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THE EFFECTS OF STAND STRUCTURE ON REGENERATION DYNAMICS OF FIR AND BEECH FORESTS IN RISNJAK NATIONAL PARK

UTJECAJ STRUKTURE SASTOJINE NA DINAMIKU RAZVOJA MLADOGA NARAŠTAJA U BUKOVO-JELOVIM ŠUMAMA NACIONALNOG PARKA "RISNJAK"

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The article deals with the results of research involving the condition of the structure, regeneration processes, features of the young growth, conditions of its development and survival, crown damage of beech and fir, as well as the possibility of applying new methods of monitoring stand development, such as three-dimensional visualization of the horizontal and vertical stand structure in forests of protected areas. The results are based on almost decade-long (1998-2007) monitoring undertaken in a permanent experimental plot in the forest of beech and fir (*Omphalodo-Fagetum* Marinček et al. 1992) in Risnjak National Park.

The results of stand structure measurements suggest a disturbed uneven-aged structure. Fir is practically absent from the lower classes of diameter distribution and scarcely represented in the middle classes, thus indicating insufficient fir recruitment over the last few decades. Fir in the lower part of diameter distribution is replaced with beech of low quality, which indicates species alternation. An over-excessive canopy cover, the absence of canopy layering, and growing stock accumulated on old, physiologically weak trees imply an inadequate uneven-aged stand structure. A combination of the above has had an unfavorable effect on the abundance, quality and survival of young plants. The results also make the expected normal process of natural regeneration uncertain.

Owing to their role, stability and sustainability, protected forest ecosystems require a more active approach to protection by enhancing positive natural processes. The results of this research, combined with past insights reached by a number of forestry scientists, allow us to conclude that Croatian foresters, ar-

med with their rich forestry tradition, have sufficient knowledge and possibilities, but also the obligation to help forest ecosystems to permanently fulfill their role in s stable and sustainable manner.

Key words: National park, uneven-aged stand structure, natural regeneration, fir, beech

INTRODUCTION
UVOD

Research, whose results are presented in this article, continues on previous research into the protected natural values in which forest communities have a dominant role. Permanent experimental plots were established for this purpose in the national parks of Risnjak, Plitvice Lakes, Paklenica, Mljet and Brijuni in 1998. The natural composition of forests has been profoundly changed by human activities in most countries of the world. In view of inescapable global changes occurring in forest ecosystems, compared to other European countries Croatia still represents an "island" of preserved natural forests with high biological diversity. This is the result of the rich tradition of Croatian forestry, which has always followed the principles of natural forest management. The presently popular and generally adopted concept of sustainable management has been known to the Croatian forestry profession for as many as 240 years. It should be pointed out that sustainable management has always formed the basic postulate of Croatian forestry. Adhering to this basic postulate (whose roots are found in the first written documents from 1769, the Forest Law of 1852, and especially in the Law of 1894, where Article 3 explicitly states: "Municipal forests shall be managed in a sustainable manner"), the main prerequisite is that, due to their primary role of fulfilling commercial and non-commercial functions, forest ecosystems must be kept in their optimal condition. One of the most vital indicators of the optimal condition and naturalness of forests is natural regeneration. Close-to-nature management based on tending treatments and natural regeneration improves and enhances the production of both market and non-market forest values (ecological and social), preserves the optimal natural stand structure and permanently protects and develops forest soil and sites (Matić 2006). A proper natural forest (virgin forest) is such a formation of forest vegetation which has developed without any human impacts; in other words, man has neither directly nor indirectly changed its composition nor affected its development. The study of a virgin forest allows us to understand the causes and consequences of various phenomena in commercial forests. The best preserved and the most numerous virgin forests in Croatia are those of beech and fir growing on Dinaric karst. At the level of forest-management area, uneven-aged forests in the Republic of Croatia extend over 318 875 ha (Forest-Management Area Plan for 2006 – 2015). Uneven-aged forests have a distinct ecological, economic and social importance. These forests have developed from a virgin forest structure and have preserved their natural characteristics. Today, natural regeneration of forests has been seriously endangered by negative ecologi-

cal changes in forest ecosystems and by subjective management failures. The task of the forestry profession is to seek and find solutions that will mitigate negative impacts on forest ecosystems. The task of silviculturalists in commercial forests is to gear every forest ecosystem towards progressive development which will guarantee maximal production and yet preserve its stability and natural regeneration. Forest ecosystems in national parks should be treated according to the adopted principles of the forestry science, at the same time acknowledging the effects of the natural structure and their intended role, which dictates management guidelines. Protected forest ecosystems, including national parks, are important for the development of basic and applied natural sciences. Their references are vital for the evaluation of forest management efficiency (Diaci et al, 2006).

Forest development in natural conditions has been studied by a number of forestry experts. As many as 70 years ago Professor I. Horvat launched the first systematic phytocoenological research of Risnjak. The beginnings of scientific forestry research in Croatian virgin forests may be attributed to the study of Čorkova Uvala in Plitvice Lakes National Park, started by Academician Milan Anić in 1957. With the goal of monitoring forest development in natural conditions in Plitvice Lakes National Park, Cestar and a group of associates established four "forest reserves" covering 1,347 ha: Medveđak (1982), Čorkova Uvala-Čudinka (1983), Kik-Visibaba (1984) and the forest reserve of Riječica-Javornik (1984). We should draw attention to research undertaken by Cestar et al. (1982), who conducted typological investigation and suggested that the applied management methods did not favor the occurrence of young growth and of young growth of beech in particular. Hren (1972) studies the virgin forest of Ramino Korito as a relict-forest of former extensive virgin forests on Velebit. Prpić (1972) investigates the features of the virgin forest of Čorkova Uvala. Klepac (1984) advocates active forest protection in Plitvice Lakes National Park. In 1994 he proposes ecological forest management and emphasizes that forests should be allowed to regenerate naturally on a permanent basis. Poštenjak and Gradečki (1994) find that stands of beech and fir in Risnjak National Park are heading towards species conversion and propose adequate interventions.

Research to date (structural features and the abundance and quality of the young generation) suggests that satisfactory natural regeneration in the studied plots in the national parks is relatively unlikely (Krejči and Dubravac 2001, Dubravac et al. 2004, 205, 2006, 2007). The insights gained so far clearly show that, despite the fact that nature is running its course, its activities do not give grounds for satisfaction. Passive protection evidently does not yield the expected results.

The goal of this research is to illustrate the structural status, regeneration processes, the characteristics of the young growth, and the conditions of its development and survival in view of the internal stand structure in Risnjak National Park. It will also illustrate the crown damage status and explore the possibility of applying new methods of monitoring stand development using three-dimensional visualization of the horizontal and vertical stand structure.

Research area
Područje istraživanja

During the 1930s, the well known professor of botany I. Horvat, initially alone and later with his numerous associates, launched a cycle of scientific research on Risnjak. At his proposal Risnjak was proclaimed a national park on 15 September 1953. His reasons illustrate the basic characteristic of the park: "Natural phenomena and beauty on Risnjak cohabitate one along the other, whereas in all other places they are scattered far apart. In addition, Risnjak was spared management impacts in the past to such a degree that its natural vegetation picture has remained almost unchanged. Even if there are some occasional changes caused by management effects, the original natural state can be restored relatively quickly" (Horvat, 1953a).

Research was undertaken in a permanent experimental plot established in the forest community of beech and fir (*Omphalodo-Fagetum* Marinček et al. 1992) which, according to Vukelić (1985), is the most dominant forest in the area of Risnjak National Park. The plot is situated at an altitude of 680 m (Leska Valley) on a geological dolomite substrate. The soil type is rendzina and in the sinkhole it is luvisol. According to Vrbek and Gašparac (1992), limestone and dolomite rocks prevail in the Park, whereas the most common soil type is brown soil on limestone and dolomite (calcocambisol). The National Park covers a total area of 6,400 ha. The largest part of the area is forested (6101.5 ha or 95.3 %), while the rest relates to meadows, mountain clearings and rocks. The highest peak of the Park is situated 1,528 m above the sea (Veliki Risnjak), and the lowest point is 290 m above the sea (near the place of Hrvatsko).

METHODS
METODE RADA

A permanent experimental plot of 100 x 100 m was established in 1998 following the methodology of Dubravac and Novotna (1992). The experimental plot is a part of the network of permanent experimental plots set up in Croatian national parks (Risnjak, Plitvice Lakes, Paklenica, Mljet, and Brijuni) for the purpose of monitoring forest ecosystems dynamics under conditions of strict nature protection (Krejči and Dubravac 2001). A sub-plot sized 60 x 60 m was placed within the plot. Diameters, total heights, stem lengths and spatial distribution (position) of all the trees thicker than 7.5 cm at breast height were recorded. Horizontal crown projections (Figure 1A) were also recorded on all the trees. The stand structure was re-measured in 2007.

A laser measurement device LaserAce 300 (Measurements Devices Ltd., Great Britain) was used to measure the heights of terrain contour lines at the root base of every tree and at several additional, characteristic terrain points. The obtained points with the respective x, y and z coordinates were interpolated using the ESRI ArcMap software package to construct a digital terrain model (Figure 1B) of the experimental plot (Hayakawa et al. 2007). Horizontal crown projections were also

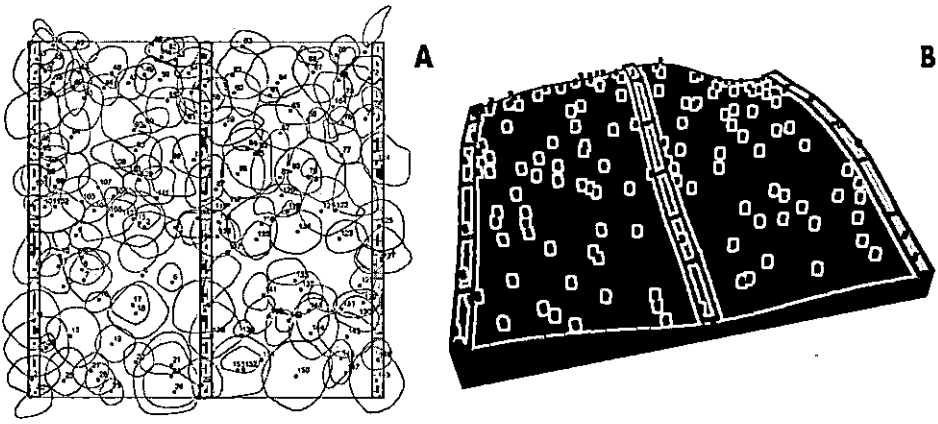


Figure 1: Map of crown projections on the subplot (A) and 3D model of subplot terrain with superimposed contour lines, postition of trees and strips for monitoring of regeneration (B)

Slika 1. Horizontalne projekcije krošanja stabala na podplohi (A) i 3D reljef terena podplohe s preklopljenim slojnicama, položajima stabala i prugama na kojima je mjeren pomladak (B)

digitalized in the ArcMap program and maps of soil coverage with crowns in terms of tree species and stand layers were also produced. The sum of crown projections by hectare in the absolute and relative amount was calculated, and so were the gaps, the mean projection and the mean crown diameter.

The structure and abundance of the young growth and the shrub layer in the sub-plot were recorded in four measurements (1998, 2001, 2003 and 2007) performed in three strips of 2 x 60 m (360 m^2). During the 2007 measurement, each strip was divided into 6 small plots of 2 x 10 m.

Crown damage was assessed using the unique method prescribed by the International Co-operative Program on Assessment and Monitoring of Air Pollution Effects on Forests (ICP Forests). Monitoring was executed in 1998, 2001, 2003 and 2005 and the results were compared with commercial forests at the level of Croatia for the period 1995 to 2006.

To visualize the experimental plots according to the measured tree and terrain relief features, a Stand Visualization System and EnVision (USDA Forest Service, USA) were used, as well as the 3D Max software package.

RESEARCH RESULTS
REZULTATI ISTRAŽIVANJA

Stand structure
Struktura sastojine

Table 1 presents the basic structural features of the experimental plot (measurements in 1998 and 2007). The total wood mass of 614 m^3/ha (1998), or 683.50 m^3/ha (2007) is significantly higher than the theoretical one which, according to

Cestar et al. (1986) amounts to 325.56 m³/ha, and according to Klepac (1961) to 346 m³/ha. With regard to diameter degrees involving those of up to 30 cm, from 31 to 50 cm and from 51 cm upwards, this stand has the following percentage relations: 10% : 18% : 72% (1998), or 9% : 16% : 75% (2007) in relation to the theoretical-ideal ones amounting to 20% : 30% : 50%. Fir participates with 32 % in the species mix (theoretical model is 50%), beech with 66 % (theoretical model is 50%), while other species participate with 2%. The above data clearly show that the stand does not even remotely have a favorable uneven-aged structure. The growing stock is predominantly accumulated on a small number of over-mature, physiologically weakened fir trees (Figure 2). Research undertaken in Slovakian virgin forests (Korpel 1996), as well as the excessive amount of growing stock with a low number of large fir trees and a high number of thin beech trees confirm the occurrence of the developmental decomposition stage with the expansion of beech. Poštenjak and Gradečki (1994) arrived at the same results in their study of beech-fir stands in Risnjak National Park.

Table 1. Basic structural elements of forest stand on experimental plot in 1998 and 2007
Tablica 1. Osnovna strukturna obilježja sastojine na pokusnoj plohi 1998. i 2007. godine

Species / *Vrsta*	1998.			2007.			Difference (2007-1998) *Razlika* (2007-1998)		
	N	G	V	N	G	V	N	G	V
	kom/ha	m²/ha	m³/ha	kom/ha	m²/ha	m³/ha	kom/ha	m²/ha	m³/ha
Fir / *Jela*	114	29.88	503.76	111	32.60	549.34	-3	+2.72	+45.58
Beech / *Bukva*	231	9.47	103.88	230	11.27	127.52	-1	+1.8	+23.65
Other / *Ostalo*	6	0.52	6.36	5	0.52	6.64	-1	+0.01	+0.28
Total / *Ukupno*	351	39.87	614.00	346	44.40	683.50	-5	+4.53	+69.51

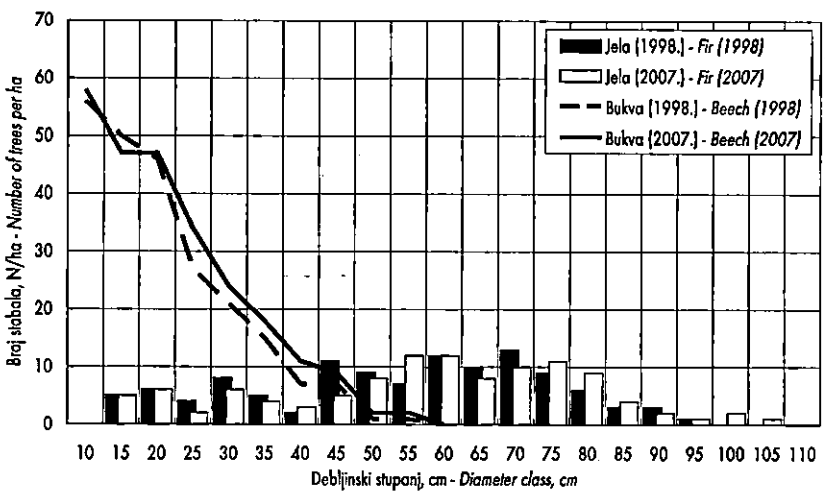
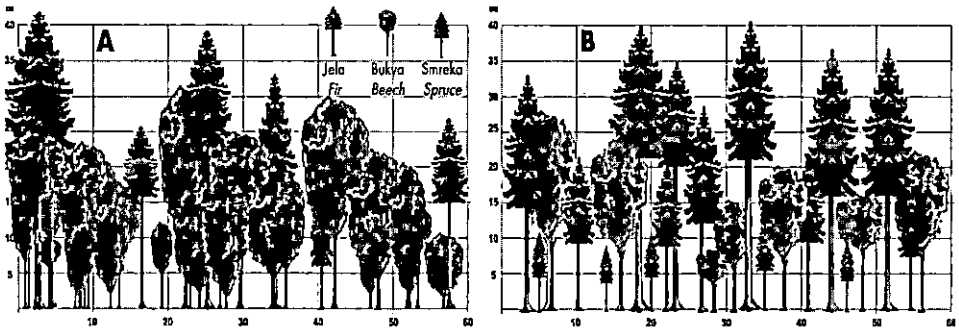


Figure 2: Diameter distribution of trees for measurements in 1998 and 2007
Slika 2. Distribucija stabala po debljinskim stupnjevima 1998. i 2007. godine

Tree number distribution in both measurements (1998 and 2007) indicates a disturbed selection structure and the absence of fir in the thinnest diameter degrees, as well as the absence of medium-thick trees (Figure 2). As breast diameter increases, this difference disappears in medium-thick trees (above 55 cm). Above this diameter there is a surplus of old, over-mature and physiologically weakened trees. The results show that in the past several decades there has been no fir recruitment from natural regeneration. The consequences are reflected in the natural crop rotation with a trend of beech expansion, in other words, in tree species alternation. The same has been confirmed by research of Šafar (1954). Thus, the biologically more aggressive beech in the subordinate layer has filled the space, as seen clearly in the vertical stand profile (Figure 3A). In Slovenia, Bončina et al. (2003) report a constant decrease in the participation of thin fir trees both in managed and in virgin forests during the last 100 years. A similar process has also been observed in some managed fir-beech forests (Čavlović 2000, Matić et al. 2001, Janeš 2006). The stand layer and its quality represent a biologically important, possibly the most important part of the stand, which is of exceptional value for its regeneration, stability, preservation of the structure and future sustainability.



Stvarni vertikalni profil istraživane sastojine
Actual vertical profile of the researched stand

Teoretski stepeničasti sklop preborne sastojine
Teoretical vertical profile of uneven-aged forest stand

Figure 3: *Vertical stand profile: A – Actual profile of the studied stand; B – Theoretical (ideal) profile of uneven-aged forest stand*

Slika 3. Vertikalni profil sastojine: A – stvarni profil istraživane sastojine; B – teoretski (idealni) profil preborne sastojine sa stepenastim skolopom

The constructed stand profile (Figure 3A) shows dense canopy (the crowns of adjacent trees penetrate one another). It is also clear that this is a vertical canopy form. Namely, due to the disturbed natural structure (the absence of thin and medium-thick fir trees in the tree layer), the typical uneven-aged canopy profile is absent (Figure 3B). The crown canopy and its structure represent a distinctly essential factor for the regulation of ecological conditions (light, precipitation, stand climate, temperature and humidity, as well as mineralization and humification of the soil organic matter), and especially the conditions for regeneration, with fir in particular due to its narrow ecological amplitude.

The vertical and horizontal crown structure was obtained with a detailed analysis of digitalized horizontal tree crown projections in the subplot (Figure 1A and Figure 4). Soil coverage with crowns was found to be 88.5%. The total sum of horizontal crown projections is 10 941.21 m²/ha, of which 3584.55 m² (32.8 %) refers to the upper fir layer and 7356.12 m² or 67.2 % refers to the lower beech layer. The gap in the forested area amounts to 11.54 %. The average surface of the horizontal crown projection of fir is 36.01 m² and of common beech it is 33.86 m², whereas the mean crown diameter of fir is 6.37 m and that of common beech is 6.25 m.

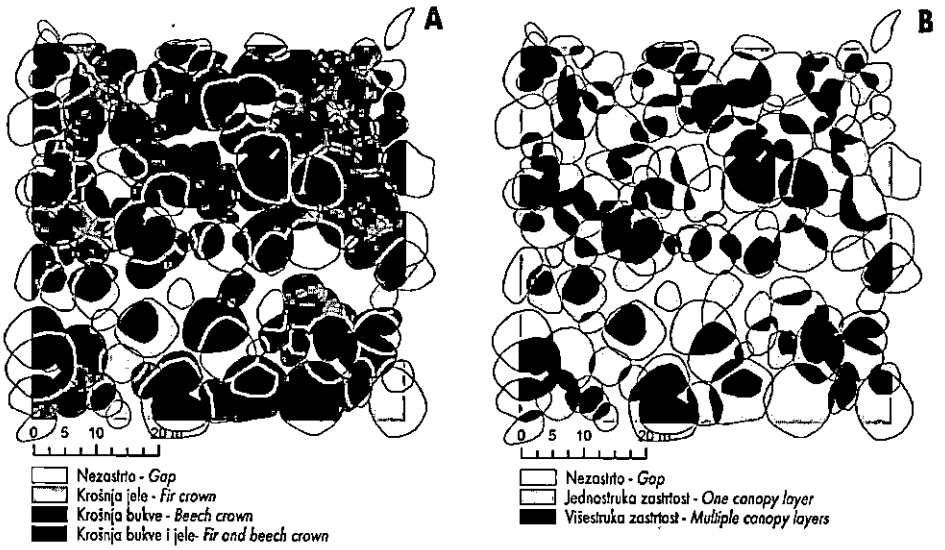


Figure 4: Canopy cover by tree species (A) and canopy layers (B)
Slika 4. Zastrtost tla krošnjama prema vrstama drveća (A) i prema slojevima sastojine (B)

The analysis of the canopy cover by tree species (Figure 4A) shows that beech and fir crowns overlap in 25.0% of the area, beech crowns alone cover 48.9% and fir crowns cover only 13.2 % of the subplot area. The total canopy cover with beech crows (independently or overlapping with fir crowns) is as much as 73.9 %. The absence of the typical uneven-aged canopy profile in the researched stand is also shown in Figure 4B, where the analysis of the canopy layer is presented according to stand layers. Only one third of the area (34.3%) is covered with multiple layers, while a single canopy layer covers 52.8% of the subplot area.

Information on the stand structure (spatial tree distribution, tree dimensions and especially crown dimensions) can currently be visually presented using one of the numerous computer programs. The stand structure in this research was visualized in two software packages: EnVision (USDA Forest Service, USA) and 3D Max. Figure 5 shows stand visualization in the EnVision program. Based on the digital model of crown projections, the parameters measured in the field (tree height, stem length, crown length and width) and the constructed base, a three-dimensional photo-realistic digital model of the stand was created in the 3D Max software package

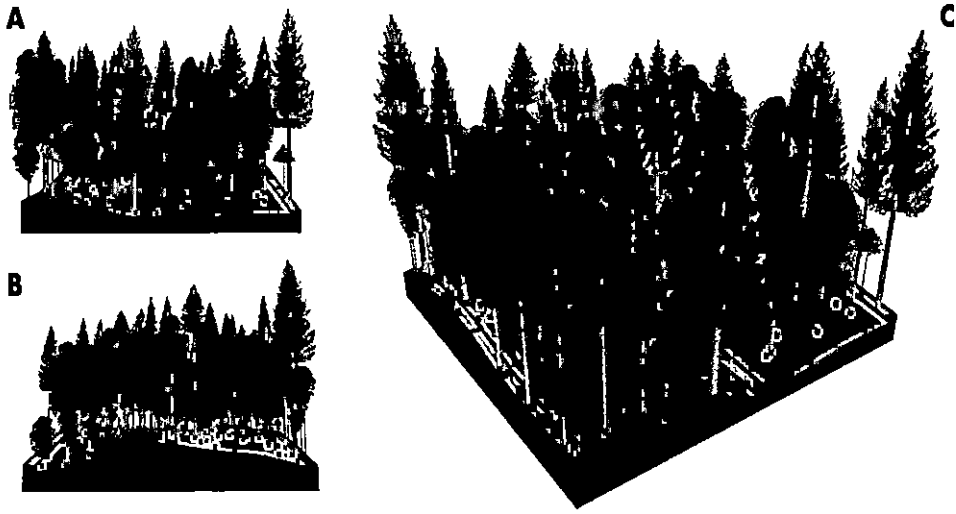


Figure 5: Stand visualization in the program EnVision (USDA Forest Service. USA); A – stand profile viewed from the north; B – stand profile viewed from the south; C – stand from bird's perspective. NE view

Slika 5. Vizualizacija sastojine na pokusnoj plohi u programu EnVision (USDA Forest Service, USA): A – profil sastojine sa sjeverne strane; B – profil sastojine s južne strane; C – izgled sastojine iz ptičje perspektive sa sjeveroistočne strane

(Figure 6). In constructing the model, account was taken of the spatial distribution of the trees and the phenotypical crown forms (Dubravac 2005). Both constructed models give a faithful presentation of basic structural stand problems which have a negative effect on regeneration processes: over-excessive canopy layer, the absence of uneven-aged canopy profile and a two-layered stand.

Structure of young growth
Struktura mladoga naraštaja

Based on the condition of the structure and the abundance and quality of the young growth recorded in 4 successive measurements (Table 2), we concluded that natural regeneration of fir is questionable. Although a significant number of fir individuals amounting to 8,945 trees per hectare were measured in 1998, it is clear that the majority (as many as 82%) of fir individuals are in the seedling developmental stage and only 12 % are in the sapling developmental stage. During the second measurement a decrease of 19 % was observed in the number of young fir plants. During the third measurement the number of individuals remained approximately the same, while the fourth measurement (2007) revealed 4,697 individuals of fir regeneration per hectare, which is a decrease of 38% in relation to the previous one. It should also be pointed out that even such a small number of young fir regeneration is threatened by deer game. The tallest fir individual recorded in the plot was only 8 m tall (Krejči

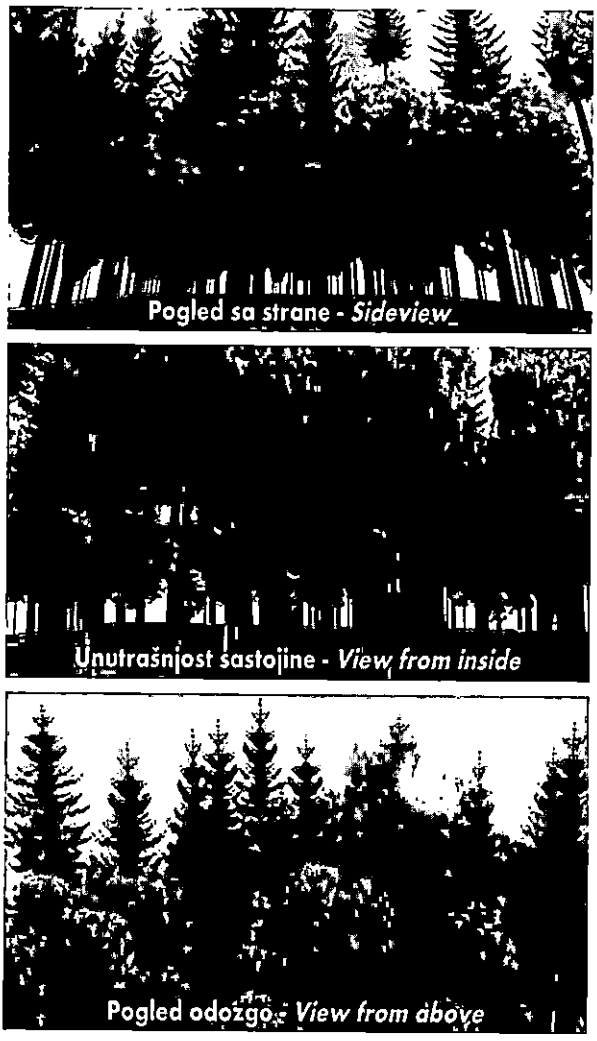


Figure 6: Three-dimensional stand model (3D Max)
Slika 6. Trodimenzionalni model sastijine (3D Max)

and Dubravac, 2001). Matić et al. (1996) detected 5,450 fir seedlings in commercial beech and fir forests. The reasons for the occurrence of regeneration elements, despite the unfavorable uneven-aged structure (the diameter class relationship is 4% : 7% : 89 %, which is similar to ours) are attributed to excessive soil humidity which plays an important role in an uneven-aged forest. Research by Šafar (1954) treats the role of air humidity and the occurrence of young fir regeneration.

The first measurement undertaken in 1998 registered 11,111 of fir germinants, while the last measurement in 2007 recorded 18,805 pieces per hectare.

It is clear that fir germinants occur in large numbers but their further survival and development is threatened. This information testifies to an adequate yield of fir

seed and its good germination, but also to its disappearance after one year. The disappearance of the young growth is attributed to lack of humidity in the soil and air as a consequence of adverse, primarily structural and ecological conditions (Matić et al. 1996).

According to research by Mazur (1989), a large number of fir seedlings (one-year plants) does not play an important role if seedlings that occur abundantly after mast crop generally die in the first year of life. Dobrowolska (1998) obtained much better results of natural fir regeneration in Poland. Some research suggests that fir regenerates much better under the crowns of some tree species that under its own canopy (Runkle 1981, Dobrowolska 1998). During the first three measurements, young beech regeneration was constantly increasing. A distinct increase in beech regeneration from 15,971 (2001) to 41,389 (2003) individuals is the consequence of ample beech mast in 2001. The fourth measurement revealed a decrease in beech regeneration by 31% in relation to the previous one. Some of the beeches were over 2.5 m tall, but they were stunted and of low quality, and had an umbrella-like form. They represent the basis of a future stand which will, apart from other tree species, also feature an occasional sycamore and rowan.

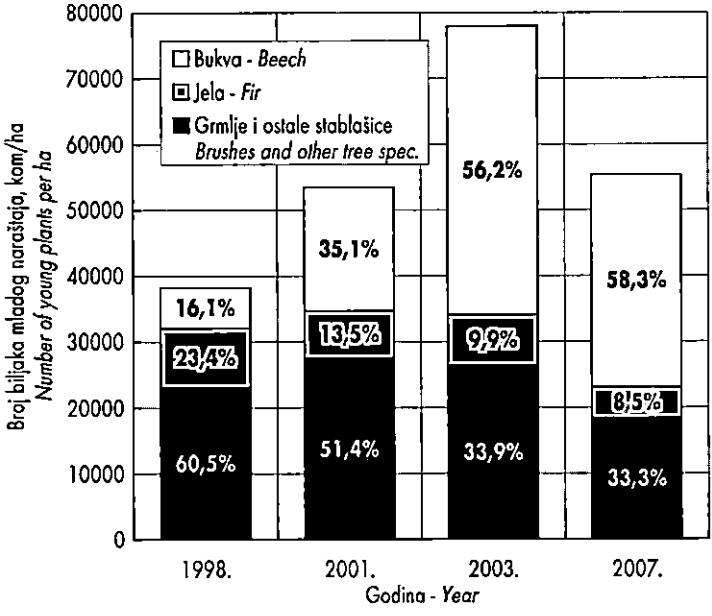


Figure 7: Share of fir, beech and shrubs and other tree species in the total number of young plants during monitoring period

Slika 7. Ukupan broj biljaka mladoga naraštaja te udio bukve, jele, te grmlja i ostalih stablašica tijekom godina izmjere

In view of the above and of the fact that the plot is in the national park, it is illusory to expect better natural regeneration of fir in the future. How much time will elapse until this takes place? The reasons lie in a set of interacting factors, and espe-

Table 2. Structure of young growth of fir, beech, other tree species and shrubs by height classes
Tablica 2. Struktura mlađog naraštaja po vrstama drveća i visinskim klasama i gustoća grmlja

Height age class cm		Measurement 1998 *Izmjera 1998.*				Measurement 2001 *Izmjera 2001.*				Measurement 2003 *Izmjera 2003.*				Measurement 2007 *Izmjera 2007.*			
Visinsko-starosni razred cm		Fir *Jela*	Beech *Bukva*	Tree s. *O.stabl.*	Bushes *Grmlje*	Fir *Jela*	Beech *Bukva*	Tree s. *O.stabl.*	Bushes *Grmlje*	Fir *Jela*	Beech *Bukva*	Tree s. *O.stabl.*	Bushes *Grmlje*	Fir *Jela*	Beech *Bukva*	Tree s. *O.stabl.*	Bushes *Grmlje*
		Number of plants per ha - *Broj biljaka po ha*															
<30	1-year old Jednog.	7306	83	7056	556	3805	1333	1778	1083	2944		305	278	1528	56	861	444
	Older *Višegod.*	1639	3833	9333	2833	3416	14638	16805	2805	4667	41389	16861	3444	3167	28603	9611	2028
Total <30 *Ukupno <30*		8945	3916	16389	3389	7221	15971	18583	3888	7611	41389	17166	3722	4695	28659	10472	2472
31-60			1194	139	2361		1749	1306	2278		1083	1833	2056		1694	2417	1444
61-130			417	28	1333		333	56	1194		589	167	1139		1056	528	1028
131-150			28				167		167		56	28	194		222		222
151-200			83				56				167		83		83		139
201-250			139				139				55				167		
>250			361	28			361				500		28		333	28	
Total *Sveukupno*		8945	6138	16584	7083	7221	18776	19945	7527	7611	43839	19194	7222	4695	32214	13445	5305

cially in the disturbed uneven-aged structure, distinctly dense canopy in the lower beech layer, excessive presence of herbivores which browse on young fir growth and disturb the stability of forest ecosystems (Krejči and Dubravac 2001), as well as in climatic changes (droughts).

The percentage share of fir in the total number of young plants is constantly falling and so is the number of shrubs and other trees. The share of fir decreased from 23.4 % to 8.5 %, of shrubs and other trees from 60.5 % to 33.3 %, whereas the share of beech went up from the initial 16.1 % in 1998 to as much as 58.3 % in 2007 (Figure 7). It can be concluded that beech, whose increment in its youth exceeds that of fir, has better chances for future development and dominance in a stand with a disturbed uneven-aged structure and worsened ecological conditions. This is also corroborated by research of Šafar (1954). The abundance of the young growth of other plants in the areas dominated by the sycamore and the shrubs (generally buckthorn, hazel, elderberry, mezereon), which has a vital effect on natural regeneration, did not change fundamentally during the first three measurements. It should be noted that during the last measurement (2007) the number of young growth of all the species decreased significantly, which can probably be attributed to the exceptionally dry year of 2003.

Crown damage
Oštećenost krošanja

Forests in Risnjak National Park, together with all the other forests in Gorski Kotar, are susceptible to mortality and dieback. An aerial survey of the Park conducted in 1988 showed that as much as 93.4% of the fir was significantly damaged (damage over 25 %), and so were 12.5 % of the beech, and 58% of the spruce (Kušan et al. 1994). It should be pointed out that the survey encompassed the total old Park area (3,400 ha). No research linked to forest dieback has been done since. Research should definitely be resumed. The crown damage status in the experimental plot (1998, 2001, 2003, 2005), and the comparison with the average values in the Republic of Croatia (Potočić and Seletković 2006) are given in Figure 8. The data show a percentage share of significantly damaged trees of beech and fir.

The highest proportion ever of significantly damaged trees of silver fir amounting to 74.1% was recorded during 2006. This is an increase of 0.3 % in relation to the assessment of 2005. The damage trend in recent years indicates further alarming dieback of silver fir in Croatia. A slightly better situation, but still very worrying, occurs in Risnjak National Park, where the growing trend of significant damage from 50 % to 63.6 % in 2005 has shown a mild decrease to 56.8 % of significantly damaged trees.

Average damage of common beech in recent years of monitoring has not changed drastically, and has ranged from 4 – 11 %. The year 2006 saw the highest ever significant beech damage of 12. 7 %, but the beech still retains the epithet of the most resistant Croatian tree species. Monitoring in Risnjak National Park shows

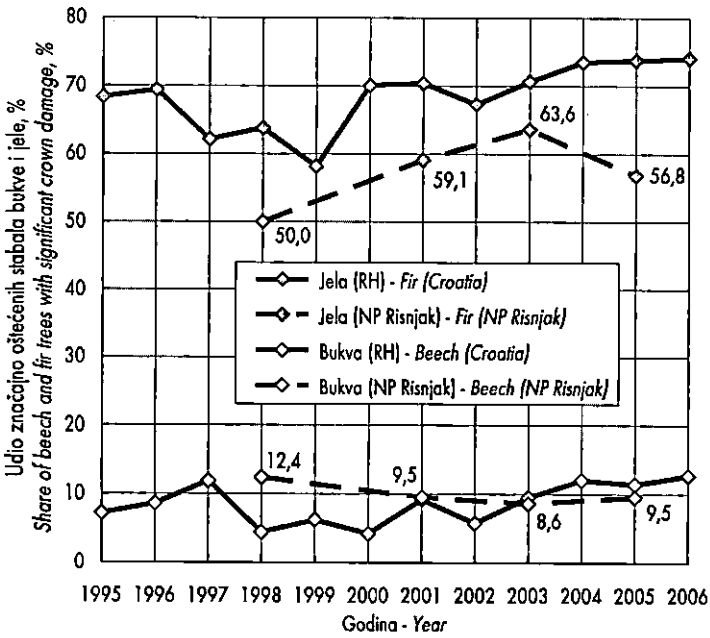


Figure 8: Comparison of fir and beech crown damage in managed forests and forests of Risnjak National Park

Slika 8. Usporedba značajne oštećenosti krošanja jele i bukve u NP Risnjak i gospodarskim šumama

that beech manifests very similar values of significant crown damage as those in commercial forests.

CONCLUSIONS
ZAKLJUČCI

The basic prerequisite for a normal, balanced and stable uneven-aged stand, as well as the condition of its sustainability, is constant natural regeneration. In terms of sustainability of the studied selection stand, the results of this research may briefly be summarized in two main conclusions: the problematic condition of fir and the aggressive onset of beech.

Namely, the proportion of significantly damaged fir trees in the experimental plot ranged from 50.0 % in 1998 to 63.6 % in 2003. The uneven-aged structure has been disturbed and consists of an excessive number of old and over-mature fir trees which have reached their physical maturity. The absence of fir from the thinnest degrees of diameter distribution suggests the absence of increment over the several past decades. The proportion of fir among the young plants in the experimental plot constantly dropped from 23.4 % in 1998 to 8.5 % in 2007. Not one fir exceeded a height of 30 cm throughout decades of monitoring.

On the other hand, the aggressiveness of beech is evident in the increased share of young beech regeneration from 16.1 % in 1998 to as much as 58.3 % in 2007. Beech crowns (alone or overlapping with fir) cover 73.9 % of the experimental plot area. The share of significantly damaged beech trees in the experimental plot did not exceed 13 % (the highest percentage of 12.4 % occurred in 1998). Fir in the thinnest degrees of the diameter distribution is being replaced with young beech trees.

The results obtained during decade-long monitoring of the structure and process of natural regeneration of beech and fir stands in Risnjak National Park do not guarantee the sustainability of the forest ecosystem, which was the basic reason for giving this area the status of a national park. The justifiability of the concept of passive protection should be re-examined in this case. There is a possibility that in the long run, such a concept of protection will harm rather than protect forest ecosystems of national parks. In order to obtain a scientifically based platform for making decisions on the future of forests in protected areas, a monitoring methodology should constantly be improved by establishing a network of permanent experimental plots in all the protected forested areas in Croatia. In no case should modern information models be neglected; on the contrary, full use should be made of their capability of presenting newly acquired knowledge in a qualitative manner.

Past insights and experience of a large number of forestry scientists, to which we contribute with our research, allows us to conclude that foresters have the knowledge, the ability but also the commitment to help forest ecosystems in protected areas to permanently fulfill their intended role. The forestry profession should definitely become more involved, particularly in those protected areas whose basic phenomenon and/or the most distinct feature are forest ecosystems. In such cases, treatment of forests should foster the preservation and naturalness of forest ecosystems in concrete sites.

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UTJECAJ STRUKTURE SASTOJINE NA DINAMIKU RAZVOJA MLADOGA NARAŠTAJA U BUKOVO-JELOVIM ŠUMAMA NACIONALNOG PARKA "RISNJAK"

SAŽETAK

U radu se iznose rezultati istraživanja stanja strukture, regeneracijskih procesa, značajki mladoga naraštaja, uvjeta njegova razvoja i opstanka, oštećenosti krošanja bukve i jele, kao i mogućnost primjene novih načina praćenja razvoja sastojina metodama trodimenzionalne vizualizacije horizontalne i vertikalne strukture sastojine. Rezultati se temelje na desetogodišnjem istraživanju (1998.-2007.) na stalnoj pokusnoj plohi u šumi bukve i jele (*Omphalodo-Fagetum* Marinček et al. 1992) unutar NP "Risnjak".

Rezultati izmjera strukture sastojine ukazuju na narušenost preborne strukture. Distribucija broja stabala ukazuje na izostanak jele u najtanjim debljinskim stupnjevima te manjak srednje debelih stabala, što potvrđuje izostanak priliva jele iz prirodnog pomlađivanja unazad više desetljeća. Taj prostor popunjava zastarčena, nekvalitetna bukva, što upućuje na izmjenu vrsta. Prevelika zastrtost tla krošnjama, izostanak stepeničastog oblika sklopa, nagomilana drvna masa na starim, fiziološki oslabljenim stablima, također ukazuju na izostanak preborne strukture. Navedeno se odrazilo na brojnost, kvalitetu i preživljenje mladog naraštaja, a rezultati ukazuju na upitnost očekivanog normalnog procesa prirodne obnove.

Zaštićeni šumski ekosustavi poradi svoje uloge, stabilnosti i potrajnosti zahtijevaju aktivniji način zaštite u smislu pomaganja pozitivnih prirodnih procesa. Rezultati ovoga istraživanja kao i dosadašnje spoznaje mnogih šumarskih znanstvenika daju nam za pravo zaključiti kako šumari poradi svoje bogate tradicije imaju znanja, mogućnosti te obvezu pomoći zaštićenim šumskim ekosustavima da trajno obavljaju namijenjenu im ulogu.

Ključne riječi: Nacionalni park, struktura preborne sastojine, prirodna obnova, jela, bukva