into higher height classes, even fir recruitment was relatively high (625 fir/ha in the height class above 130 cm). On the contrary, in non-fenced areas fir and sycamore have not succeeded to overgrow the height of 50 and 130 cm, respectively. Fir regenerated successfully (3,352 seedlings/ha in the height class of up to 20 cm), but its recruitment was practically neutralized since only 152 fir/ha were registered in the height class of 20-49 cm. Above the height of 50 cm, no fir was tallied. Similar was found for sycamore, which successfully recruited to the height of 130 cm, but no higher sycamore saplings were surveyed. In contrast, beech successfully regenerated and recruited in fenced and non-fenced areas. Spruce was, however, rare since only 189/ha in fenced areas and 208/ha in non-fenced areas was tallied.
During the past century, fir underwent large changes in mixed fir-beech forests. The analysis of its diameter structure suggested two countervailing courses of its dynamics: “a regeneration” of its population in Jelovica and “an ageing” in Dinaric Mountains (Leskova dolina and Trnovo). In Jelovica, the increase in the number of thin fir was mostly a consequence of the application of close-to-nature, irregular shelterwood silvicultural system with longer regeneration periods (GGN Jelovica, 1973; 1983; GGN Notranji Bohinj, 1973; 1983) and a consequence of lower densities of large ungulates, especially of red deer, before 1990, which both enabled a successful regeneration and recruitment of fir. In Leskova dolina and Trnovo, insufficient recruitment of thin fir – a consequence of past forest management goals and measures (Gašperšič, 1967) and a high impact of large ungulates (Klopčič et al., 2010) – resulted in the fir population’s reduced number and ageing process. Similar dynamics of fir was reported from Croatia (Čavlović, 2000), the Italian Alps (Motta and Garbarino, 2003), and the Carpathians (Vrška et al., 2009), while others reported on an ageing process in some other tree species (e.g. of eastern hemlock (Tsuga canadensis (L.) Carr.); Frelich and Lorimer, 1985).

An excess of fir mortality over its recruitment reduced its proportion in stand volume, obviously in the Dinaric Mountains, but less in the Alps. The observed dynamics of beech (and partly also spruce) was exactly the opposite of the dynamics of fir, indicating the “natural” process of their alternation (Korpel, 1995) or, in our opinion more appropriately, the fluctuations in dominance among these species in fir-beech forests (Wick and Möhl, 2006; Vrška et al., 2009; Diaci et al., 2010). Šercelj (1996) perceived that in these forests fir and beech do not thrive together and at the same time, but that fir encroaches upon beech stands, and vice versa. Both species fluctuate in their dominance in stand volume and in mature stands they only give an impression of a united formation. In the last centuries, these fluctuations have not been (only) naturally driven, as was frequently thought in the past (e.g. Korpel, 1995), but have more or less posed (directly and indirectly) as a human-driven process (Vrška et al., 2009; Diaci et al., 2010; Klopčič et al., 2010). In mixed forests, a replacement of fir with beech (e.g. Gašperšič, 1967; Vrška et al., 2009) or spruce (Heuze et al., 2005) has frequently been reported, generated and influenced mainly by past forest use such as litter raking and forest pasture (Vrška et al., 2009), by differences in past forest management, reflected in different distributions of canopy gap size (Nagel et al., 2010), and by the impact of large ungulates (Klopčič et al., 2010). Similar factors influenced fir dynamics as well, with past forest use, large ungulate impact and site conditions standing out. The latter affected mainly the proportion of fir in a “natural” tree species composition. In fir-beech forests, the proportion of fir in the “natural” tree species composition is somewhat lower in the Alps (~20%) than in the Dinaric

**Fig. 6:** The impact of large ungulates on the regeneration of Dinaric silver fir-European beech forests in Leskova dolina: the comparison of regeneration between fenced and non-fenced areas.

**Slika 6:** Vpliv rastlinojedcev na pomlajevanje dinarskih jelovo-bukovih gozdov v Leskovi dolini: primerjava števila mladic na ograjenih in neograjenih površinah.

**DISCUSSION**

**RAZPRAVA**

Fig. 6: The impact of large ungulates on the regeneration of Dinaric silver fir-European beech forests in Leskova dolina: the comparison of regeneration between fenced and non-fenced areas.

Slika 6: Vpliv rastlinojedcev na pomlajevanje dinarskih jelovo-bukovih gozdov v Leskovi dolini: primerjava števila mladic na ograjenih in neograjenih površinah.
Mountains (≈30-40%), while the proportion of spruce is noticeably higher in the Alps (Veselič and Robič, 2001).

Past use of fir-beech forests substantially altered the “natural” structure and tree species composition of forest stands before the introduction of regular forest management, but even more so after its beginning. Differences among silvicultural systems and the intensities of silvicultural measures were often identified as an important factor influencing stand dynamics (Sendak et al., 2003; Montes et al., 2005; Yoshida et al., 2006). The same was (indirectly) proven also in our study, since past forest management differed between study areas (Klopčič, 2011; Klopčič and Bončina, 2012). In Jelovica, past forest management system followed the classical approach to forestry, which favoured spruce over other tree species (GGN Jelovica, 1897); the proportion of fir consequently decreased. After the 1960s, more close-to-nature oriented forest management system (GGN Jelovica, 1973; 1983; GGN Notranji Bohinj, 1973; 1983) stabilized the proportion of fir at around 10%, while its current diameter structure indicates a possible increase of its proportion in the future. In Trnovo, regular shelterwood silvicultural system (GGN Trnovo, 1897) and, after the 1960s, more large-scale irregular shelterwood system (GGN Trnovo, 1973) were obviously favourable for regeneration of beech, but less so for fir. The latter was recognized as not prosperous when large-scale silvicultural systems are applied (Stanciu and O’Hara, 2006). In Leskova dolina, fir was exclusively promoted for its economic reasons in the past (Gašperšič, 1967). It was of crucial importance for the selection forest management practiced there from the beginning of the 20th century (Schollmayer, 1906). The prescribed accumulation of volume increment and the subsequent rise of stand volume, together with a high browsing rate of fir regeneration, resulted in an insufficient recruitment of fir and a consecutive ageing of fir population. In the 1970s, the recruitment of fir was still inhibited, in some cases still made impossible, despite the introduction of the small-scale irregular shelterwood silvicultural system in combination with the selection system (GGN Leskova dolina, 1994; 2004), which both should promote shade-tolerant species (Stanciu and O’Hara, 2006).

Fir dynamics was importantly influenced by large ungulates (i.e. red deer, Roe deer (Capreolus capreolus L.), chamois (Rupicapra rupicapra L.), and mouflon (Ovis musimon Pallas)), which selectively browse tree species regeneration and thus codetermine tree species composition and reduce the number of recruited trees, in particular of the most palatable tree species such as fir (Motta, 1996). The impact of large ungulates on fir dynamics is long-lasting. In some areas in Central Europe, fir regeneration is browsed to the extent that it never passes the seedling phase (Ott, 1989; Senn and Suter, 2003; Jarni et al., 2004; Heuze et al., 2005). Moreover, Klopčič, Jerina and Bončina (2010) proved that beside past forest management high red deer densities in Leskova dolina were one of the key reasons for the decrease in the number of thin fir due to its insufficient recruitment in the past century.

Differences in large ungulate densities between study areas have substantially influenced fir dynamics. In the observation period, the highest large ungulate densities were recorded in Leskova dolina, where red deer density reached 5.8 animals/km² in the 1980s, but was afterwards reduced to a current density of approximately 3 animals/km² (Klopčič et al., 2010). Densities of other large ungulate species were noticeably lower: roe deer 1.3 animals/km², chamois 0.04 animals/km² (Stergar et al., 2009). In Trnovo, the impact of large ungulates has been significantly lower than in Leskova dolina, since in 2004-2008 the average red deer density was only 0.3 animals/km², roe deer density 3.7 animals/km², chamois density 2.1 animals/km², and mouflon density 0.06 animals/km² (Stergar et al., 2009). It would have been expected that lower densities of large ungulates would manifest in a higher share of more palatable tree species (e.g. fir) in regeneration and/or mature stands, but this hypothesis has not been confirmed in Trnovo. Obviously, (past) forest management and site conditions are much more important than the impact of large ungulates in this study area. In Jelovica, large ungulate densities were lower in the past than in the last two decades, which contributed to the enhancement of fir and broadleaves and their higher proportions in regeneration and recruitment. In the last two decades, the red deer density rose substantially and averaged 1.8 animals/km² in 2004-2008, while densities of other species were much lower: roe deer 0.6 animals/km², chamois 0.5 animals/km², and mouflon 0.05 animals/km² (Stergar et al., 2009). Due to the increased red deer density, higher browsing damages on regeneration can be expected, in particular on regeneration of more palatable tree species such as fir and some broadleaves.

Population of current canopy trees, but also of some sub-canopy trees, in Leskova dolina (Gašperšič, 1967;
Klopčič et al., 2010 and Trnovo (GGN Trnovo, 1887) should have germinated in the mid-19th century, when red deer was exterminated after 1848. It can be concluded that one of the possible survival strategies of fir is the so-called “window of opportunity” (Senn and Suter, 2003) – a contemporary occurrence of appropriate environmental (site) and stand conditions, such as low population densities of large ungulates, partial- and full-seed years, an accordant (natural and anthropogenic) disturbance regime, an appropriate structure and composition of mature stands – which enables its abundant regeneration and successful recruitment into the stand canopy. “The window of opportunity” was recognized as a survival strategy of eastern hemlock in mixed stands with broadleaves in North America (Frelich and Lorimer, 1985), which is of similar importance there as fir in mixed fir-beech forests, and Scots pine (Pinus sylvestris L.) and spruce in boreal forests in Sweden (Linder, 1998). However, the question that arises is in what spatial and temporal constellation such “window of opportunity” might occur in mixed fir-beech forests. Additional question is as to what densities of large ungulates, especially of red deer, would allow fir to successfully regenerate and recruit into the stand canopy. The relationship between browsing rate of fir and red deer density was found to be explicitly non-linear and weak. Some results indicated that a reduction in the browsing rate of fir should be recorded only for exceptionally low large ungulate densities (Jerina, 2008); the main cause for that is supposed to be its high palatability.

Future potential of fir in mixed fir-beech forests differed significantly between study areas. In Leskova dolina and Trnovo, a further decrease of fir proportion in stand volume may be expected, since its population is relatively old and significantly older than populations of beech and spruce. Additionally, its share in regeneration and recruitment is low. In Jelovica, maintenance or even a small increase of fir proportion in stand volume may be expected due to its relatively young population and significant share in regeneration and recruitment.

Despite a delineated future potential of fir, predicting its future in fir-beech forests and broader is rather unreliable. Most of the research (Eckstein et al., 1983; Senn and Suter, 2003; Vrška et al., 2009; Ficko et al., 2011) demonstrated a decline in fir proportion in the future, in the Dinaric Mountains most likely to the level before the (intensive) forest management began. However, on certain sites in Slovenia (e.g. Bohor region; Simončič and Bončina, 2010) and elsewhere (e.g. Poland; Dobrowolska and Veblen, 2008), observations showed a progression of fir, indicating that fir can be successful even in the current environmental conditions and that “the window of opportunity” may occur even in current conditions. In mixed fir-beech forests or any other mixed forests, a constant proportion of fir should not be accurately determined. Fir (or any other species) proportion is a dynamic parameter, which should be critically judged and determined according to site conditions and (long-term) stand dynamics. In the analysed forests, fir has been an important component for several millennia, as well as large ungulates. Therefore, a compromise solution through a constructive, common work of all interested public, but most of all through an adaptive forest management has to be found to maintain both of them.

**POZETEK**

**SUMMARY**

Jelka (Abies alba Mill.) is the most frequent species in Slovakia's forests. In recent decades, due to the extermination of red deer, it has become more dominant in mixed forests. Observations showed a progression of fir, indicating that fir can be successful even in the current environmental conditions and that “the window of opportunity” may occur even in current conditions. In mixed fir-beech forests or any other mixed forests, a constant proportion of fir should not be accurately determined. Fir (or any other species) proportion is a dynamic parameter, which should be critically judged and determined according to site conditions and (long-term) stand dynamics. In the analysed forests, fir has been an important component for several millennia, as well as large ungulates. Therefore, a compromise solution through a constructive, common work of all interested public, but most of all through an adaptive forest management has to be found to maintain both of them.

Debelinska struktura jelke se je v zadnjem stoletju značilno spremnjevala v vseh raziskovalnih objektih, vendar sta se dinamika in velikost sprememb v objektih razlikovala. V Leskovi dolini in na Trnovem se je sestojna gostota v zadnjem stoletju značilno zmanjšala za 68 oziroma 217 jelk/ha. Število debelih jelk (prsnki premer ≥ 50 cm) (in njihov delež v lesni zalogi) se je opazno povečal, kar ob hkratnem zmanjšanju števila tankih dreves nakazuje staranje njene populacije. Na Jelovici je v opazovanem obdobju skupno število jekl naraso, predvsem zaradi povečanja števila tankih dreves (prsnki premer < 30 cm). V vseh raziskovalnih objektih je bila populacija jelke razvojno starejša od populacij bukve in smreke.


Vrast jelke je bila v zadnjem inventurnem obdobju v splošnem majhna in v vseh raziskovalnih objektih značilna, manjša od vrasti bukve in smreke. Vrast jelke je dosegla splošno majhna in v vseh raziskovalnih objektih značilna podobna sliko kot analiza vrasti. Njen delež v skupnem številu mladic je bil majhen, najmanjši na Trnovem (2,3 %), nekoliko večji pa v Leskovi dolini (4,8 %) in na Jelovici (7,6 %). V raziskavni smo ugotovili velik vpliv rastlinjoedcev na obilje in preraščanje pomlad-ka jelke.


Ker naj bi trenutna populacija vladajočih in sovladajočih pa tudi nekaterih podstojnih jelk v Leskovi dolini in na Trnovem vključila v dokaj kratkem časovnem obdobju sredi 19. stoletja, lahko zamenjačimo, da je ena izmed možnih strategij uspeha jelke t.i. »okno priložnosti« (angl.: window of opportunity), sovpadanje ustreznih okoljskih in sestojnih razmer, kot so dovolj nizke gostote rastlinjoedcev, obdobja polnih obrodnih, ustrezen režim (naravnih in antropogenih) motenj, težave v omogočanju njeno obilje in preraščanje pomlad-ka jelke.

Ker naj bi trenutna populacija vladajočih in sovladajočih pa tudi nekaterih podstojnih jelk v Leskovi dolini in na Trnovem vključila v dokaj kratkem časovnem obdobju sredi 19. stoletja, lahko zamenjačimo, da je ena izmed možnih strategij uspeha jelke t.i. »okno priložnosti« (angl.: window of opportunity), sovpadanje ustreznih okoljskih in sestojnih razmer, kot so dovolj nizke gostote rastlinjoedcev, obdobja polnih obrodnih, ustrezen režim (naravnih in antropogenih) motenj, težave v omogočanju njeno obilje in preraščanje pomlad-ka jelke.

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ACKNOWLEDGEMENT


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Acknowledgements

The authors wish to express their gratitude to the students and researchers who provided invaluable assistance during the course of this research. They also acknowledge the financial support received from the Slovenian Research Agency, which made this study possible. Finally, the authors would like to thank the reviewers for their insightful comments and suggestions, which helped improve the quality of this paper.


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