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ANNALES
EXPERIMENTIS SILVARUM CULTURAE PROVEHENDIS

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SVEUČILIŠTE U ZAGREBU
ŠUMARSKI FAKULTET
UNIVERSITAS STUDIORUM ZAGRABIENSIS
FACULTAS FORESTALIS

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Original scientific paper
Izvorni znanstveni članak

ECOLOGICAL-VEGETATIONAL PROPERTIES OF FOREST "ŽUTICA"

EKOLOŠKO-VEGETACIJSKE ZNAČAJKE ŠUME ŽUTICA

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Received – *Prispjelo*: 1.9.1998. Accepted – *Prihvaćeno*: 1.11.1998.

The paper presents synecological-vegetational research carried out in the Management Unit "Žutica" over a total area of 6,116.68 ha.

During three-years' research in the forest "Žutica", its phytocoenology was described, and the forest recorded, systematized and mapped. The present condition of this forest was compared with that of the past, as well as with the research in lowland forests growing on pedunculate oak sites affected by dieback (Kalje, Turopoljski lug, Pokupski bazen).

Eight forests in all were phytocoenologically described, of which the forest of pedunculate oak and great green weed with common hornbeam was described for the first time. Changes pointing to a disturbed ecosystem were recorded in most cases.

Deviations from normal lowland forest associations, as well as general destabilization of the "Žutica" forest ecosystem, were caused by factors of synergetic nature.

According to research, over 700 ha of the most interesting and valuable forests of pedunculate oak were affected by abrupt external and internal influences of high intensity during the dieback period of some thirty years ago. The principal tree species were desiccated, site conditions and forest associations were changed, and a negative succession of forest vegetation took place.

A vegetation map of forest associations in the Management Unit "Žutica" on a scale of 1 : 25,000 was drawn up on the basis of phytocoenological and other research.

Site and stand degradation can only be curbed, and a return to a normal state and progression achieved, through a multidisciplinary approach to this and similar problems.

Key words: Žutica, synecological-vegetative research, forest associations, disturbed ecosystem, synergism, vegetative map, multidisciplinary approach

INTRODUCTION
UVOD

In the second half of this century, lowland forest regions of Croatia were subjected to strong meliorative, technological and other anthropogenic influences. Their synergistic action led to sporadic changes and instability of forest ecosystems. These influences caused extensive forest dieback in several regions along the river Sava in western Croatia, while in some other regions they led to various syndynamic changes linked to a retreat or expansion of individual tree species or forest associations.

The forest "Žutica" is particularly important in this sense. A disturbance in normal relationships among synecological factors has led to changes in principal tree species participation, floral composition and forest associations, resulting in unstable forest stands. For this reason, the forest "Žutica" is a very valuable and interesting object of scientific vegetational research.

It needs to be stressed that the study of such ecosystems should be multidisciplinary. Forest phytocoenology represents an indispensable factor in any study of the forest "Žutica". Phytocoenological research gives data on the original climatogenous vegetation and development trends of the existing vegetation. This makes the choice of the most natural methods of repairing degraded areas easier, and provides a base for silvicultural operations, and for the management, protection and exploitation of forests.

GOALS AND METHODS OF RESEARCH
CILJ I METODE ISTRAŽIVANJA

The research goals are:

- to provide a phytocoenological description of the Management Unit "Žutica",
- to obtain a phytocoenological recording of forest associations in the studied area,
- to systematise forest associations,
- to draw up a map of forest associations,
- to compare the present state of forest associations in the Management Unit "Žutica" with the present state of the same associations in the areas affected by pedunculate oak dieback (Kalje, Turopoljski lug, Pokupski bazen),
- to compare these associations with those in the areas where no disturbances of the above nature took place (Lipovljani forests and others),
- to predict the direction of syndynamic development of forest associations using other ecological research as well,
- to provide such practical solutions for this and similar problems in Croatian lowland ecosystems which will preserve their ecological stability, maintain

biological diversity, and achieve an optimal wood mass production. All this will make an important contribution to sustainable management.

The following research methods were used:
- classical principles of the Zürich-Montpellier school (Br-Bl. 1964),
- guidelines from the "Handbook of Typological Research and Vegetation Mapping" (Horvat et al., 1950),
- biological plant forms taken from Rauš and Šegulja (1983),
- plant nomenclature concorded according to Ehrendorfer (1973).
- data processing.

All these research methods have been concorded with the existing Phytocoenological Nomenclature Codex (Barkman et al., 1986).

NATURAL FEATURES OF THE STUDIED AREA
PRIRODNE ZNAČAJKE ISTRAŽIVANOGA PODRUČJA

GEOGRAPHICAL LOCATION, SURFACE AREA, AND GROWING STOCK
ZEMLJOPISNI POLOŽAJ, POVRŠINE I DRVNA ZALIHA

"Žutica" is a forest complex bounded by the Zagreb – Lipovac motorway in the north, the river Sava in the south, the river Lonja in the west, and the river Česma in the east. It is located between 16°21' and 16°31 eastern longitude, and 45°34' and 45°41 northern latitude. In a wider sense, it belongs to the region of Posavina.

Within the structure of the Public Enterprise "Croatian Forests", this area represents the Management Unit of "Žutica" with 200 departments. It belongs to Zagreb Forest Management, Forest Office of Novoselec Križ.

The Management Unit covers 6,116.68 ha, of which 5,107.41 ha are under forest stands, and 1,009.27 ha are non-forested and infertile soils (511.25 ha are non-forested – productive, 205.69 ha are non-forested – non-productive, and 292.32 ha are infertile).

The largest part of infertile and non-forested – non-productive land belongs to INA-Naftaplin Oil Company.

In terms of tree species, the structure is as follows: pedunculate oak - 622,397 m^3, or 55% of the total growing stock, black alder - 160,360 m^3 or 14.17% , narrow-leaved ash - 160,192 m^3, or 14.16%, common hornbeam - 119,004 m^3, or 10.52%, poplar - 30,021 m^3, or 2.65%, maple - 18,096 m^3, or 1.60%, OTL - 10,652 m^3, or 0.94%, common beech 4,422 m^3, or 0.39%, OML - 3,675 m^3, or 0.33%, and lowland elm 2,740 m^3, or 0.24%, which is a total of 1,131,559 m^3 of growing stock. The current annual increment is 37,191 m^3.

CLIMATIC CONDITIONS
KLIMATSKE PRILIKE

The data for the period 1983 – 1992, provided by the Sisak Meteorological Station, are as follows: the mean annual air temperature is 11.0°C, the mean annual precipitation quantity is 872 mm (471 mm in the vegetation period), and the mean annual relative air humidity is 77%, which, according to Köppen's classification, denotes a temperate rainy climate marked with Cfwbx" type.

Table 1. Mean monthly and annual air temperature (T) and quantity of precipitation (O) for the period 1983 - 1992.
Tablica 1. Srednje mjesečne i godišnje temperature zraka (T) i količine oborina (O) za razdoblje od 1983. do 1992. godine

Months *Mjeseci*	I	II	III	IV	V	VI	VII	VIII	IX	X	XI	XII	Mean values *Srednjak*
T °C	0.5	0.9	6.5	11.4	15.9	18.6	21.4	20.7	16.4	10.7	4.9	1.5	11.0
O mm	58.1	56.7	63.5	60.6	107.3	97.5	66.0	64.8	74.9	84.4	95.3	42.8	871.7

Table 2. Annual trends in mean relative humidity (%) for the period 1983 - 1992.
Tablica 2. Godišnji hod srednje relativne vlage (%) za razdoblje od 1983. do 1992. godine

Months *Mjeseci*	I	II	III	IV	V	VI	VII	VIII	IX	X	XI	XII	Mean values *Srednjak*
%	84	79	73	69	71	73	71	73	78	83	86	86	77

According to Lang's rain factor (annual) Kfg = O/T = 872/11 = 79, the climate type is semi-humid with a tendency towards a humid one.

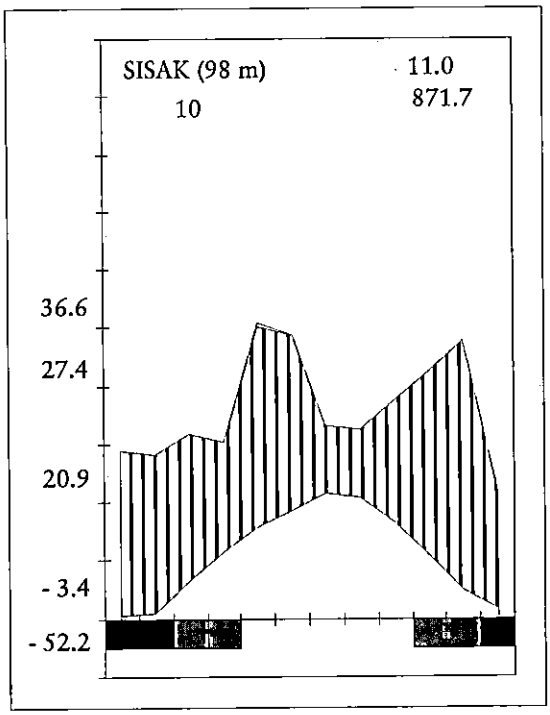
Gračanin's monthly rain factor (Kfm) shows that the annual climate type is semi-humid.

Since whether the climate is cold, temperate or warm with certain humidity levels is relevant for the occurrence and growth of plants, Gračanin also adds a climate temperature character (TK). In the area under research, the TK is moderately warm, since the mean annual air temperature ranges between 8.0 and 12.0°, or 11.0°C on average.

Table 3. Monthly rain factor (Kfm), humidity (H) and climate warmth nature (TK) according to Gračanin for the period 1983 - 1992.
Tablica 3. Mjesečni kišni faktor (Kfm), humiditet (H) i toplinski karakter klime (TK), prema Gračaninu, u razdoblju od 1983. do 1992. godine

Months *Mjeseci*	I	II	III	IV	V	VI	VII	VIII	IX	X	XI	XII	Annual *Godišnje*
Kfm	116	63	9.8	5.3	6.8	5.2	3.1	3.1	4.6	7.9	19.4	28.5	79
H	ph	ph	h	sh	h	sh	a	a	sa	h	ph	ph	sh
TK	n	h	uh	ut	t	t	v	v	t	ut	uh	h	ut

Figure 1. Climate diagram according to Walter for the period 1983–1992.
Slika 1. Klimatski dijagram prema Walteru za razdoblje 1983–1992. god.



Late and early frosts (and especially the former) also play an important role. As they usually occur in May, they interfere with flower pollination and fruit embryo formation, and kill young shoots. Early autumn frosts prevent crops from ripening.

The most harmful winds come from a south-westerly and westerly direction, but their impact is not too negative.

It can be concluded from the above that the climatic conditions in the studied area are favourable for the growth of vegetation.

GEOLOGICAL SUBSTRATE AND SOIL
GEOLOŠKA PODLOGA I TLO

The Management Unit "Žutica" and the Posavina Plain where it is located, are developed on a geological substrate of pebbles, sands, clays and loams. It was formed in the Pleistocene as the result of depositions in the Pannonian Sea and of river deposits. The main characteristic of such a geological base is its horizontal and vertical heterogeneity. Genetically, a younger alluvial layer composed of clays, loams, mud and pulverized materials lies above this heterogeneous material.

The lowest river valleys are composed of deposits of the Holocenic age (Mayer, 1996).

The erosion of recent alluvial substrate under the influence of a specific water regime has resulted in the formation of hydromorphous soils, in the first place pseudogleys, semigleys and gleys.

A number of authors (Vajda, Kalinić, Škorić, Martinović, Vranković, Prpić, Bašić, Mayer, and others) have always pointed out that specific hydrological conditions represent a dominant pedogenetic factor in valleys. A richly indented lowland microrelief, which determines the redistribution of incoming water, is a decisive factor in the formation of drier and wetter sites, and consequently of differently productive forest soils.

In 1996, Mayer drew up a table of pedological-vegetational pairs for natural pedotaxons in lowland pedunculate oak forests in Croatia, which he based on the data from different papers (Rode 1960; Ćirić 1984; Škorić et al. 1989; Vranković and Bašić, 1989; Dekanić 1962, 1971, 1974, 1975; Rauš 1974; Rauš et al. 1992; Prpić et al. 1979; Prpić 1985). Table 4 shows a part of the table referring to forest associations in the Management Unit "Žutica".

Table 4. Natural pedological-vegetation pairs in lowlend forests of penduculate oak in Croatia

Tablica 4. Prirodni pedološko-vegetacijski parovi u nizinskim šumama hrasta lužnjaka u Hrvatskoj

Forest association	List of pedotaxons	Topographic sequences	Groundwater veget. average
Forest of pedunculate oak and great green weed with remote sedge	amphigley, hypogley, epigley, humogley	Micro-depressions	about 150 cm (Dekanić 1962)
Forest of pedunculate oak and great green weed with quaking sedge	amphigley, epigley, pseudogley-gley, hyopgley	Micro-depressions on micro-elevations, humid micro-elevation, transition micro-depression - micro- elevation in western Posavina	about 200 cm (Dekanić 1962)
Forest of pedunculate oak and common hornbeam	pseudogley lowland, pseudogley-gley, semigley, hypogley, eutric brown, luvisol pseudogleyic	Micro-elevations and humid micro-elevations in valleys, Pleistocene terraces	about 220 cm (Dekanić 1962)
Forest of pedunculate oak and common hornbeam with beech	pseudogley lowland, pseudogley-gley, semigley, hypogley, eutric brown, luvisol pseudogleyic	Micro-elevations in valleys, Pleistocene terraces	about 220 cm (Dekanić 1962)

So, for example, the association of pedunculate oak and common hornbeam grows on lowland pseudogley, the association of pedunculate oak and great green weed on mineral-swampy soils and lowland pseudogley, and the associations of black alder with dogwood, and narrow-leaved ash with autumn snowflake on eugley soils (the former on an amphigley subtype, and the latter on epigley).

In general, it was found (Forestry Institute Jastrebarsko, 1979) that the above soils are of slight to neutral acidity, have a clayey mechanical composition, are mostly non-carbonate, and have a high humus content, but low nitrogen and phosphorus content.

The study of redox potential carried out by Vranković and Bašić (1989), showed that unfavourable reduction conditions in swampy compartments last over the entire growing season. Particularly strong reduction is caused by surface water (flood and precipitation) which cannot run off, because forest roads and other communications make its retreat after floods more difficult. On the basis of research in Lipovljani, Škorić and Vranković (1975) concluded that the degree of anaerobiosis correlates with dieback intensity, which increases from pseudogley towards gley soil; therefore, pollution is excluded as a possible cause of dieback.

GEOMORPHOLOGIC AND HYDROLOGICAL CONDITIONS
GEOMORFOLOŠKE I HIDROLOŠKE PRILIKE

The Management Unit "Žutica" is an undulating plain with mild elevations and equally mild depressions, intersected with smaller and larger water courses. The lowest points are characterised by swamps of stagnant water over the best part of the year. Altitude ranges between 93 and 99 m. Crna Humka is the central elevation from which numerous other elevations extend in all directions. The largest part of "Žutica" consists of flatlands with very small height differences. In this sense, the region called Ravneš is particularly characteristic. The total height difference of 6 m over a distance of 4.5 km between Crna Humka and the river Lonja gives an average gradient of 1.33%, which only just enables the run-off of surface water in "Žutica".

A very rich hydrographic system, which is characteristic of lowland Posavina, is made up of the rivers Lonja and Česma, the streams Črnec and Lonjica, and a number of smaller water courses with indistinct river beds.

Other hydrographic features include micro-depressions and swamps with mainly stagnant water. According to Šarin et al. (1994), top layers in the forest "Žutica" are impermeable to medium permeable.

Until the beginning of the 20th century, vast areas of Posavina were covered with floods, but due to hydro-technical operations in this century, flooding has been considerably reduced.

Since the end of the 19th century, water regimes of most Croatian rivers have been extensively regulated. This has disturbed water relations in forest sites. Groundwater levels have dropped, and floods are either absent, or occur at inconve-

nient periods (or when water management authorities release water into forests). A combination of the above and of other negative factors has resulted in a lowered resistance of individual trees, tree dieback, and regression processes both in plant communities and in sites.

Unfortunately, most of the roads and dams built through forest ecosystems do not have adequate water draining systems. Therefore, as water coming into the area cannot retreat as it would under a normal regime, it remains trapped until it evaporates. The result is a waterlogged terrain. The sites degrade, the soil oxygen content drops, microbiological activity is reduced, and vegetation not accustomed to such conditions dies.

Since the influence of human activity on the Management Unit "Žutica" and its water regime is very strong, the site has been turned into a retention area for the rivers Sava, Česma and Lonja by the water management authorities. Thus, the whole region, except for that of Žalkovo, has been surrounded with new river courses and dams. However, this has conflicted with natural relationships in the area, and has badly disturbed the whole ecosystem.

In recent times, the monitoring of hydropedological research has been introduced (Mayer 1981, 1988, 1991, 1995) into lowland forests in Croatia. The forest of "Žutica" should on no account be excluded from the research as the changes in its ecosystems are very great.

Field monitoring of water movement in and on the soil with piezometers, carried out by the Forestry Institute in Jastrebarsko, has proved to be the best method of obtaining accurate data on forest water regimes. It is also the main indicator for forest ecosystem management in lowland regions.

RESULTS OF RESEARCH
REZULTATI ISTRAŽIVANJA

FOREST ASSOCIATIONS IN THE STUDIED AREA AND THEIR SYSTEMATIC POSITION
ŠUMSKE ZAJEDNICE ISTRAŽIVANOGA PODRUČJA I NJIHOV SISTEMATSKI POLOŽAJ

Observations, which were part of field research, have shown that the studied area abounds in numerous forest associations, which can be classified into the following systematic groups:

Class: *Querco-Fagetea* Br.-Bl. Et Vlieg. 1973
Order: *Fagetalia sylvaticae* Pawl. 1928
Alliance: *Carpinion betuli* Ht. 1956

Ass: *Carpino betuli-Quercetum roboris* (Anić 1959)
emend. Rauš 1969
Subass: *typicum* Rauš 1971
Subass: *fagetosum* Rauš 1971

Class: *Alno-Populetea* Fk. et Fb. 1964
Order: *Populetalia albae* Br. - Bl. 1931
Alliance: *Alno-Quercion roboris* Ht. 1938
Ass: *Genisto elatae-Quercetum roboris* Ht. 1938
Subass: *caricetosum remotae* Ht. 1938
Subass: *caricetosum brizoides* Ht. 1938
Subass: *carpinetosum betuli* Glav. 1961
Ass: *Frangulo-Alnetum glutinosae* Rauš 1968
Subass: *typicum* Rauš 1971
Ass: *Leucoio-Fraxinetum angustifoliae* Glav. 1959
Subass: *typicum* Glav. 1959
Subass: *alnetosum glutinosae* Glav. 1959

Initial vegetation of willows and reed is also present, as well as the cultures of Euro-American poplars (*Populus* x *euroamericana*) enriched with natural, pioneering species of narrow-leaved ash and black alder, There is a spruce culture (*Picea abies*) and Waymouth pine (*Pinus strobus*) in a very small area.

FOREST OF PEDUNCULATE OAK AND COMMON HORNBEAM
ŠUMA HRASTA LUŽNJAKA I OBIČNOGA GRABA
(*Carpino betuli-Quercetum roboris* /Anić 1959/ Rauš 1969)

Research so far: The forest of pedunculate oak and common hornbeam in Croatia has been a frequent subject of research. From a vegetational standpoint, it has been studied by Horvat (1938, 1959, 1962), Anić (1940, 1959), Glavač (1960, 1961, 1962, 1968), Rauš (1966-1995) and others.

It has sometimes been described as an association, and sometimes as a subassociation under different names: *Querco-Genistetum elatae* Ht. 1938, subass. *Carpinetosum betuli* Vuk. 1959 prov., *Querco-Carpinetum ruscetosum aculeati* Ht. 1949, *Querceto roboris-Carpinetum betuli* Anić 1959, *Querco-Genistetum elatae carpinetosum betuli* Glavač 1961, *Querco robori-Carpinetum slavonicum* Soó 1962, and *Carpino betuli-Quercetum roboris* /Anić 1959/ Rauš 1969. The last has been accepted today, as well as its status as an association.

Gračanin (1948, 1951), Dekanić (1959, 1962), Bertović (1960), Šafar (1963), Prpić (1966-1995), and others have studied this forest from various ecological-management standpoints.

Distribution of phytocoenosis: The association of pedunculate oak and common hornbeam is distributed over the entire region of the pedunculate oak range.

The best stands grow along the large lowland rivers Sava and Drava and their tributaries, and in the region of Pokuplje in central Croatia. In the Management Unit "Žutica", the association is distributed over about 40% of the total area, mainly in the central part of the Unit and in the regions of Žalkovo, Pleso and Vratoč.

Site of phytocoenosis: The association inhabits raised terrains (micro-elevations) out of reach of flood water. Groundwater is relatively low, and its average level, according to some earlier research, ranges from 1.5 to 4 m. In winter, the soil is saturated with water. It has a slightly acid to neutral reaction, and its type is lowland pseudogley.

Floral composition and vegetational structure: The above factors are reflected in the association's floral composition. Apart from pedunculate oak, there is also considerable participation of hornbeam and maple, and various shrubs and herbaceous plants of drained terrains commonly found in forests of sessile oak and hornbeam. M. Anić (1959) describes this association as a pedunculate forest of a drier type.

The tree layer is made up mostly of pedunculate oak and common hornbeam, and a small percentage of the beech in the beech subassociation.

The shrub layer consists of hazel, dogwood, wayfaring tree, hawthorn and other plants.

Numerous mesophyllic species indicating fresh and drained sites, but not wet and flooded areas, as shown in Table 5, occur in the ground layer.

Biological range: According to Ranunkiaer (1905), the biological range of biological (live) forms from 20 phytocoenological recordings (Table 5) show the following structure of plant species: phanerophytes (Ph) 27%, chamaephytes (Ch) 11%, hemicryptophytes (H) 45%, geophytes (G) 12%, and therophytes (Th) 5%. This is an indication of a hemicrypto-phanerophytic (45 + 27%) association with a significant participation of geophytes (12%). A high presence of hemicryptophytes places this association into a central European region and shows its resistance to winter colds. A large number of phanerophytes indicates very warm summers, while that of geophytes reflects the micro-relief and micro-climatic conditions in this association, and shows a large participation of many plants of the *Fagetalia* order.

Classification of the phytocoenosis: The classification of these forests done and described by Rauš (1969-1971) has been fully accepted today. According to Rauš, there are four subassociations:

- subass.: *typicum* Rauš 1971
- subass.: *fagetosum* Rauš 1971
- subass.: *quercetosum cerris* Rauš 1969
- subass.: *tilietosum tomentosae* Rauš 1969.

Research carried out over three years in the forest "Žutica" has confirmed the presence of the first two subassociations. Their phytocoenology has been recorded and described and they have been inserted into the forest association distribution map.

Phytocoenotic syndynamics: According to various researches carried out by many researchers and by this author, the forest of pedunculate oak and common hornbeam is a culminating point in a natural development of lowland forests. It is a point to which all foresters should aspire, but always bearing in mind the state in the field. This forest is the result of a natural succession from the forest of pedunculate oak and great green weed *(Genisto elatae-Quercetum roboris)*, and represents a terminal association, marking the final stage in the development of lowland vegetation.

Stability of the phytocoenosis: Of all the associations in the area, the forest association of pedunculate oak and common hornbeam has proved to be the most stable and the most resistant to dieback. However, even this association is not completely immune to changes in ecological conditions. In all other localities (Kalje, Turopoljski lug, and Pokupski bazen), which, together with the Management Unit "Žutica", represent the most extreme examples of pedunculate dieback in Croatia, it was shown that this association is the least dependent on high groundwater levels. Here, pedunculate oak has adapted to dry conditions, and its growth has not been stunted by a changed water regime. However, other changes of a different character have taken place in this association, which will be described in more detail later.

Forest-economic characteristics: As already mentioned, the tree layer is dominated by pedunculate oak, with an ample presence of common hornbeam in the understorey. This combination suits the pedunculate oak very well: the trees are large, clean and full-bodied. The forests are characterised by a large wood mass, so from the economic standpoint it is the most favourable stand form in the lowland region.

Allowing for the state of the sites, the association of pedunculate oak and common hornbeam is the ideal to which every forester in this and similar lowland regions should aspire. All forest activities should be directed towards that goal. Stands of pedunculate oak grow much better and have more thinning material if the understorey is rich in hornbeams. Such stands benefit from sunlight much more, because the part of light which penetrates through rarified oak crowns is stopped by the hornbeams in the understorey, and is put to use for the increase of wood mass, while in pure oak stands this part of light remains unused. Understorey hornbeams are useful not only because they provide shade for the soil under oak stands, but also because their leaf litter creates a thick humus layer and improves the physical and chemical properties of the soil.

Matić (1996) points out the importance of natural rejuvenation or natural regeneration. It is the most perfect form of regeneration of every stand, as it does not break the continuity of the joint action and mutual influence of ecosystem members. Most importantly, natural regeneration preserves the forest soil - the most perfect and the most important part of the ecosystem containing the entire living world on the planet in its full wealth.

The minimal rotation in pedunculate oak forests is 140 years. Treatments involving natural regeneration should be carried out in stands with normal structural

Table 5. - *Tablica 5.*

Association:		*CARPINO BETULI-QUERCETUM ROBORIS* Rauš 1969																				D	B
Subassociation:		*typicum* Rauš 1971										*fagetosum* Rauš 1971										e	i
Number of recording:		1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	g	o
Area:												Žutica										r	l
Department, compartment:		156a	187a	128b	123d	113a	83a	36e	33a	122b	60b	124a	116a	112a	88a	29a	31a	48b	104a	79a	40a	e	o
Plot size (m^2):		400	400	400	400	400	400	400	400	400	400	400	400	400	400	400	400	400	400	400	400	e	g
Date:		3.VI.	16.VI.	26.VI.	26.VI.	23.VI.	1.VII.	3.VII	2.VII.	27.VI.	4.IX.	26.VI.	27.VI.	27.VI.	1.VII.	2.VII.	2.VII.	26.VIII.	27.VIII.	24.IX.	3.VII.		i
Cover (%):																						o	c
Tree layer		100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	95	95	100	90	f	a
Shrub layer		1	1	1	5	1	20	1	20	1	5	1	1	5	15	5	10	5	5	5	60		l
Ground vegetation layer		50	60	40	80	70	90	70	50	90	30	20	50	60	90	80	70	70	40	70	40	p	
FLORAL COMPOSITON																						a	f
																						r	o
Characteristic and distinguishing species of the association:																						t	r
Quercus robur L.	A	4	4	4	5	4	4	4	4	4	5	4	4	4	5	4	4	5	4	4	4	i.	m
Quercus robur L.	B	+	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	V	Ph
Veronica montana L.	C	1	.	2	2	1	1	1	1	.	1	.	1	1	2	.	1	.	+	.	1	I	Ph
Quercus robur L.		+	2	.	1	2	1	.	2	.	1	+	.	2	1	2	1	.	1	2	1	IV	Ch
Carex brizoides L.		2	.	1	2	1	2	.	.	+	1	2	2	2	1	1	+	.	1	1	2	IV	Ph
Rubus hirtus W.K.		1	.	1	+	+	4	1	+	.	+	+	.	+	+	+	+	+	.	.	+	IV	H
Lysimachia nummularia L.		+	.	+	+	.	.	+	1	+	.	+	.	.	.	.	.	.	.	.	1	IV	Ch
Carex remota L.		+	.	.	+	+	.	+	+	1	.	.	.	.	.	.	.	.	.	+	+	II	Ch
Glechoma hederacea L.		+	.	.	.	.	.	+	.	1	+	.	.	.	.	.	.	.	.	.	.	II	H
																						I	Ch
Distinguishing species of the subassociations (*fagetosum*):																							
Fagus sylvatica L.	A	.	.	.	.	.	.	.	.	.	.	1	2	1	1	3	2	+	2	2	1	III	Ph
Ruscus aculeatus L.	B	.	.	+	.	.	.	.	.	.	.	+	+	+	.	.	+	+	.	+	.	II	Ch
Fagus sylvatica L.		.	.	.	.	.	.	.	.	.	.	.	+	+	.	.	1	.	+	.	.	I	Ph
Fagus sylvatica L.		.	.	.	.	.	.	.	.	.	.	1	2	.	.	.	1	.	.	.	.	I	Ph
Mycelis muralis (L.) Rchb.		.	.	.	.	.	.	.	.	.	.	.	.	+	.	+	.	.	.	.	.	I	H
Luzula pilosa (L.) Willd.		.	.	.	.	.	.	.	.	.	.	.	.	+	.	.	.	.	.	.	.	I	H
Characteristic and distinguishing species of the alliance (*Carpinion betuli*):																							
Carpinus betulus L.	A	4	3	3	3	3	3	4	3	3	3	2	3	3	3	2	3	2	3	3	2	V	Ph
Carpinus betulus L.	B	+	+	+	.	.	+	.	2	.	+	.	+	.	+	+	+	+	1	.	1	IV	Ph
Euonymus europaea L.		+	.	+	.	.	+	+	+	.	1	.	.	.	+	+	.	+	.	+	+	III	Ph
Acer campestre L.		.	.	.	.	.	+	+	+	+	+	.	.	+	.	.	.	+	.	+	+	III	Ph

Stellaria holostea L.	C	.	2	3	2	+	3	+	.	+	.	2	1	.	2	+	+	.	2	.	.	IV	H
Acer campestre L.		.	+	.	+	+	.	.	.	+	+	.	.	.	1	.	.	.	+	+	.	II	Ph
Carpinus betulus L.		+	.	.	.	1	3	.	.	.	.	1	.	2	2	2	2	.	.	.	.	II	Ph
Vinca minor L.		.	.	.	.	.	.	.	.	.	.	.	.	2	+	.	.	.	.	.	+	I	Ch
Characteristic species of the order (*Fagetalia*) and class (*Querco-Fagetea*):																							
Corylus avellana L.	B	+	.	.	.	+	2	+	1	.	1	.	.	.	2	1	+	1	.	1	3	III	Ph
Crataegus oxyacantha L.		.	.	+	1	+	.	.	+	+	+	.	+	1	.	+	.	.	.	+	+	III	Ph
Crataegus monogyna Jacq.		.	.	.	.	.	.	.	.	.	.	.	.	.	+	+	1	+	.	.	1	II	Ph
Circaea lutetiana L.	C	1	+	.	1	+	+	2	1	+	2	+	1	+	+	+	1	+	1	+	2	V	G
Viola reichenbachiana Jor. ex Bor.		+	+	1	1	1	+	1	1	1	1	1	2	2	2	+	.	2	+	2	+	V	G
Galium odoratum (L.) Scop.		.	1	1	3	4	3	1	1	1	.	2	.	3	3	3	3	2	2	3	2	V	G
Lamiastrum galeobdolon (L.) E.et P.		.	3	2	3	2	1	3	.	2	.	1	2	1	1	2	3	1	1	3	1	V	Ch
Polygonatum multiflorum (L.) All.		+	1	+	1	+	+	+	1	.	.	1	+	+	1	+	+	+	+	1	.	V	G
Ajuga reptans L.		2	1	1	1	+	+	1	.	3	+	1	1	1	1	1	+	+	1	2	1	V	H
Dryopteris filix mas (L.) Sch.		+	+	1	+	+	+	.	+	+	.	+	.	+	+	+	1	+	+	.	+	IV	H
Carex maxima L.		.	.	.	1	.	.	2	3	1	+	.	.	2	+	1	1	+	.	+	2	III	H
Brachypodium silvaticum R.S.		+	.	.	+	.	+	.	+	+	.	.	.	+	+	.	+	+	.	.	.	III	H
Anemone nemorosa L.		.	1	2	1	1	+	.	1	.	.	.	2	.	.	.	.	.	+	.	+	III	G
Paris quadrifolia L.		+	.	+	.	.	.	1	.	1	.	+	1	.	1	1	+	.	.	.	+	III	G
Carex silvatica Huds.		+	.	.	1	.	.	1	1	+	.	.	.	.	.	.	.	3	.	1	.	II	H
Asarum europaeum L.		.	2	.	.	.	+	2	.	.	.	.	.	1	1	+	.	+	.	2	.	II	H
Scrophularia nodosa L.		+	.	.	+	.	.	.	.	.	.	.	.	+	1	+	+	.	.	+	.	II	H
Primula vulgaris Huds.		.	+	.	.	.	.	.	1	.	+	.	.	.	.	1	.	.	.	.	1	II	
Sanicula europaea L.		.	.	+	.	.	.	.	.	.	.	.	.	.	.	1	.	.	.	+	.	I	H
Euphorbia amygdaloides L.		.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	1	.	.	.	.	I	Ch
Other species:																							
Rhamnus cathartica L.	B	.	.	.	+	+	.	+	+	.	.	.	.	+	+	+	.	+	+	.	1	III	Ph
Viburnum opulus L.		.	.	.	.	.	.	.	+	.	+	.	.	.	+	.	.	+	+	.	+	II	Ph
Ulmus carpinifolia Gled.		+	.	.	.	.	.	+	.	+	.	.	.	.	+	+	.	.	.	.	.	II	Ph
Sambucus nigra L.		+	.	.	.	.	.	.	.	.	+	.	.	.	.	.	+	.	.	.	.	I	Ph
Pyrus pyraster (L.) Borkh.		.	.	.	+	.	.	.	+	.	.	.	.	.	.	.	.	+	.	.	.	I	Ph
Frangula alnus Mill.		+	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	I	Ph
Oxalis acetosella L.	C	1	2	3	3	3	+	1	1	3	2	2	2	3	2	3	3	+	2	1	1	V	H
Galeopsis tetrahit L.		1	+	1	1	+	1	.	.	+	+	+	1	+	.	+	+	+	+	+	+	V	Th
Symphytum tuberosum L.		.	1	.	.	1	.	1	1	+	.	+	1	2	.	.	2	.	+	.	1	III	G
Hedera helix L.		.	+	+	.	+	.	1	1	.	+	.	.	.	1	+	.	1	+	+	+	III	Ph
Fragaria vesca L.		.	.	.	.	1	.	.	+	.	.	.	.	+	.	+	+	+	+	.	1	III	H
Geum urbanum L.		.	+	+	.	.	+	+	.	.	.	.	+	+	+	.	.	.	.	.	.	II	H

Aegopodium podagraria L.	.	.	.	2	2	+	.	.	.	.	.	.	2	.	.	.	2	.	2	.	II	H
Athyrium filix femina (L.) Roth.	.	.	+	.	+	.	.	.	.	+	.	1	.	.	+	.	.	.	1	+	II	H
Angelica silvestris L.	.	.	.	.	.	.	1	1	.	2	.	.	.	.	1	.	.	+	.	1	II	H
Cerastium silvaticum W.K.	.	.	+	+	+	.	+	.	1	.	.	.	.	.	.	.	.	.	.	.	II	Ch
Festuca gigantea (L.) Vill.	+	.	1	.	.	.	.	.	+	.	.	.	.	.	.	.	.	.	.	.	II	H
Impatiens noli tangere L.	+	.	2	+	.	.	.	.	1	.	.	.	.	.	.	+	.	.	.	.	II	Th
Platanthera bifolia (L.) Rich.	.	.	.	.	.	+	1	1	.	.	.	.	.	.	.	.	.	.	.	.	I	G
Geranium robertianum L.	.	.	+	.	.	.	.	.	.	.	.	.	+	+	.	.	.	.	.	.	I	Th
Urtica dioica L.	.	.	.	.	.	.	.	.	+	.	.	.	+	.	.	.	.	.	.	2	I	H
Deschampsia caespitosa (L.) Beauv.	+	.	.	.	.	1	.	.	.	.	.	.	.	.	.	.	+	.	.	.	I	H
Melampyrum silvaticum L.	.	+	.	.	.	.	.	.	.	.	1	.	.	.	.	.	.	.	.	+	I	Th
Pulmonaria officinalis L.	.	2	.	.	.	.	1	.	.	.	.	.	.	.	.	.	+	.	.	.	I	H
Veronica chamaedrys L.	.	.	.	.	.	.	.	.	2	.	.	.	.	.	1	.	.	.	.	.	I	H
Moehringia trinervia (L.) Clairv.	+	.	.	.	.	+	.	.	.	.	.	.	.	.	.	.	.	.	.	.	I	H
Galium aparine L.	+	+	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	I	H
Galium palustre L.	.	.	+	+	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	I	H
Galium silvaticum L.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	1	.	.	+	.	I	H
Senecio nemorensis L.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	+	.	+	.	.	I	H
Hypericum hirsutum L.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	+	.	.	2	.	I	H
Cardamine savensis Schulz.	.	+	.	.	.	.	.	.	.	.	.	.	.	+	.	.	.	.	.	.	I	H
Maianthemum bifolium (L.) Schm.	.	.	.	.	.	.	1	.	.	.	.	+	.	.	.	.	.	.	.	.	I	H
Nephrodium spinulosum Stremp.	+	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	I	H
Ranunculus ficaria L.	.	.	.	.	.	.	.	.	.	+	.	.	.	.	.	.	.	.	.	.	I	G
Millium effusum L.	.	.	.	.	.	.	.	.	.	.	.	+	.	.	.	.	.	.	.	.	I	H
Rubus caesius L.	.	.	.	.	.	.	.	+	.	.	.	.	.	.	.	.	.	.	.	.	I	H
Myosotis scorpyoides L.	.	.	.	.	.	.	.	.	+	.	.	.	.	.	.	.	.	.	.	.	I	H
Lapsana communis L.	.	.	+	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	I	Th
Rumex sanquineus L.	.	.	.	.	.	.	.	.	+	.	.	.	.	.	.	.	.	.	.	.	I	H
Cephalanthera rubra (L.) L.C. Rich.	.	.	.	.	+	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	I	G
Torylis anthriscus (L.) Gmel.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	+	.	.	.	.	I	

Explantation of abbreviations:
A - Tree layer
B - Shrub layer
C - Ground vegetation layer
+, 1, 2, 3, 4, 5 - Combined assessment of abundance and cover - (Braun-Blanquet 1964)
I - V - Degree of participation
Ph, Ch, H, Th, G - Biological form (Raunkiaer 1905)

relationships and with a preserved forest soil, while those relating to artificial regeneration should be applied in stands where acorn yields are unsatisfactory. In the latter case, silvicultural principles of natural regeneration should be applied, that is, three cuts: the preparatory, seeding and final cut.

Typical forest of pedunculate oak and common hornbeam
Tipična šuma hrasta lužnjaka i običnoga graba
(*Carpino betuli-Quercetum roboris typicum* Rauš 1971)

Site of the phytocoenosis: It develops mostly on re-deposited "swampy" loess, which occurs on micro-elevations and river terraces (Takšić 1970).

The soil is lowland brown, lowland pseudogley and mineral-swampy moderate ogley (semigley). These sites are out of reach of flood water, but in case they reach lower humid micro-elevations, they are usually weak, of short duration, and rare.

Common hornbeam is the best indicator of the state of stagnant water and groundwater, since it tolerates passing floods of short duration, but not stagnant water and high levels of groundwater (Dekanić 1959). Therefore, it occurs only when the water table is 2 to 3 m high, which is the case only on micro-elevations. When a micro-elevation gradually turns into a micro-depression, groundwater levels rise and hornbeam disappears from the floral composition.

The association dominates in the central part of the "Žutica" Unit, which is also the highest point of the relief. The most characteristic complexes are found in the areas around Petica, Vratoč, along the old course of the Lonjica, along the Ćesma on river terraces, around Pleso, and at other points. It covers about 30 % of the total area.

Floral composition and vegetational structure: The floral composition, based on 10 characteristic recordings taken in various parts of the "Žutica", is shown in Table 5. The recordings register 67 species, of which 42 participate with over 20% in the association. It is important to point out that phytocoenological recordings were made during the full growing season from June to September. Depending on weather conditions, this association comes to life at the end of March or the beginning of April. Common hornbeam is the first to break into leaf, maples and hawthorns follow, and pedunculate oak is the last. The reason why this association is the first in the area to enter the leafing stage lies in its position. As it is out of reach of floods, the temperature of the soil is higher than in other places. According to Rauš (1973), the spring aspect in the "Žutica" pedunculate oak forests consists of the following species in the ground layer: *Galanthus nivalis, Leucoium aestivum, Caltha palustris, Symphytum tuberosum, Anemone ranunculoides, Anemone nemorosa, Ranunculus ficaria, Viola reichenbachiana, Oxalis acetosella, Lathyrus vernus, Veronica montana, Veronica chamaedrys, Euphorbia amygdaloides*, and others. The number of species in the association and its floral composition is somewhat different from the recordings, since most of the spring plants later disappear from the floral composition.

In terms of phytocoenology, a typical forest of pedunculate oak and common hornbeam (*Carpino betuli-Quercetum roboris typicum)* represents a clearly defined association whose layers contain all the important constitutive elements.

As seen in Table 5, the tree layer consisting of well-defined dominant and subordinate storeys covers 100% of the area. Old, thick pedunculate oaks prevail, assisted by hornbeams and some maples. Of the species that characterize and distinguish this association from others, pedunculate oak (*Quercus robur*) in the tree layer and common hornbeam (*Carpinus betulus*) in the understorey occur with the highest constancy.

Pedunculate oak is the most important edifier and common hornbeam the subedifier in the tree layers. Diagnostically, they take up the most important place due to their constant presence in the subassociation, which they build completely. These two species occur not only in the tree layer, but also in other layers in the form of young growth and seedlings. The participation of pedunculate oak in the phytocoenosis is very large, and so is its influence on its growth and economic value. In spite of this, pedunculate oak is not nearly as important as common hornbeam for the definition of the association, because it often occurs outside a typical forest, in associations where life conditions are drastically different from those in a forest of pedunculate oak and common hornbeam. A comparison of the presence of common hornbeam in other forest associations of a lowland region reveals its strong links to a mixed forest of pedunculate oak and common hornbeam, because it does not occur in other phytocoenoses, or does so only sporadically. As already mentioned, its growth in other sites is prevented by stagnant surface water or groundwater, which is yet another indication of its exclusive ties to this association.

The shrub layer covers 1 - 5 % of the area, except in recordings 6 and 8, where it covers 20 %. It is made up of cobnut (*Corylus avellana*), common hornbeam (*Carpinus betulus*), spindle tree (*Evonymus europaea*), hawthorn (*Crataegus oxyantha*), and maple (*Acer campestre*), as well as of characteristic species of the alliance, order and family *Querco-Fagetea*. There is a large number of bushes, for example buckthorn (*Rhamnus cathartica*), guelder rose (*Viburnum opulus*), elm (*Ulmus carpinifolia*), and others, which occur frequently, but are not linked to the association.

Depending on individual recordings, the layer of ground vegetation covers wide range of the area (30 to 90 %). Of the species that characterise and distinguish this association from others, those that indicate the specific features of the site are particularly prominent: *Veronica montana* (speedwell), *Quercus robur* (pedunculate oak), *Carex brizoides* (quaking sedge), *Rubus hirtus* (blackberry), *Lysimachia nummularia* (moneywort), and others. A large number of species are linked to the order *Fagetalia* and the alliance *Carpinion betuli*, of which the most important are: *Stellaria holostea*, *Circaea lutetiana* (enchanter's nightshade), *Viola reichenbachiana* (violet), *Galium odoratum* (woodruff), *Lamiastrum galeobdolon* (deadnettle), *Polygonatum multiflorum* (Solomon's seal), *Ajuga reptans* (common bugle), *Brachypodium silvaticum* (bromegrassw), *Anemone nemorosa* (wood anemone) *Asarum europaeum* (wild ginger) and others.

These species are accompanied by a large number of very constant companions, which can be seen from a synthetic table of phytocoenological recordings of the association.

A comparison of floral compositions in 10 recordings from the synthetic table shows some differences among them. So, for example, recording 2 shows an association with species of a distinctly mesophyllic character. Almost all species favouring a more humid terrain are absent, which indicates a very dry site. Recordings 9 and 10 show a slightly more humid variant, with species such as *Ajuga reptans, Veronica chamaedrys*, and particularly *Carex remota, Cerastium silvaticum, Impatiens noli tangere, Lysimachia nummularia, Glechoma hederacea, Carex brizoides, Rumex sanguineus* and *Ranunculus lanuginosus*. Recording 6, with a substantially larger cover of shrub layer and with species such as *Carex brizoides, Rubus caesius* and *Deschampsia caespitosa* in the ground layer, indicate a certain disturbance in the stand.

Comprehensive vegetative research and a comparison with normally developed stands in Lipovljani have shown that the present state of forest vegetation in a typical association of pedunculate oak and common hornbeam in the Management Unit "Žutica" is satisfactory. In other words, the existing composition and arrangement of the storeys and plants ensures the stability of the association, except in some localities where the onset of narrow-leaved ash and black alder, prompted by increased site humidity, has interfered with the progression. The layer of ground vegetation is normal and does not display any signs that can be linked to dieback of pedunculate oak in this subassociation.

Stability of the phytocoenosis: On the basis of the distribution map of forest associations in "Žutica" made by Medvedović (1973-1975) in the course of his research, and the state of the forest in 1997, which was established with research by this author, it can be concluded that hydro-meliorative activities (drainage, flood defence) have had a double effect on these forests. A shortage of water in the sites of lowland forests accelerates progressive succession, as seen in compartments 39a and 168 in the Žalkovo region, where this association has spread into the area previously inhabited by the association of pedunculate oak and great green weed *(Genisto elatae-Quercetum roboris*). The association of pedunculate oak and common hornbeam also develops better on raised terrains along the river Ćesma and some other older water courses. On the other hand, a surplus of water causes these forests to shrink in size and give way to forests of more humid sites, such as those of narrow-leaved ash and black alder. The latter have penetrated the sites affected by dieback, despite the association's stability. The result is that compartments 107a, 113b. 119b, 126d, 129a and 129d, including some others, are now inhabited by associations of pedunculate oak and great green weed with common hornbeam (*Genisto elatae-Quercetum roboris carpinetosum betuli*) in place of pedunculate oak and common hornbeam. This is the first step towards the regression of the site and the association. Higher humidity in compartments 28a and b, 34b, 41b, 48a and c, 131a and c, part of 132 and 139a and some others, has favoured the appearance of pedunculate oak and great green weed with quaking sedge (*Genisto ela-*

tae-Quercetum roboris caricetosum remotae), while in compartments 25d, 101a, 103a, 119a, 187b, 188d and some others, it has led to the occurrence of pedunculate oak and great green weed with remote sedge (*Genisto elatae-Quercetum roboris caricetosum remotae*). Extreme examples of waterlogging in the localities marked as associations of pedunculate oak and common hornbeam in the 1975 map are compartments 27d and 72f, which are under ash forest today, and compartments 80b, 88a, 100b, 112b, 113d, and 126c, which are under the forest of black alder. In conclusion, it can be said that on the whole this is a fairly stable association, and that the areas under this association twenty years ago and today are equal in size, although the understoreys in some localities have been aggressively attacked by narrow-leaved ash. These localities include river terraces on micro-elevations within reach of flood water Black alder occurs in parts of forests in which water remains for longer periods after controlled floods have been let in by water management authorities.

Forest of pedunculate oak and common hornbeam with beech
Šuma hrasta lužnjaka i običnoga graba s bukvom
(*Carpino betuli-Quercetum roboris fagetosum* Rauš 1971)

Research so far: Numerous scientists have studied the occurrence of beech in lowland regions ever since the last century. These include Šulek (1866), M. Anić (1942), Fukarek (1954, 1964), Petračić (1955), M. Anić (1966), Rauš (1969, 1975), and many others. Rauš (1971) described the forest of pedunculate oak and hornbeam with beech from a vegetational point as a subassociation with beech.

Distribution of the phytocoenosis: The forest of pedunculate oak and common hornbeam with beech grows in lowland regions of Croatia within a typical forest of pedunculate oak and common hornbeam. Rauš (1971) cites 22 localities in Croatia: three in Pokuplje, eleven in Posavina, six in Podravina, and two in Baranja. In Posavina, the most important areas are Žutica, Lipovljani and Spačva; in Podravina the most important area is Repeš; then the Česma basin, the Pokuplje forests and some regions in Baranja.

Site of the phytocoenosis: It develops exclusively on micro-elevations. The soil is drained but fresh, slightly acid to neutral, of a lowland pseudogley, therefore, similar to that of the association described above.

After examining the terrain, it can be stated that in the Management Unit "Žutica" the forest of pedunculate oak and common hornbeam with beech covers a very small area (slightly over 5 %). It grows on the highest micro-elevations and river terraces completely out of reach of floodwater, and at the highest altitudes in the unit. The majority of beeches are found in the region of Crna Humka (compartments 30, 31, 125, 116), then along the stream Draščina (compartments 104-47), in compartments 107, 112, 117, 118, 124, and in areas leading towards compartments 106-100 and 80-88. Fragments of the forest can also be found in various small areas. Such a sporadic arrangement of vegetation indicates that in the past the entire area was probably densely inhabited by beech, which has been slowly disappearing.

In general, beech occurs in stands either individually or in smaller groups. The trees are fairly thick, of good appearance, and high quality.

Floral composition and vegetational structure: The floral composition is shown in the synthetic Table 5, on the basis of 10 (no. 11-20) phytocoenological recordings from characteristic parts of the association. The recordings show a rich floral composition with 74 species in all, of which 48 participate at a rate of more than 20%. As seen from the Table, the forest of pedunculate oak and common hornbeam with beech (*Carpino betuli-Quercetum roboris fagetosum)* is distinguished by its characteristic floral composition. This forest is a very interesting object of research because its present floral composition and structure is a reflection of numerous secular climatic changes.

The tree layer, with very well developed main and subordinate storeys, covers 90 - 100 % of the area. Pedunculate oak (*Quercus robur*), common hornbeam (*Carpinus betulus*) and beech (*Fagus sylvatica*) are the most constant components. In the mixture with common hornbeam and beech, pedunculate oak grows as well as it does in the mixture with common hornbeam.

In a sociological sense, beech, which distinguishes this association from others in the studied area, is the most important species, followed by common hornbeam and pedunculate oak. In a diagnostic sense, beech and its companions also take up a primary position in the shrub and ground layer.

The shrub layer is not very well developed, and covers 1 - 15 % of the area, with the exception of Recording 10, where it covers 60 %. It is composed of common hornbeam (*Carpinus betulus*), cobnut (*Corylus avellana*), spindle tree (*Euonymus europaea*) and hawthorns (*Crataegus* sp.), as characteristic species of the alliance, order and class *Querco-Fagetea*, and butcher's broom (*Ruscus aculeatus*) and beech (*Fagus sylvatica*) as distinguishing species of the subassociation, together with a smaller number of some other species.

The ground vegetation layer covers 40 - 90 % of the area, with the exception of Recording 1, where it covers 20 %. Its composition is very different from that of a typical forest of pedunculate oak and common hornbeam. Rauš classified this association as a special subassociation on the basis of the following distinguishing species: *Mercurialis perennis, Dentaria bulbifera, Cardamine trifolia, Allium ursinum, Luzula pilosa, Maianthemum bifolium, Anemone hepatica, Ruscus aculeatus, Rubus hirtus, Staphylea pinnata, Crocus banaticus, Galanthus nivalis*, and others. Of these species, the following have been recorded: *Rubus hirtus, Fagus silvatica, Ruscus aculeatus, Luzula pilosa* and *Maianthemum bifolium. Crocus banaticus* and *Galanthus nivalis* are expected to be part of the layer in springtime.

Apart from the already mentioned distinguishing species in the subassociation, the ones most constantly present are also *Veronica montana, Carex brizoides* and *Rubus hirtus*, as well as *Stellaria holostea, Circaea lutetiana, Lamiastrum galeobdolon, Viola reichenbachiana, Galium odoratum, Polygonatum multiflorum, Ajuga reptans, Asarum europaeum*, and others as characteristic species of the alliance, order and class *Querco-Fagetea*.

Along with characteristic and distinguishing species of the class, order, alliance and association, this subassociation also has a large number of constant accompanying species, such as *Oxalis acetosella, Galeopsis tetrahit, Symphytum tuberosum*, and others.

When floral compositions in 10 recordings in the association's synthetic table were compared, it was not possible to establish any significant differences among them. The relatively rich floral compositions are dominated by elements of beech-oak forests (*Querco-Fagetea*). Recording 20 is the only exception, in that the shrub cover is larger and the ground vegetation cover smaller than in other recordings. This is attributed to a partial dieback of oak in this area in the past, which opened the stands and allowed the shrub layer to grow more lusciously as it received more light.

Stability of the phytocoenosis: In terms of forest dieback and stability, the condition in the association is satisfactory. It is thanks to its mixed character (oak, hornbeam, beech) that this association has an advantage over other, more uniform, associations.

By comparing this association's distribution in the old vegetation map (Medvedović 1975) and its present state in the new vegetation map, it can be concluded that the area under the association of pedunculate oak and common hornbeam with beech has expanded, which is certainly the result of natural succession. It can also be partly attributed to a more detailed differentiation of this association from a typical forest of pedunculate oak and common hornbeam.

The forest is regenerated naturally, and our task is to assist it in this direction.

Syndynamics of the phytocoenosis: By studying the climate in the Earth's past, as well as by analyzing pollen in the bogs on the edges of the Pannonian Plain and in central Hungarian mountains, R. Soo and his associates Zolyomi and Kintzler (1940) conclude that beech has been in the plains ever since the Sub-Boreal period (about 2,500 - 800 BC). This means that a mixed forest of pedunculate oak, common hornbeam and beech came into being during secular changes in the climate, and that it used to cover much larger areas in the Pannonian Plain.

Research into vegetational and syndynamic relationships in the forests of Spačva led Rauš (1975) to conclude that in lowland regions, beech has regenerated by self-fertilisation since the Sub-Boreal period. According to his findings, seeds in the past were gradually but constantly being brought into the area from nearby hills and mountains by streams, small rivers, animals, birds and people, which enabled the beech to regenerate continuously. The seeds coming from nearby hills and mountains and the seeds resulting from the fructification of beeches in the plain came into contact and mixed. Later, these two newly-formed populations (originating from the seeds of different provenance), cross-bred and created new, more resistant beech species capable of adapting to different site conditions. It is not surprising, therefore, that beech, being a species of wide ecological amplitude and plasticity, can even be found on the very edge of swamp regions, as is the case in "Žutica". Its hundreds of years of development have helped it to adapt to life con-

ditions in lowland regions. This does not solve all the problems connected with beech and the evolution of vegetation in general. Further systematic-morphological, genetic, biological, ecological and phytocoenological research on the beech and its sites in lowland regions should be conducted in order to arrive at acceptable answers.

Just like the one described earlier, this association has also been affected by biotic (particularly anthropogenic) influences, which have played a significant role in its formation and present appearance.

FOREST OF PEDUNCULATE OAK AND GREAT GREEN WEED
ŠUMA HRASTA LUŽNJAKA I VELIKE ŽUTILOVKE
(*Genisto elatae-Quercetum roboris* Ht. 1938)

Research so far: Different aspects of this association were studied and described by J. Kozarac (1886, 1888), Bech-Mannagetta (1901), I. Horvat (1938, 1949, 1974), Glavač (1960, 1969), Rauš (1968, 1970-1995), and others. It was I. Horvat who set up the foundations of a comprehensive study of pedunculate oak in Posavina (1938). The soundness of his hypotheses is daily confirmed by research in these forests. A big contribution to the study of pedunculate oak forests was made by Glavač, M. Anić, and above all by Rauš.

Distribution of the phytocoenosis: The forest of pedunculate oak and great green weed, the world-renowned "Slavonian forest", covers large areas of lowland terrains. It is found in the valleys of the rivers Sava and Drava and their tributaries. The most valuable forests lie in the basins of the Spačva and the Česma.

This is the best-represented association in the Management Unit "Žutica", covering 30 - 40 % of the area. The largest complexes of this association are found in forest regions of Šumarak, Gospođice, partly Ravneš and Žalkovo, and along the Crna Humka - Carev Bok area. It is not present in swampy areas inhabited by ashes and alders, on micro-elevations in the central part, and along river terraces.

Site of the phytocoenosis: It develops above willows, poplars, black alders and narrow-leaved ashes. The terrain where it appears is several metres above the normal water level. It inhabits sites of flooded micro-depressions from which water, whose depth is about 1 m, retreats during the growing season. The terrain is either periodically covered with floods of short duration, or is outside the scope of floods but is still abundantly fresh. The soil is mineral-swampy, more or less acid, and pseudogley.

Floral composition and vegetational structure: This is the most valuable and best known forest association in Croatia, because its appearance, composition and value are the result of a mixture of diverse drier and more humid vegetational elements. At the transition from a micro-elevation to a micro-depression, common hornbeam and the majority of mesophyllic species of the *Fagetalia* order disappear, and hygrophyllic species of the *Populetalia albae* order, which can tolerate floods and higher groundwater levels, appear.

Table 6. - *Tablica 6.*

Association:		*GENISTO ELATAE-QUERCETUM ROBORIS* Ht. 1938			
Subassociation:		*carpinetosum betuli* Glav. 1961	*caricetosum brizoides* Ht. 1938	*caricetosum remotae* Ht. 1938	
Number of recordings:		10	10	10	
Area:		Žutica			
Plot size (m^2):		400	400	400	
FLORAL COMPOSITION		Degree of participation			Biological form
Characteristic species of association and alliance (*Alno-Quercion*):					
Quercus robur L.	A	V	V	V	Ph
Alnus glutinosa (L.) Gartn.		IV	V	II	Ph
Fraxinus angustifolia Vahl.		III	II	I	Ph
Ulmus carpinifolia Gled.		.	I	.	Ph
Ulmus carpinifolia Gled.	B	III	IV	III	Ph
Viburnum opulus L.		I	II	I	Ph
Acer tataricum L.		I	I	I	Ph
Sambucus nigra L.		I	I	I	Ph
Alnus glutinosa (L.) Gartn.		.	IV	III	Ph
Genista tinctoria subs. *elata*		.	I	II	Ph
Quercus robur L.		.	I	.	Ph
Quercus robur L.	C	IV	II	III	Ph
Rumex sanquineus L.		IV	III	III	H
Cerastium silvaticum W.K.		III	II	III	Ch
Lycopus europaeus L.		III	IV	III	H
Nephrodium spinulosum Strempel.		II	II	I	H
Impatiens noli tangere L.		III	II	I	Th
Lysimachia nummularia L.		III	III	IV	H
Angelica silvestris L.		II	II	I	H
Cardamine dentaria L.		I	I	I	H
Solanum dulcamara L.		.	III	II	H
Valeriana dioica L.		.	I	I	H
Viburnum opulus L.		I	.	.	Ph
Fraxinus angustifolia Vahl		.	.	I	Ph
Ulmus carpinifolia Gled.		.	.	I	Ph
Acer tataricum L.		.	.	I	Ph
Characteristic species of order (*Populetalia*) and class (*Alno-Populetea*):					
Ulmus laevis Pall.	B	I	.	II	Ph
Rubus ceasius L.		I	.	.	H
Rubus ceasius L.	C	IV	IV	V	H
Glechoma hederacea L.		IV	IV	IV	H

Distinguishing species for individual subassociations:					
Carpinus betulus L.	A	V	II	.	Ph
Acer campestre L.	B	V	III	II	Ph
Crataegus monogyna Jacq.		IV	II	I	Ph
Euonymus europaea L.		III	I	I	Ph
Veronica montana L.	C	IV	II		Ch
Viola reichenbachiana Jor. ex Bor.		IV	I	I	H
Scrophularia nodosa L.		III	.	I	H
Anemone nemorosa L.		II	.		G
Asarum europaeum L.		II	.		H
Ajuga reptans L.		IV	I	I	H
Carex maxima		III	.	.	H
Geum urbanum L.		IV	I	I	H
Oxalis acetosella L.		IV	.	.	H
Frangula alnus Mill.	B	II	V	III	Ph
Carex brizoides L.	C	III	V	.	H
Deshampsia caespitosa (L.) Beaur.		II	V	II	H
Dryopteris filix mas (L.) Sch.		III	IV	I	Th
Fraxinus angustifolia Vahl.	B	I	II	IV	Ph
Carex remota L.	C	IV	II	V	H
Carex strigosa Huds.		II	.	III	H
Leucoium aestivum L.		I	.	III	G
Iris pseudacorus L.		II	III	V	G
Ranunculus repens L.		II	II	IV	H
Lysimachia vulgaris L.		.	III	IV	H
Symphytum officinale L.		.	I	III	H
Carex elata All.		.	.	II	H
Caltha palustris L.		.	.	II	H
Euphorbia palustris L.		.	.	IV	H
Characteristic species of order (*Fagetalia*) and class (*Querco-Fagetea*):					
Acer campestre L.	A	I	I	.	Ph
Crataegus oxyacantha L.	B	IV	III	III	Ph
Prunus spinosa L.		II	II	I	Ph
Pyrus pyraster (L.) Borkh.		II	II	I	Ph
Carpinus betulus L.		IV	III	.	Ph
Corylus avellana L.		II	I	.	Ph
Circaea lutetiana L.	C	V	IV	II	G
Urtica dioica L.		IV	IV	V	H
Aegopodium podagraria L.		II	I	I	H
Humulus lupulus L.		I	II	I	H
Lamiastrum galeobdolon (L.) Ehr. et Pol		II	I	.	Ch
Brachypodium silvaticum (Huds.) R.S.		II	II	.	H
Paris quadrifolia L.		II	I	.	G
Galium odoratum (L.) Scop.		I	I	.	G
Geranium robertianum L.		I	I	.	Th
Stellaria holostea L.		I	I	.	H

Acer campestre L.		I	.	I	Ph
Primula sp.		I	.	.	
Chrysosplenium alternifolium L.		I	.	.	H
Polygonatum multiflorum (L.) All.		I	.	.	G
Ranunculus ficaria L.		I	.	.	G
Vinca minor L.		I	.	.	Ch
Crataegus oxyacantha L.		I	.	.	Ph
Carpinus betulus L.		I	.	.	Ph
Ranunculus lanuginosus L.		I	.	.	H
Sanicula europaea L.		I	.	.	H
Carex silvatica Huds.		.	I	.	H
Arum maculatum L.		.	I	.	G
Other species of wet and flooded sites:					
Salix cinerea L.	B	.	I	I	Ph
Polygonum hydropiper L.	C	IV	IV	III	Th
Myosotis scorpioides L.		III	IV	III	H
Galium palustre L.		III	IV	V	H
Poa palustris L.		II	I	I	H
Peucedanum palustre (L.) Monch.		II	III	III	H
Juncus effusus L.		I	III	III	H
Senecio fluviatilis Wallr.		I	II	I	H
Festuca gigantea (L.) Vill.		I	I	I	H
Lytrum salicaria L.		I	III	II	H
Stachys palustris L.		.	II	III	H
Succisa pratensis Mch.		.	I	I	H
Carex elongata L.		.	II	III	H
Alisma plantago aquiatica L.		.	I	.	H
Frangula alnus Mill.		.	I	.	Ph
Carex riparia Curt.		.	.	I	H
Carex vulpina L.		.	.	I	H
Carex vesicaria L.		.	.	I	H
Roripa amphibia (L.) Bess.		.	.	I	
Mentha aquatica L.		.	.	I	H
Thalictrum sp.		.	.	I	
Stellaria aquiatica		.	.	I	H
Other plants:					
Populus euroamericana	A	I	.	.	Ph
Fraxinus americana		I	.	.	Ph
Rhamnus cathartica L.	B	III	I	III	Ph
Cornus sanquinea L.		.	I	I	Ph
Rosa canina L.		.	I	I	Ph
Fraxinus americana		I	.	.	Ph
Galeopsis tetrahit L.	C	IV	V	III	
Hedera helix L.		II	I	I	Ph
Athyrium filix femina (L.) Roth.		III	III	I	H

Prunella vulgaris L.	I	I	I	H
Pulmonaria officinalis L.	I	I	I	H
Aristolochia clematitis L.	.	I	I	H
Hypericum acutum L.	.	II	I	H
Lychnis flos cuculi L.	.	I	I	H
Bidens tripartitus L.	.	I	I	Th
Agrostis alba L.	.	I	I	H
Stellaria media (L.) Mill.	I	.	II	Ch
Galium aparine L.	II	I	.	H
Ballota nigra L.	I	I	.	
Eupatorium cannabinum L.	I	I	.	H
Moehringia trinervia (L.) Clairv.	I	.	.	
Symphytum tuberosum L.	I	.	.	G
Rhamnus cathartica L.	I	.	.	Ph
Veronica chamaedrys L.	I	.	.	H
Torilis anthriscus (L.) Gmel.	.	I	.	
Galium silvaticum L.	.	I	.	H
Amorpha fruticosa L.	.	.	I	Ph
Solidago sp.	.	.	I	H
Melandrium rubrum Garcke.	.	.	I	H
Tamus communis L.	.	.	I	G

Explantation of abbreviations:
A - Tree layer
B - Shrub layer
C - Ground vegetation layer

Biological range: The biological range of life forms was based on 30 phytocoenological recordings (Table 6). Its structure is as follows: phanorephytes (Ph) 33%, chamaeophytes (Ch) 4%, hemicryptophytes (H) 52%, geophytes (G) 7%, and therophytes (Th) 4%. It can be concluded from the above that it is a hemicrypto-phanerophytic (52 + 33 %) association, with a small participation of geophytes (7%).

Due to a large participation of hemicryptophytes, this association belongs to the Central European region and shows its resistence to winter colds. A considerable share of phanerophytes indicates very warm summers.

Structure of the phytocoenosis: As already said, the basic postulates on vegetational and syndynamic relationships in lowland forests were established by I. Horvat (1963). He wrote: "The Slavonian forest can be divided into three subassociations: *Genisto-Quercetum caricetosum brizoides* Horv., *Genisto-Quercetum caricetosum remotae* Horv., and *Genisto-Quercetum carpinetosum betuli* Glav. The first association contains some acidophyllic species, and is therefore rich in black alders. The Slavonian forest achieves its vegetational-sociological optimum in the second association, while the third one is terminal, that is, a transition towards the

Fagetalia order, which develops as soon as the levels of groundwater or floodwater drop."

M. Anić (1959) and Rauš (1969, 1975) exclude the subassociation *Genisto elatae-Quercetum roboris carpinetosum betuli* from the *Populetalia albae* order, raise it to the rank of an association, divide it into subassociations and place it into the *Fagetalia* order. However, this author has established the subassociation *carpinetum betuli* in the sense in which Glavač described it (1961).

In the current research in the studied area, the following three subassociations were found:

Genisto elatae-Quercetum roboris caricetosum brizoides Ht. 1938
Genisto elatae-Quercetum roboris caricetosum remotae Ht. 1938
Genisto elatae-Quercetum roboris caricetosum betuli Glav. 1961

The fourth subassociation, *Genisto elatae-Quercetum roboris aceretosum tatarici* Rauš 1971 (Forest of pedunculate oak and great green weed with arrow wood), is very interesting and important. However, it is connected to eastern Slavonia and Baranja, and is not the subject of this research.

Syndynamics of the phytocoenosis: The forest of pedunculate oak and great green weed is one step below the forest of pedunculate oak and common hornbeam in the vegetation chain. With a gradual decrease in humidity, this association naturally passes into the latter terminal association. In addition, in the vegetation chain, this association is above the forest of narrow-leaved ash and black alder, which inhabit lower, more humid terrains in which pedunculate oak cannot survive.

Stability of the phytocoenosis: The research carried out in the regions afflicted by large-scale dieback of lowland forests (Kalje, Turopoljski Lug, Pokuplje basin), the data on forest dieback in the Management Unit "Žutica", and the existing condition in the field show that it is precisely this association that has undergone, and is still undergoing, the biggest changes in lowland forest habitats and the most serious dieback of pedunculate oak. Therefore, this association is unfortunately the best indicator of how endangered the forest "Žutica" is. It is in this forest that the worst defoliation, the strongest fungi attacks, and the largest pedunculate oak dieback have been recorded. In the last few decades, anthropogenic activities causing a drop in groundwater levels and an increase in floods have had the most serious impact on the pedunculate oak, which has dramatically changed the typical appearance of this association.

Forest-economic importance: The Management Unit "Žutica", and the whole of Posavina, offer very favourable natural conditions for the growth of these forests. Only man and his harmful actions can cause problems.

As mentioned earlier, the Zagreb School of Forestry stresses the importance of natural regeneration for all forests, and particularly for the forest of pedunculate oak. Natural regeneration is done with the shelterwood method over a rotation period of at least 140 years. Natural regeneration and proper tending activities have resulted in the world-renowned quality of Slavonian oak, relative stability, biologi-

cal diversity and a preserved genofund. Therefore, everything that relates to a forest of pedunculate oak and common hornbeam also relates to this forest, with some added features. According to Dekanić (1961), shelterwood fellings in pedunculate oak stands growing in micro-depressions (pedunculate oak and great green weed) should favour the regeneration of pedunculate oak, as it is the weakest species in a silvicultural sense. Shelterwood fellings should be carried out in two cuts: a seeding cut and a final one.

Silvicultural and other forest operations should take into account the changes and dieback occurring in the site and the association. Forest experts should adapt their activities to the existing state and deal with each problem in a multidisciplinary manner. This point will be dealt with in more detail in the chapter Discussion.

Forest of pedunculate oak and great green weed with common hornbeam
Šuma hrasta lužnjaka i velike žutilovke s običnim grabom
(Genisto elatae-Quercetum roboris carpinetosum betuli /Ht. 1938/ Glav. 1961)

Research so far: The most comprehensive research into this subassociation was carried out by V. Glavač (1961). Following the work by J. Kozarac, I. Horvat and other authors, Glavač concluded that forests of pedunculate oak and common hornbeam differ in an ecological, floral, and forest-economic sense, despite their uniform appearance and structure. For this reason, they are divided into two phytocoenoses. One of these phytocoenoses, occurring on elevated and unflooded positions (micro-elevations), was described by Horvat (1938) under the name *Querceto-Carpinetum croaticum* subas. *ruscetosum acuti*. The other, growing in more humid positions, was described for the first time by Glavač (1961) under the name *Querceto-Genistetum elatae* subas. *carpinetosum betuli*, or "humid type of pedunculate oak and common hornbeam forest". Today, the first phytocoenosis represents the forest of pedunculate oak and common hornbeam (*Carpino betuli-Quercetum roboris* Anić 1959), while the second, due to its floral composition and specific developmental conditions, represents the driest variant of the subassociation of pedunculate oak and great green weed *(Genisto elatae-Quercetum roboris carpinetosum betuli* Glav. 1961). In the course of this research, the specific features of the subassociation mentioned by Glavač were also noticed, as well as the specific site conditions, which are reflected in the floral composition. These forest sites can be called "humid micro-elevations".

Distribution of the phytocoenosis: According to Glavač, this phytocoenosis is distributed over large areas in lowland Posavina and Podravina. It sometimes covers large areas in continuous, unbroken units, and sometimes occurs sporadically between dry, non-flooded micro-elevations and swampy, flood-affected areas.

Site of the phytocoenosis: Forests of pedunculate oak and great green weed with hornbeam grow both within and outside flood zones. Those within the flood zone relate to drained areas, which are flooded for short periods. The latter invol-

ve much larger areas over flat or slightly raised humid micro-elevations, the so-called humid micro-elevations.

The soils are wet variants of pseudogley in transition towards mineral-swampy soils. In terms of texture, they are clays and loams. The soil permeability is mostly poor. The surface horizons are usually acid, and the supply of nutrients is satisfactory.

This subasscociation, which grows in a mosaic-like pattern over only about 5% of the area in "Žutica", is provided with all the necessary and specific life conditions by the above factors.

Floral composition and vegetational structure: 10 phytocoenological recordings in Table 7 show a very rich and diverse floral composition. I have registered 90 species in all, of which 54 participate at a rate of over 20% in the subassociation.

Its floral composition distinguishes this association from both forests of pedunculate oak and common hornbeam and typical forests of pedunculate oak and great green weed. The tree layer of the former is made up almost exclusively of pedunculate oaks and common hornbeams without any narrow-leaved ashes and black alders, while that of the latter consists almost exclusively of pedunculate oaks, a small percentage of narrow-leaved ashes and black alders, and very few hornbeams. On the other hand, the association in question is characterized by the dominance of pedunculate oaks and hornbeams, and a considerable presence of narrow-leaved ashes, lowland elms, spreading elms and black alders. There are also maples, wild pears and other species. The vitality of trees in the upper storey is very high, but that of hornbeams is low due to excessive humidity. Although the number of hornbeams is high, they lack the dimensions, competitiveness, vitality and generative capability that they have on typical micro-elevations. Their roots are shallow, and the root collars have distinctive root branches above the ground, which is linked to site conditions.

Although the tree layer is sometimes dominated by narrow-leaved ash, on the whole the stand displays its mixed character. The tree cover differs from recording to recording, and ranges between 50 - 90%.

The shrub layer coverage ranges from very low 1% to very high 80%, and points to certain influences on the association which should be studied and described in more detail. It is important to point out that, according to Glavač's description of the association, the shrub layer covers 1 - 3% of the area. A somewhat higher participation of lowland elm (*Ulmus carpinifolia*) and dogwood (*Frangula alnus*) is characteristic of the association and alliance *Alno-Quercion* and the order *Populetalia.* However, the participation of distinguishing species and those of the *Fagetalia* order and *Querco-Fagetea* class is much higher. These include maple (*Acer campestre*), common hornbeam (*Carpinus betulus*), hawthorns (*Crataegus monogyna* and *C. oxyacantha*) and hazel (*Corylus avellana*). The best represented accompanying species is buckthorn (*Rhamnus cathartica).*

The layer of ground vegetation is made up of numerous different species. The average cover is 50 - 100%. Hygrophytes and mesophytes inhabit very small areas

in a mosaic-like pattern. *Carex brizoides* and *Carex remota* alternately dominate the layer.

Table 7 shows that this forest type consists of three sociologically and ecologically different groups. The first includes a total of 24 characteristic species of the association of the pedunculate oak floodplain forest (*Genisto elatae-Quercetum roboris*), the alliance of the alder and pedunculate oak forest (*Alno-Quercion roboris* Horv.). and the order of *Populetalia* Br.-Bl. The most numerous are: *Quercus robur, Alnus glutinosa, Fraxinus angustifolia, Ulmus carpinifolia, Carex remota, Glechoma hederacea, Rumex sanquineus, Rubus caesius, Cerastium silvaticum, Lysimachia nummularia, Carex brizoides,* etc. As Glavač claimed that these species had very important phytocoenological significance, he added this forest type to the floodplain forest of pedunculate oak.

The second group consists of distinguishing species of the subassociation and species of the *Querco-Fagetea class.* These species outnumber those of the *Populetalia* order (15 in all). However, the frequency and cover of individual species is much lower. The importance of the group does not lie in the sociological importance of its individual members, but in its characteristic composition. The most important phytocoenological characteristic of the studied type is the relatively high number of types of vegetation. The species that differentiate this subassociation from other subassociations of floodplain forests of pedunculate oak are: *Carpinus betulus, Acer campestre, Euonymus europaea, Veronica montana, Viola reichenbachiana, Scrophularia nodosa, Ajuga reptans, Carex maxima, Polygonatum multiflorum, Lamiastrum galeobdolon, Anemone nemorosa,* and others.

The third group consists of accompanying species, which are mostly found in humid and swampy meadows and forests. These species are: *Polygonum hydropiper, Myosotis scorpioides, Galium palustre, Iris pseudacorus, Ranunculus repens,* and others. The ecological importance of this group testifies to its affiliation to the floodplain forest of pedunculate oak.

As the floral composition is very diverse, each recording should be described in more detail. Recording no. 1 is characterised in the following way: hornbeam is distributed over the whole compartment, and pedunculate oak has declined and has been replaced by Euro-American poplar and American ash. Now poplar is dying, while American ash is almost completely desiccated, which has allowed shrubs to cover large areas. Recording no. 2 shows a similar situation: the EA poplar was introduced in 1968 after the pedunculate oak dieback. Currently, narrow-leaved ash and black alder are penetrating the area. The well-developed shrub layer is dominated by dogwood and spreading elm. The situations in recordings 3, 4, and 5 also show the effects of pedunculate oak dieback, which has degraded typical micro-elevation sites. Currently, the species on micro-elevations are complemented with black alders (recordings no. 3 and 4), and narrow-leaved ashes (recording 5), and a large number of species favouring more humid sites (*Carex brizoides, Carex remota, Glechoma hederacea, Lysimachia nummularia, Polygonum hydropiper, Rumex sanguineus*). Species such as *Deshampsia caespitosa, Rubus cae-*

sius and *Juncus effusus* show a certain degree of site degradation. On the other hand, Recording 6 shows the situation along the river Česma, where the terrain has been gradually elevated by river depositions. Former forests of narrow-leaved ash have been replaced by forests of pedunculate oak and common hornbeam growing at the highest points immediately along the river. The recording shows the forest of pedunculate oak and great green weed with common hornbeam on a slightly lower terrain. Previous research and recordings 7 and 8 show that the site is in progression with a tendency towards a drier site. Recording 7 shows a transition from the subassociation *caricetosum* brizoides to that of *carpinetosum betuli*, while Recording 8 shows a progression from *caricetosum remotae* to *carpinetosum betuli*. In Recording 7 there is still a considerable participation of species of more humid sites, while a characteristic of Recording 8 is well-sized ashes but no ash seedlings or saplings, and good-quality hornbeams and oaks. Mesophyllic and hygrophyllic elements are approximately equal in number. Recording 10 is characterised by a very large cover of quaking sedge (*Carex brizoides)*, which makes it difficult to determine whether this recording belongs to the subassociation with quaking sedge or to that with common hornbeam. This is a general problem with a whole series of similar associations in the studied area. In this case, a large participation of mesophyllic elements from the class *Querco-Fagetea (Corylus avellana, Veronica montana, Galeobdolon luteum, Asarum europaeum, Brachypodium silvaticum, Scrophularia nodosa, Aegopodium podagraria)* indicates a humid micro-elevation.

Syndynamics of the phytocoenosis: As humidity decreases, this subassociation continues the hygrophytic subassociations of the floodplain forests of pedunculate oak (*Genisto elatae-Quercetum roboris caricetosum remotae* and *caricetosum brizoides*). By comparing the map of forest communities in "Žutica" (Medvedović 1975), in which this association was not singled out, and the research of this author from 1997, it can be concluded that the site and vegetation progression from the subassociation *caricetosum brizoides* to that of *carpinetosum betuli* has taken place in compartments 118a and 162c, and from *caricetosum remotae* into *carpinetosum betuli* in compartments 63a, 65a, 154a and 155b. Therefore, this is the driest subassociation of the forest of pedunculate oak and great green weed. As humidity continues to decrease, it is transformed into a dry type of pedunculate oak and common hornbeam forest (*Carpino betuli-Quercetum roboris*), which is characterized by a complete absence of species in the *Querco-Fagetea* class. However, regression processes resulting from plant dieback and terrain waterlogging are also taking place here, so that a typical micro-elevation is being transformed into a humid one (compartments 107a, 113b, 119b, 126d, 129a, etc.). This confirms the observations made on the condition in the recordings described above.

In nature there are no sharp boundaries between these types, so it is sometimes difficult to decide to what association a certain subassociation belongs.

This, and the state shown in the recordings, point to the conclusion that the subassociation in the area of "Žutica" is not of a stable character, but is the result of dieback and consequent changes in the site rather than of natural succession.

Table 7. - *Tablica 7.*

Association:		*GENISTO ELATAE-QUERCETUM ROBORIS* Ht. 1938										
Subassociation:		*carpinetosum betuli* Glav. 1961										D
Number of recording:		1	2	3	4	5	6	7	8	9	10	e
Area:		Žutica										g
Department, compartment:		90b	34b	155b	119b	146a	196b	161c	62a	166b	78a	r
Plot size (m^2):		400	400	400	400	400	400	400	400	400	400	e
Date:		3.6.97.	2.7.97.	24.6.97.	27.6.97.	24.6.97.	6.6.97.	19.6.97.	4.9.97.	19.6.97.	24.9.97.	e
Cover (%):												
Tree layer		70	80	50	90	50	90	90	90	90	70	o
Shrub layer		70	80	5	1	40	50	5	20	50	30	f
Ground vegetation layer		90	90	90	100	100	60	90	50	50	100	
FLORAL COMPOSITON												p a r t.
Characteristic species of association and alliance (*Alno-Quercion*):												
Quercus robur L.	A	3	3	1	4	3	4	3	4	4	4	V
Alnus glutinosa (L.) Gartn.		1	1	2	1	.	.	2	.	1	2	III
Fraxinus angustifolia Vahl		2	1	.	.	2	1	.	3	1	.	III
Ulmus carpinifolia Gled.	B	+	.	.	.	+	+	.	+	1	.	III
Viburnum opulus L.		.	+	.	.	.	+	.	.	.	.	I
Fraxinus angustifolia Vahl		.	.	.	.	.	.	.	.	3	+	I
Acer tataricum L.		.	.	+	.	.	.	+	.	.	.	I
Sambucus nigra L.		.	.	.	.	.	.	+	.	.	.	I
Quercus robur L.	C	+	.	.	1	+	+	1	+	2	+	IV
Carex remota L.		+	.	.	4	3	+	2	1	3	.	IV
Rumex sanquineus L.		+	+	+	+	1	+	.	.	1	.	IV
Carex brizoides L.		2	3	4	1	.	.	4	.	.	4	III
Impatiens noli tangere L.		+	.	.	3	1	2	3	.	.	.	III
Cerastium silvaticum W.K.		.	.	.	+	+	+	.	+	1	.	III
Lysimachia nummularia L.		.	.	+	1	2	.	2	+	1	.	III
Lycopus europaeus L.		+	+	+	1	+	.	.	.	.	.	III

Nephrodium spinulosum Strempel.		+	.	+	.	+	.	+	.	.	.	II
Carex strigosa Huds.		.	.	.	+	.	.	1	+	2	.	II
Angelica silvestris L.		.	.	+	.	+	.	.	.	.	1	II
Cardamine dentaria L.		+	.	.	.	.	+	.	.	.	.	I
Viburnum opulus L.		.	.	.	.	.	.	+	.	+	.	I
Leucoium aestivum L.		.	.	.	.	.	.	.	.	+	.	I
Characteristic species of order (*Populetalia*) and class (*Alno-Populetea*):												
Frangula alnus Mill.	B	.	3	1	.	1	.	+	.	.	.	II
Ulmus laevis Pall.		.	2	.	.	.	.	.	.	.	.	I
Rubus ceasius L.		.	.	.	.	.	+	.	.	.	.	I
Rubus ceasius L.	C	+	+	2	+	+	.	2	1	.	3	IV
Glechoma hederacea L.		1	.	3	1	2	+	3	+	3	.	IV
Distinguishing species and class species (*Querco-Fagetea*):												
Carpinus betulus L.	A	1	2	3	3	2	2	2	2	3	1	V
Acer campestre L.		1	.	.	.	.	+	.	.	.	.	I
Acer campestre L.	B	+	+	+	+	+	1	+	1	+	1	V
Carpinus betulus L.		1	.	+	+	2	+	1	1	2	.	IV
Crataegus monogyna Jacq.		+	+	+	.	1	+	+	1	.	.	IV
Crataegus oxyacantha L.		+	+	+	+	+	+	.	.	+	.	IV
Euonymus europaea L.		.	+	.	.	+	+	.	+	.	+	III
Corylus avellana L.		4	.	.	.	.	.	.	1	.	3	II
Prunus spinosa L.		+	1	.	.	+	.	.	.	.	.	II
Pyrus pyraster (L.) Borkh.		.	1	.	+	.	.	.	.	+	.	II
Circaea lutetiana L.	C	+	1	1	+	+	+	2	1	1	+	V
Veronica montana L.		+	.	.	1	+	1	.	1	+	2	IV
Viola reichenbachiana Jor. ex Boreu.		+	.	+	1	+	+	.	1	+	.	IV
Ajuga reptans L.		1	+	1	2	+	+	1	.	1	.	IV
Urtica dioica L.		.	3	+	.	+	+	.	3	+	1	IV
Scrophularia nodosa L.		+	.	+	+	+	.	.	+	.	+	III
Dryopteris filix mas (L.) Sch.		+	+	1	.	.	.	+	.	1	.	III
Carex maxima		+	4	.	.	+	+	.	.	1	.	III

Lamiastrum galeobdolon (L.) Ehr. et Pol.	3	+	.	.	.	+	.	.	.	3	II
Brachypodium silvaticum (Huds.) R.S.	+	.	.	.	.	.	.	.	1	2	II
Anemone nemorosa L.	+	+	.	.	.	1	.	.	.	.	II
Asarum europaeum L.	1	2	.	.	.	.	.	.	.	1	II
Paris quadrifolia L.	+	+	.	.	.	.	.	+	.	.	II
Aegopodium podagraria L.	.	.	+	.	.	.	.	3	.	1	II
Galium odoratum L.	1	.	.	1	.	.	.	.	.	.	I
Primula sp.	.	.	.	.	.	+	.	1	.	.	I
Acer campestre L.	.	.	.	.	.	.	+	.	+	.	I
Stellaria holostea L.	1	.	.	.	.	.	.	.	.	1	I
Sanicula europaea L.	.	.	.	.	+	.	.	.	.	.	I
Chrysosplenium alternifolium L.	+	.	.	.	.	.	.	.	.	.	I
Polygonatum multiflorum (L.) All.	+	.	.	.	.	.	.	.	.	.	I
Ranunculus ficaria L.	+	.	.	.	.	.	.	.	.	.	I
Vinca minor L.	.	.	.	.	.	+	.	.	.	.	I
Crataegus oxyacantha L.	.	.	.	.	.	.	.	.	+	.	I
Humulus lupulus L.	.	.	+	.	.	.	.	.	.	.	I
Geranium robertianum L.	.	2	.	.	.	.	.	.	.	.	I
Carpinus betulus L.	.	.	.	1	.	.	.	.	.	.	I
Ranunculus lanuginosus L.	.	+	.	.	.	.	.	.	.	.	I
Species of wet and flooded sites:											
Polygonum hydropiper L. C	.	.	2	+	2	.	1	+	+	+	IV
Myosotis scorpioides L.	.	+	+	1	+	.	+	.	1	.	III
Galium palustre L.	.	1	+	+	+	.	1	.	.	.	III
Iris pseudacorus L.	+	+	.	.	+	.	.	.	+	+	II
Ranunculus repens L.	+	.	+	.	+	.	.	+	.	.	II
Deshampsia caespitosa (L.) Beaur.	+	.	2	.	3	.	.	.	.	.	II
Poa palustris L.	.	.	+	.	+	.	1	.	.	.	II
Peucedanum palustre (L.) Monch.	.	+	.	+	+	.	.	.	.	.	II
Lytrum salicaria L.	.	.	+	.	+	.	.	.	.	.	I
Juncus effusus L.	.	.	+	.	1	.	.	.	.	.	I
Senecio fluviatilis Wallr.	.	+	+	.	.	.	.	.	.	.	I

Festuca gigantea (L.) Vill.		+	.	.	.	.	.	.	.	.	.	I
Other species:												
Populus euroamericana	A	1	.	.	.	.	.	.	.	.	.	I
Fraxinus americana		+	.	.	.	.	.	.	.	.	.	I
Rhamnus cathartica L.	B	.	1	.	.	+	2	.	1	+	.	III
Fraxinus americana		+	.	.	.	.	.	.	.	.	.	I
Galeopsis tetrahit L.	C	+	+	1	+	+	+	.	+	1	.	IV
Oxalis acetosella L.		+	+	1	2	+	.	3	.	.	1	IV
Athyrium filix femina (L.) Roth.		+	+	.	.	.	+	1	.	.	+	III
Galium aparine L.		2	.	.	.	.	1	.	.	.	+	II
Hedera helix L.		.	.	.	.	.	+	.	1	.	+	II
Moehringia trinervia (L.) Clairv.		.	.	+	.	.	+	.	.	.	.	I
Symphytum tuberosum L.		1	.	.	.	.	.	.	.	.	.	I
Prunella vulgaris L.		.	.	.	.	.	+	.	.	.	.	I
Rhamnus cathartica L.		.	.	.	.	.	.	.	.	+	.	I
Ballota nigra L.		.	.	1	.	.	.	.	.	.	.	I
Veronica chamaedrys L.		.	.	+	.	.	.	.	.	.	.	I
Stellaria media (L.) Mill.		.	.	.	+	.	.	.	.	.	.	I
Pulmonaria officinalis L.		.	1	.	.	.	.	.	.	.	.	I
Eupatorium cannnabinum L.		.	+	.	.	.	.	.	.	.	.	I

Exenplation of abbreviations:
A - Tree layer
B - Shrub layer
C - Ground vegetation layer

+, 1, 2, 3, 4, 5 - Combined assessment of abundance and cover (Braun-Blanquet 1964)

Stability of the phytocoenosis: Vukelić and Rauš (1993) wrote about the association of pedunculate oak and great green weed with common hornbeam in Turopoljski Lug: "In points in which the subassociation borders with other die-back-affected associations, individual trees and even small groups of trees growing on the borderline, are not spared. They are also declining." According to the current observations in the Management Unit of "Žutica", the association is fairly loose and dynamic, despite its mixed composition, which is the result of constant changes in site conditions.

Forest of pedunculate oak and great green weed with quaking sedge
Šuma hrasta lužnjaka i velike žutilovke s drhtavim šašem
(*Genisto elatae-Quercetum roboris caricetosum brizoides* Ht. 1938)

Research so far: The subassociation, first described by I. Horvat in 1938, was found in the area of Draganički and Šašinovečki Lug. Various other localities of these forests were studied by a number of other researchers.

Distribution of the phytocoenosis: The subassociation is distributed in western regions of the Croatian lowlands (the Pokuplje basin, Česma, Žutica, Lipovljani, and others). Research into the lowland forests of Croatia, especially by Rauš, showed that, going eastwards, this subassociation gradually recedes and completely disappears before Slavonski Brod.

Site of the phytocoenosis: This subassociation occurs in a slightly higher region of micro-elevations and on a transition towards the forest of pedunculate oak and hornbeam. Groundwater levels are lower here, and flooding with surface water, if it takes place, is shorter than in the subassociation with remote sedge (caricetosum remotae). The soils are slightly more acid pseudogleys and mineral-swampy compact clays and loams.

In the area under study, the subassociation occurs most frequently along micro-elevations in the central part, and covers about 10% of the total area of the Management Unit.

Floral composition and vegetational structure: Phytocoenological features of the subassociation Genisto elatae-Quercetum roboris caricetosum brizoides are shown in 10 of the most characteristic recordings in Table 8. A total of 88 species are mentioned, of which 50 participate at a rate of over 20 % in the area.

The tree layer, with a 60 - 90% coverage, is dominated by pedunculate oak with additions of black alder, narrow-leaved ash, and lowland elm, which are characteristic species of the *Alno-Quercion* association and alliance, and common hornbeam and wild pear as the species of the *Fagetalia* order and *Querco-Fagetea* class. The percentage of black alder in the composition is particularly large in coupes and young stands.

The shrub layer is rich in species and covers a large range: from 5% to 60%. It is composed mainly of *Alnus glutinosa*, *Ulmus carpinifolia*, *Fraxinus angustifolia*, *Genista tinctoria* ssp. *elata* and *Viburnum opulus* as characteristic species of the

Alno-Quercion association and alliance, *Frangula alnus* as a characteristic species of the *Populetalia* order and *Alno-Populetalia* class, and *Crataegus oxyacantha* and *Crataegus monogyna*, *Acer campestre*, *Carpinus betulus* and *Prunus spinosa* as characteristic species of the *Fagetalia* order and *Querco-Fagetea* class.

The ground vegetation covers 80 - 100% of the area, except in Recording 6, where it covers 50%. It is especially luscious in the spring and early summer, when the forest is abundantly humid. The humidity factor is reflected in the whole constitution of the association. The ground layer is dominated by *Carex brizoides*, *Deschampsia caespitosa* and *Dryopteris filix* mas as distinguishing species of the subassociation, and *Lycopus europaeus*, *Solanum dulcamara*, *Rumex sanquineus*, *Lysimachia nummularia* and *Nephrodium spinulosum* as characteristic species of the association and alliance *Alno-Quercion*. Of characteristic species belonging to the order *Populetalia* and the class *Alno-Populetalia*, especially prominent are *Rubus caesius* and *Glechoma hederacea*, of those characterising the *Fagetalia* order and *Querco-Fagetea* class there are *Circaea lutetiana* and *Urtica dioica*, while the accompanying species are *Myosotis scorpioides*, *Galium palustre*, *Geleopsis tetrahit*, *Polygonatum hydropiper*, *Juncus effusus*, *Iris pseudacorus*, *Lysimachia vulgaris* and *Peucedanum palustre*.

A significant presence of acidophyllic elements (*Carex brizoides*, *Deschampsia caespitosa*, *Polytrichum attenuatum* in the moss layer and others) indicates that the subassociation grows on somewhat more acid soils, because these elements do not occur in other typical subassociations of the Slavonian forest. In some places, quaking sedge covers up to 100% of the area, which is a typical feature of this subassociation.

As the recordings show a large variety of plant species, a detailed analysis has been made of each. The recordings, particularly Recording 9, show typical features of this association. In all recordings, except in No. 10, there is a significantly larger participation of black alder and doogwood, as well as of species favouring fresher sites. This is particularly true of Recording 4, which shows the following species: *Lycopus europaeus*, *Polygonum palustre*, *Ranunculus repens*, *Juncus effusus*, *Lysimachia nummularia*, *Peucedanum palustre*, *Myosotis scorpioides*, *Carex remota*, *Poa palustris*, and *Lytrum salicaria*. This is a transition between the subassociation in question and the subassociation with remote sedge (*caricetosum remotae*). On the other hand, the already mentioned Recording 10 is a slightly drier variant, and represents a transition towards the subassociation with common hornbeam (carpinetosum betuli), which is evident by a large quantity of narrow-leaved ashes, common hornbeams and hazels in the tree and shrub layers, and hygrophyllic and mesophyllic elements in the ground vegetation.

It is important to note that these recordings show not only a typical subassociation of *caricetosum brizoides*, but also a non-typical one in a number of compartments, as well as transitions between these two associations. This is largely due to changes in the site and the dieback of pedunculate oak. These compartments and changes will be described in the sub-chapter Stability of the phytocoenosis.

Table 8. - *Tablica 8.*

Association:		*GENISTO ELATAE-QUERCETUM ROBORIS* Ht. 1938										Degree of partic.
Subassociation:		*caricetosum brizoides* Ht. 1938										
Number of recording:		1	2	3	4	5	6	7	8	9	10	
Area:		Žutica										
Department, compartment:		144a	127a	161d	168a	145a	125e	32a	44a	115a	41d	
Plot size (m^2):		400	400	400	400	400	400	400	400	400	400	
Date:		3.6.97.	3.6.97.	19.6.97.	19.6.97.	24.6.97.	26.6.97.	2.7.97.	26.8.97.	27.8.97	11.9.97	
Cover (%):												
Tree layer		70	80	70	80	60	80	60	70	70	90	
Shrub layer		30	30	40	20	5	60	40	50	10	60	
Ground vegetation layer		100	100	100	100	100	50	100	80	100	95	
FLORAL COMPOSITON												
Characteristic species of the association and alliance (*Alno-Quercion*):												
Quercus robur L.	A	3	4	4	4	4	4	4	4	4	4	V
Alnus glutinosa (L.) Gartn.		2	3	+	3	2	2	.	+	1	+	V
Fraxinus angustifolia Vahl		.	.	+	+	.	+	.	.	.	2	II
Ulmus carpinifolia Gled.		+	.	.	.	.	.	.	.	.	1	I
Alnus glutinosa (L.) Gartn.	B	+	1	1	2	.	2	2	2	.	.	IV
Ulmus carpinifolia Gled.		+	.	1	+	.	+	1	+	.	1	IV
Fraxinus angustifolia Vahl.		.	.	+	.	.	+	.	1	.	+	II
Viburnum opulus L.		.	.	.	.	.	+	+	.	.	+	II
Genista tinctoria ssp. *elata* Wend.		.	.	.	.	.	.	+	+	.	.	I
Sambucus nigra L.		.	.	+	.	.	.	.	.	.	.	I
Quercus robur L.		.	.	.	.	.	.	.	+	.	.	I
Acer tataricum L.		.	.	.	.	+	.	.	.	.	.	I
Lycopus europaeus L.	C	.	+	.	2	1	2	+	2	.	+	IV
Solanum dulcamara L.		.	+	+	.	.	2	.	+	+	.	III
Rumex sanquineus L.		.	.	+	+	+	.	+	+	+	.	III
Lysimachia nummularia L.		.	+	.	2	+	.	.	.	1	2	III

Nephrodium spinulosum Strempel.		1	1	.	.	1	.	.	.	+	.	II
Impatiens noli tangere L.		.	2	2	1	2	.	.	.	.	.	II
Quercus robur L.		.	+	.	.	.	.	.	3	.	+	II
Carex remota L.		.	.	.	2	.	.	.	+	.	1	II
Angelica silvestris L.		.	.	.	2	.	.	1	.	.	+	II
Cerastium silvaticum W.K.		.	.	.	.	+	.	+	+	.	.	II
Valeriana dioica L.		.	.	.	.	.	.	.	2	1	.	I
Cardamine dentaria L.		.	.	.	.	.	+	.	.	.	.	I
Characteristic species of the order and class (*Alno-Populetea*):												
Rubus caesius L.	C	3	+	1	.	+	+	.	+	+	1	IV
Glechoma hederacea L.		.	+	+	.	3	.	1	2	1	3	IV
Frangula alnus Mill.		.	.	.	.	.	.	.	.	.	+	I
Distinguishing species of the subassociation:												
Frangula alnus Mill.	B	2	3	1	1	+	3	1	2	2	1	V
Carex brizoides L.	C	5	4	4	2	3	2	5	3	5	3	V
Deshampsia caespitosa (L.) Beaur.		1	1	.	4	3	+	3	4	3	1	V
Galeopsis tetrahit L.		2	1	1	1	2	.	2	+	1	1	V
Dryopteris filix mas (L.) Sch.		+	.	+	+	+	.	+	+	.	+	IV
Characteristic species of the order and class (*Querco-Fagtea*):												
Carpinus betulus L.	A	.	2	.	.	.	.	.	.	+	2	II
Acer campestre L.		.	.	.	.	.	.	.	.	.	+	I
Crataegus oxyacantha L.	B	+	.	+	.	.	1	+	.	+	.	III
Acer campestre L.		+	.	1	+	.	+	+	.	.	.	III
Carpinus betulus L.		+	+	.	.	.	.	+	+	.	+	III
Prunus spinosa L.		.	.	.	.	.	1	+	.	.	.	II
Crataegus monogyna Jacq.		.	.	.	.	.	1	+	.	.	+	II
Pyrus pyraster (L.) Borkh.		.	+	.	.	.	1	+	.	.	+	II
Euonymus europaea L.		+	.	.	.	.	.	.	.	.	+	I
Corylus avellana L.		2	.	.	.	.	.	.	.	.	3	I
Circaea lutetiana L.	C	1	+	.	.	1	.	2	1	1	+	IV

Urtica dioica L.	.	.	+	+	+	.	+	+	2	+	IV
Brachypodium silvaticum (Huds.) R.S.	.	.	.	.	.	.	+	+	+	+	II
Humulus lupulus L.	.	.	+	.	1	.	.	.	+	.	II
Veronica montana L.	+	.	.	.	.	.	+	.	.	+	II
Aegopodium podagraria L.	.	.	.	.	+	3	.	.	.	.	I
Ajuga reptans L.	.	+	.	.	.	.	.	.	.	1	I
Geranium robertianum L.	.	.	.	.	.	.	+	.	.	.	I
Viola reichenbachiana (L.) Jor. ex Boreu.	.	.	.	.	.	.	.	.	.	+	I
Carex silvatica Huds.	.	.	.	.	.	.	.	.	.	+	I
Galium odoratum (L.) Scop.	.	.	.	.	.	.	.	.	.	+	I
Lamiastrum galeobdolon (L.) Ehr. et Pol.	.	+	.	.	.	.	.	.	.	.	I
Arum maculatum L.	+	.	.	.	.	.	.	.	.	.	I
Paris quadrifolia L.	+	.	.	.	.	.	.	.	.	.	I
Stellaria holostea L.	.	.	.	.	.	.	.	.	+	.	I
Other species of wet and flooded sites:											
Salix cinerea L. B	.	.	.	.	.	.	+	.	.	.	I
Myosotis scorpioides L. C	.	+	+	2	1	+	+	1	+	.	IV
Galium palustre L.	.	+	+	1	+	2	+	.	.	+	IV
Polygonum hydropiper L.	.	.	2	3	2	.	+	+	1	1	IV
Juncus effusus L.	.	.	+	1	+	+	+	.	.	.	III
Iris pseudacorus L.	.	+	.	.	.	+	+	+	.	+	III
Lysimachia vulgaris L.	.	+	.	+	1	2	+	+	.	.	III
Peucedanum palustre (L.) Monch.	.	+	.	1	1	1	1	1	.	.	III
Lytrum salicaria L.	.	.	.	+	2	2	+	+	+	.	III
Senecio fluviatilis Wallr.	.	.	.	.	+	.	+	.	+	.	II
Stachys palustris L.	.	.	.	.	.	+	.	1	+	.	II
Carex elongata L.	.	2	+	.	.	3	.	.	.	.	II
Ranunculus repens L.	.	.	.	.	1	.	.	1	.	+	II
Poa palustris L.	.	.	.	+	.	.	.	.	+	.	I
Festuca gigantea (L.) Vill.	.	+	.	.	.	.	.	.	.	+	I
Alisma plantago aguiatica L.	.	.	.	.	+	.	.	.	.	+	I
Symphytum officinale L.	.	.	.	.	.	.	+	.	.	.	I

Succisa pratensis Mch.		.	.	1	.	.	.	.	.	.	.	I
Other species:												
Rhamnus cathartica L.	B	.	.	.	.	.	.	.	+	+	.	I
Cornus sanquinea L.		.	.	.	.	.	.	.	.	.	1	I
Rosa canina L.		.	+	.	.	.	.	.	.	.	.	I
Athyrium filix femina (L.) Roth.	C	+	.	1	.	.	.	+	+	1	1	III
Hypericum acutum L.		.	.	.	+	.	.	+	.	+	+	II
Eupatorium cannabinum L.		.	.	.	.	.	.	+	.	1	.	I
Lychnis flos cuculi L.		.	+	+	.	.	.	.	.	.	.	I
Geum urbanum L.		.	.	+	.	+	.	.	.	.	.	I
Bidens tripartitus L.		.	.	.	.	.	.	.	+	.	+	I
Prunella vulgaris L.		.	.	.	.	.	.	.	+	.	+	I
Senecio rivularis (W.K.) D.C.		.	.	.	.	.	.	+	.	.	.	I
Galium silvaticum L.		.	.	.	+	.	.	.	.	.	.	I
Ballota nigra L.		2	.	.	.	.	.	.	.	.	.	I
Pulmonaria officinalis L.		.	.	.	.	.	.	.	.	.	1	I
Galium aparine L.		.	.	.	.	.	.	.	.	.	+	I
Hedera helix L.		.	.	.	.	.	.	.	.	.	+	I
Agrostis alba L.		.	.	2	.	.	.	.	.	.	.	I
Aristolochia clematitis L.		.	.	.	.	.	.	.	.	.	+	I
Torilis anthriscus (L.) Gmel.		.	.	.	.	.	.	.	.	.	+	I

Explanation of abbreviations:
A -Tree layer, B - Shrub layer, C -Ground vegetation layer

+, 1, 2, 3, 4, 5 -Combined assessment of abundance and cover (Braun-Blanquet 1964)

Syndynamics of the phytocoenosis: The progression of site conditions has allowed the association to gradually pass into a slightly drier subassociation with common hornbeam, with some mesophyllic elements of forests of pedunculate oak and common hornbeam. The subassociation with remote sedge (*Genisto elatae-Quercetum roboris caricetosum remotae*) grows in more humid sites.

Stability of the phytocoenosis: By comparing the present arrangement of vegetation with that described by Medvedović (1975), it could be said that the subassociation is in regression in its larger part, which is the consequence of pedunculate oak dieback and waterlogging of the terrain. So, the forest of black alder has replaced the forest of pedunculate oak and great green weed with quaking sedge in departments and compartments 70c and d, 111d, 117b, 140b and 141b. Similarly, compartments 33b, 58b, e, and f are now covered with a forest of narrow-leaved ash, and compartments 130a and b, 134, 136e and d, 149, 150 and 168 with the subassociation with remote sedge.

In compartments 28a and b, 34b, 41b, 48a and c, 131a and c, 132 and 139, there are regression processes in favour of the subassociation with quaking sedge. This is the consequence of pedunculate oak dieback and terrain waterlogging, and the subsequent entrance of black alder and narrow-leaved ash into the site of pedunculate oak and common hornbeam.

Site progression has taken place in very small areas in compartments 118a and 162c, where *Genisto elatae-Quercetum roboris carpinetosum* betuli has replaced *Genisto elatae-Quercetum roboris caricetosum brizoides*, and in compartments 35b and 168, which are currently inhabited by *Carpino betuli-Quercetum roboris*.

A survey of all compartments shows that quaking sedge (*Carex brizoides*) is intensively invading hornbeam sites on micro-elevations, an indication that some sites are too humid for this species, and it is therefore moving to drier ones. Pedunculate oak dieback is noticeable, and the subassociation is in the regression stage. In some smaller areas, black alder and narrow-leaved ash have entered all stand layers.

Consequently, along with a large participation of plants of humid sites, there is a number of species such as *Frangula alnus*, *Salix cinerea*, *Juncus effusus*, *Peucedanum palustre*, *Cirsium palustre* and others, while mesophyllic elements are disappearing. They all show a tendency towards a wet and waterlogged biotop.

Good-quality hornbeam and a number of mesophyllic elements from the forest of pedunculate oak and common hornbeam occur in a small area.

Based on his research of forest vegetation in dieback-affected plots in "Žutica", the analyses of floral recordings in the period 1969 - 1973, and a comparison with a typical condition in Lipovljani, Rauš concluded that the forest of pedunculate oak and great green weed with quaking sedge was in a relatively stable condition, and did not show any disorders in its development and composition that might have been the consequence of low-intensity dieback of pedunculate oak. According to Rauš, the subassociation was then in a state of progression.

On the other hand, some other dieback-afflicted areas show a much more serious condition of this subassociation. On the basis of research done in Turopoljski Lug (1993), Vukelić and Rauš concluded that it was the most unstable association undergoing the biggest changes.

Forest of pedunculate oak and great green weed with remote sedge
Šuma hrasta lužnjaka i velike žutilovke s rastavljenim šašem
(*Genisto elatae-Quercetum roboris caricetosum remotae* Ht. 1938)

Research so far: Horvat (1938) was the first to describe the subassociation, while Rauš later dealt with its synecological-vegetational features in depth (1970, 1973, 1975, 1980).

Distribution of the phytocoenosis: The Slavonian forest, or the forest of pedunculate oak and great green weed with remote sedge, stretches in a mosaic-like pattern in the lowland part of Croatia along the principal rivers of Sava, Drava and their tributaries. It is distributed in Pokuplje along the river Odra, in Posavina and Podravina, and in Central Croatia.

The association is well represented in the studied area (about 25%), and the largest complexes are Šumarak, Gospođice, Ravneš, and areas stretching from compartments 52 to 75 in the northern part, and from 169 to 195 in the southern part.

Site of the phytocoenosis: It grows on mineral-swampy, moderately distinct soil, of slightly acid to practically neutral reaction.

The groundwater level remains rather high over the whole year (1 - 3 m). According to Dekanić (1959), the groundwater level in the spring and autumn is high and exceeds the soil surface. Water stagnates on the surface for a very long period (June, July), or until it evaporates, as the soil is not permeable. The water comes from precipitation, which remains on impermeable soils, and from river floods. The association is usually flooded once or twice a year.

The terrain altitude ranges from 95 to 97 m, which, together with the micro-relief, plays an important role in the growth of this asociation, since groundwater levels depend on these two factors.

Floral composition and vegetation structure: The floral composition of the association is shown in Table 9, on the basis of 10 phytocoenological recordings. A total of 89 species is shown, of which 41 participate in the association at a rate of over 20 %.

The tree layer, in which the pedunculate oak is the main tree species, covers 50 - 90% of the area. It occurs in all plots and regularly dominates the subassociation, while black alders and narrow-leaved ashes occur is smaller numbers. It should be stressed that these are characteristic species of the association and alliance *Alno-Quercion*. Compared to typically developed stands in Lipovljani, where the tree layer coverage is 80 - 90%, the stands in the Management Unit "Žutica" display some disorders.

The shrub layer covers 30 - 80% of the area and is not equally developed in all recordings. The predominant species is narrow-leaved ash, which indicates two things: a transition towards a wetter site, and a gradual invasion of narrow-leaved ash (*Fraxinus angustifolia*) and black alder (*Alnus glutinosa*) into such sites. Other species present in larger numbers are lowland elm (*Ulmus carpinifolia*) and spreading elm (*Ulmus laevis*), also characteristic of the association and alliance *Alno-Quercion*, and hawthorn (*Crataegus oxyacantha*) and maple (*Acer campestre*) as characteristic species of the order *Fagetalia* and class *Querco-Fagetea*. Buckthorn (*Rhamnus cathartica*) is the most important accompanying species.

There is also a large number of *Genista tinctoria* ssp.*elata*, a characteristic species of the association.

The ground layer, taking between 50 to 100% of the area, features the following most important characteristic species of the association and alliance *Alno-Quercion*: pedunculate oak (*Quercus robur*), remote sedge (*Carex remota*), moneywort (*Lysimachia nummularia*), summer snowflake (*Leucoium aestivum*), gypsywort (*Lycopus europaeus*), wood dock (*Rumex sanguineus*), *Carex elongata*, mouse-ear (*Cerastium silvaticum*) and *Carex strigosa*.

The most important distinguishing species of the subassociation are remote sedge (*Carex remota*), yellow flag (*Iris pseudacorus*), tufted sedge (*Carex elata*), marsh marigold (*Caltha palustris*), broad-leaved ragwort (*Senecio fluviatilis*), greater pond sedge (*Carex riparia*), *Carex strigosa*, summer snowflake (*Leucoium aestivum*), creeping buttercup (*Ranunculus repens*), common comfrey (*Symphytum officinalis*) and others.

Common nettle (*Urtica dioica*) as a characteristic species of the *Fagetalia* order and *Querco-Fagetea* class is also prominent.

Galium palustre, *Polyganum hydropiper*, *Myosotis scorpioides*, *Juncus effusus*, *Peucedanum palustre*, *Carex elongata*, *Lysimachia vulgaris*, *Euphorbia palustris* and other accompanying species with a high degree of constancy indicate increased humidity. Furthermore, these species connect this subassociation with other described associations of similar sites and similar compositions.

Therefore, the layer of ground vegetation is distinguished by a wealth of plants of the *Populetalia* order and of accompanying species covering large parts of the forest, which is an indication that this is the most humid subassociation of forests of pedunculate oak and great green weed.

On the basis of detailed analyses of individual phytocoenological recordings, it can be concluded that an aggressive onset of narrow-leaved ash and black alder has been enabled by the newly formed (swampy) conditions. With their number and fast growth, these species are suppressing the pedunculate oak. Due to increased humidity, oak regenerates poorly, while older trees die prematurely. Narrow-leaved ash and black alder have taken dominance either in the tree layer or the shrub layer. The result is that in some recordings, such as 1, 2, 3, 4, and 5, the stands are monodominant, while in some others the narrow-leaved ash and black alder occur both in the shrub and in the tree layer.

The process of water logging is especially visible in Recordings 3, 4 and 5, where narrow-leaved ash and black alder are accompanied by a large number of the following species: *Amorpha fruticosa*, *Carex elata*, *Carex vesicaria*, *Roripa amphybia*, *Deshampsia caespitosa*, *Polygonum hydropiper*, *Carex elongata*, and others. According to Ellenberg (1979), Oberdorfer (1983) Zolyomi and others (1967), the auto-ecological characteristics of these species confirm that they belong to very wet and flooded sites and do not occur in drier habitats. Except for *Deshampsia caespitosa* and *Carex elongata*, all these species require full light or semi-light, which also indicates changes in the sites and structural factors of the association.

The most typical recording of the association is Recording 5, while Recording 10 represents the driest variant of the subassociation, with species such as *Viola reichenbachiana*, *Circaea lutetiana*, *Stellaria media*, *Geum urbanum*, and *Urtica dioica*.

Table 9. - *Tablica 9.*

Association:		*GENISTO ELATAE-QUERCETUM ROBORIS* Ht. 1938										
Subassociation:		*caricetosum remotae* Ht. 1938										D
Number of recording:		1	2	3	4	5	6	7	8	9	10	e
Area:		Žutica										g
Department, compartment:		188d	181b	135d	24a	75c	119a	191a	84a	9c	56c	r
Plot size (m^2):		400	400	400	400	400	400	400	400	400	400	e
Date:		16.6.97.	17.6.97	24.6.97.	3.7.97.	27.8.97.	27.6.97	16.6.97	1.7.97.	2.7.97.	26.8.97.	e
Cover (%):												
Tree layer		70	80	50	70	80	80	90	50	90	80	o
Shrub layer		70	60	30	70	40	50	60	50	80	50	f
Ground vegetation layer		90	100	100	80	100	80	90	100	70	50	
FLORAL COMPOSITON												P a r t.
Characteristic species of the association and alliance (*Alno-Quercion*):												
Quercus robur L.	A	4	5	3	4	5	4	4	3	4	5	V
Alnus glutinosa (L.) Gartn.		.	.	.	.	.	2	+	1	.	+	II
Fraxinus angustifolia Vahl		.	.	.	.	.	.	2	.	2	.	I
Alnus glutinosa (L.) Gartn.	B	.	+	2	+	.	2	1	1	.	.	III
Ulmus carpinifolia Gled.		2	1	.	1	1	.	2	.	.	1	III
Genista elata Wend.		.	3	+	.	3	.	.	.	5	.	II
Acer tataricum L.		.	.	.	.	.	.	1	.	.	.	I
Sambucus nigra L.		.	.	.	.	.	.	.	1	.	.	I
Viburnum opulus L.		.	.	.	.	.	.	.	.	.	+	I
Lysimachia nummularia L.	C	+	.	+	+	.	+	1	1	+	1	IV
Quercus robur L.		2	2	.	2	1	.	1	.	2	.	III
Lycopus europaeus L.		.	+	.	2	1	1	+	1	.	.	III
Rumex sanquineus L.		1	1	.	+	.	.	+	1	1	.	III
Cerastium silvaticum W.K.		+	+	.	+	.	.	+	.	+	.	III
Solanum dulcamara L.		.	.	.	+	.	1	.	1	.	.	II

Impatiens noli tangere L.		+	.	.	.	.	.	2	.	.	.	I
Nephrodium spinulosum Strempel.		.	.	.	.	.	.	.	.	.	+	I
Fraxinus angustifolia Vahl.		.	.	.	.	.	.	1	.	.	.	I
Angelica silvestris L.		.	.	1	.	.	.	.	.	.	.	I
Valeriana dioica L.		.	.	.	.	2	.	.	.	.	.	I
Cardamine dentaria L.		.	.	.	+	.	+	.	.	.	.	I
Ulmus carpinifolia Gled.		.	.	.	.	.	.	2	.	.	.	I
Acer tataricum L.		.	.	.	.	.	.	+	.	.	.	I
Characteristic species of the order and class (*Alno-Populatea*):												
Frangula alnus Mill.	B	+	+	1	.	.	+	+	.	.	.	III
Ulmus laevis Pall.		.	.	.	+	.	1	.	1	+	.	II
Rubus caesius L.	C	1	1	1	1	+	+	+	3	1	1	V
Glechoma hederacea L.		+	1	.	1	2	.	4	2	.	+	IV
Distinguishing species of the subassociation:												
Fraxinus angustifolia Vahl.	B	3	1	1	3	+	2	2	.	1	.	IV
Carex remota L.	C	3	2	2	3	+	1	1	3	2	2	V
Iris pseudacorus L.		2	1	+	1	+	2	+	2	.	+	V
Ranunculus repens L.		2	3	+	3	2	.	.	2	2	.	IV
Lysimachia vulgaris L.		2	3	1	1	.	+	.	+	1	.	IV
Euphorbia palustris L.		1	+	+	.	.	1	1	+	1	.	IV
Carex strigosa Huds.		3	.	.	1	.	.	3	.	3	1	III
Symphytum officinale L.		.	1	.	1	+	1	.	3	.	.	III
Leucoium aestivum L.		.	1	+	+	.	1	.	.	2	.	III
Carex elata All.		.	3	3	.	4	.	.	.	.	.	II
Caltha palustris L.		2	.	.	.	.	1	+	.	.	.	II
Characteristic species of the order and class (*Querco-Fagetea*):												
Crataegus oxyacantha L.	B	.	.	.	2	.	.	+	2	+	+	III
Acer campestre L.		1	.	.	+	.	.	+	1	.	.	II
Prunus spinosa L.		+	.	.	.	.	+	.	.	.	.	I

Crataegus monogyna Jacq.		.	.	.	.	.	.	.	1	.	.	I
Pyrus pyraster (L.) Borkh.		.	.	.	+	.	.	.	1	.	.	I
Euonymus europaea L.		.	.	.	.	.	.	.	.	.	+	I
Urtica dioica L.	C	+	+	+	1	+	2	+	2	.	1	V
Circaea lutetiana L.		.	.	.	2	+	.	2	.	.	1	II
Ajuga reptans L.		1	.	+	.	.	.	.	.	.	.	I
Dryopteris filix mas (L.) Sch.		+	.	.	.	.	1	.	.	.	.	I
Humulus lupulus L.		.	.	.	.	.	.	.	1	.	.	I
Aegopodium podagraria L.		.	.	.	.	.	.	.	.	+	.	I
Viola reichenbachiana Jor. ex Boreu.		.	.	.	.	.	.	.	.	.	+	I
Scrophularia nodosa L.		.	.	.	.	.	.	+	.	.	.	I
Acer campestre L.		.	.	.	.	.	.	+	.	.	.	I
Euonymus europaea L.		.	.	.	+	.	.	.	.	.	.	I
Other species of wet and flooded sites:												
Salix cinerea L.	B	.	+	.	.	.	.	.	.	.	.	I
Galium palustre L.	C	1	2	+	1	+	1	2	2	1	+	V
Carex elongata L.		.	3	3	.	.	4	.	3	+	.	III
Peucedanum palustre (L.) Monch.		+	.	1	.	+	1	2	.	+	.	III
Myosotis scorpioides L.		1	1	.	+	.	.	2	1	.	.	III
Polygonum hydropiper L.		.	+	1	.	+	.	.	2	3	.	III
Juncus effusus L.		+	+	.	.	+	.	+	+	.	.	III
Stachys palustris L.		.	.	.	1	1	1	.	2	1	.	III
Deshampsia caespitosa (L.) Beaur.		.	.	4	.	.	.	+	+	2	.	II
Senecio fluviatilis Wallr.		+	.	+	.	.	.	.	.	1	.	II
Lytrum salicaria L.		.	.	.	+	1	+	.	.	.	.	II
Carex vulpina L.		+	.	2	.	.	.	.	.	.	.	I
Carex vesicaria L.		.	2	2	.	.	.	.	.	.	.	I
Roripa amphibia (L.) Bess.		.	3	.	.	.	.	.	.	1	.	I
Carex riparia Curt.		.	.	.	.	.	.	2	.	.	.	I
Succisa pratensis Mch.		.	.	.	.	1	.	.	.	.	.	I
Mentha aquatica L.		.	.	.	.	+	.	.	.	1	.	I

Poa palustris L.		.	.	.	.	.	+	.	.	.	.	I
Festuca gigantea (L.) Vill.		.	.	.	+	.	.	.	.	.	.	I
Stellaria aquatica		.	.	.	.	.	.	+	.	.	.	I
Other species:												
Rhamnus cathartica L.	B	1	.	+	1	.	.	+	2	.	3	III
Amorpha fruticosa L.		.	3	+	.	.	.	.	.	.	.	I
Galeopsis tetrahit L.	C	+	1	.	.	.	+	+	+	.	+	III
Stellaria media (L.) Vill.		.	.	.	+	.	.	+	.	.	+	II
Geum urbanum L.		.	.	.	.	.	.	.	2	.	+	I
Athyrium filix femina (L.) Roth.		.	.	.	.	.	.	+	+	.	.	I
Hedera helix L.		.	.	.	+	.	.	.	.	.	+	I
Agrostis alba L.		3	1	.	.	.	.	.	.	.	.	I
Solidago sp.		.	3	.	.	1	.	.	.	.	.	I
Hypericum acutum L.		+	.	.	.	.	.	.	.	.	.	I
Lychnis flos cuculi L.		.	.	.	.	.	.	+	.	.	.	I
Thalictrum sp.		.	.	+	.	.	.	.	.	.	.	I
Bidens tripartitus L.		.	.	.	.	+	.	.	.	.	.	I
Prunella vulgaris L.		.	.	.	.	.	.	.	.	+	.	I
Pulmonaria officinalis L.		.	.	.	.	.	.	1	.	.	.	I
Melandrium rubrum (Weigel.) Garcke.		.	.	.	.	.	.	+	.	.	.	I
Aristolochia clematitis L.		.	.	.	.	.	.	+	.	.	.	I
Cornus sanquinea L.		.	.	.	.	.	.	+	.	.	.	I
Tamus communis L.		.	.	+	.	.	.	.	.	.	.	I
Rosa canina L.		.	.	.	.	.	.	.	+	.	.	I

Explanation of abbreviations:
A - Tree layer, B - Shrub layer,
C -Ground vegetation layer

+, 1, 2, 3, 4, 5 - Combined assessment of abundance and cover (Braun-Blanquet 1964)

Syndynamics of the phytocoenosis: I. Horvat (1938) considered this subassociation a typical forest of the Slavonian plain. In a vertical sense, it occurs slightly below the forest of pedunculate oak and great green weed with quaking sedge. The forest of narrow-leaved ash (*Leucoio-Fraxinetum angustifoliae* Glav. 1959) is more humid than the forest of pedunculate oak and great green weed, and one follows the other towards a more humid site.

Stability of the phytocoenosis: According to research (Rauš 1980), this subassociation in the Management Unit "Žutica" is in a state of regression, because its stability has been greatly disturbed by the dieback of lowland elm, followed by an abrupt and mass dieback of pedunculate oak. The ground layer is very rich, which means that an excessive quantity of light passes through rarefied, broken, canopies - the result of permanent dieback of pedunculate oak (preceded by that of lowland elm) in the subassociation.

Too much light in the stand allows weed vegetation to grow very fast, which, combined with abundant humidity, contributes to water logging of the terrain. Stability will have to be restored with silvicultural and draining measures.

Black alder and narrow-leaved ash fill in the empty places and thus help stabilise these stands.

An analysis of the phytocoenological recordings, and a comparison of distribution maps of the "Žutica" forest associations (Medvedović 1975) and the present condition show that swamping processes are still taking place. Compartments 54a and b, 78 (north), 92b and c, 132, 134, and 154c are now inhabited by forests of black alder in place of the earlier association of pedunculate oak and great green weed with remote sedge. A similar phenomenon has occurred in compartments 15, 20, 56b, 61b, 62b, 64f, 164b, 194c, and 196a, now inhabited by forests of narrow-leaved ash. A certain degree of regression resulting from dieback is visible in compartments 130a and b, 134, 136e and d, 149, 150, and 168, where the subassociation *caricetosum remotae* has replaced that of *caricetosum brizoides*. However, the subassociation *caricetosum remotae* is showing a tendency to expand at the expense of other associations in the Unit. The same is happening in compartments 25d, 37 (a part), 83a, 101a, 103a, 119a, 187b, and 188d, where site regression is even greater, because the association of pedunculate oak and common hornbeam has been replaced by the association of pedunculate oak and great green weed with remote sedge.

Certain progression is only visible in compartments 63a, 65a, 154a, and 155b, where *Genisto elatae-Quercetum roboris caricetosum remotae* has been replaced by *Genisto elatae-Quercetum roboris carpinetosum betuli*, and in compartment 37a and parts of compartments 62 and 65, which are now inhabited by *Carpino betuli-Quercetum roboris*.

In can be concluded that the biggest vegetative and ecological changes have occurred, and are still occurring, mainly in this subassociation. The association is unstable, and digressions from floral compositions and structures of normally developed stands are frequent. The size of the area under this association has not changed, which is connected with what has been said above, but very serious regression processes are visible in the entire Management Unit "Žutica".

In order to establish the causes of pedunculate oak dieback, Dekanić (1962) conducted research on the water regime in the forest "Žutica". He found that the water regime in the forest of pedunculate oak and great green weed with remote sedge was highly unfavourable. Among other negative impacts of dams, roads and canals, there are also disturbances in the rhizosphere.

Research in other localities affected by pedunculate oak dieback, such as Kalje, Turopoljski Lug and the Pokuplje Basin, also show visible changes in the phytocoenological structure, which indicate stagnant water and excessive humidity of the biotop (Vukelić et al. 1997).

THE FOREST OF BLACK ALDER WITH ALDER BUCKTHORN
ŠUMA CRNE JOHE S TRUŠLJIKOM
(*Frangulo-Alnetum glutinosae* Rauš 1968)

Research so far: Although it covers a much smaller area than the above described associations, the forest of black alder with alder buckthorn is an interesting and important association of the lowland region in Croatia. Horvat (1938, 1963), Glavač (1960, 1962), Fukarek (1963) and Rauš (1968, 1971) studied the forest of black alder from different viewpoints, but Rauš was the first to describe this association in Posavina.

Horvat (1938) described the forest of black alder in Croatia under the name *Carici brizoides-Alnetum glutinosae*. Later (1963), he went on to describe alder forests on peat and humus-gleyic soils of Podravina under the name *Carici elongatae-Alnetum glutinosae* (W. Koch) Tx. et Bodeux. According to Horvat, the latter association has the character of a relic, and has survived since the glacial period in the sites in which oscillations of groundwater represent fundamental factors in the growth of the association.

Distribution of the phytocoenosis: According to research so far, the forest of black alder and alder buckthorn is found in Podravina, Podunavlje, Pokuplje and the entire region of Croatian Posavina, where it occurs in smaller areas in a mosaic-like pattern. Some research (Erdeši 1971) shows that black alder is disappearing from the region of lower Posavina, and has almost completely gone from Podunavlje.

Typical stands of black alder with alder buckthorn cover slightly over 5% of the entire area of the "Žutica". Larger stands are situated in the northern part, while elsewhere they occur fragmentarily in micro-depressions.

Site of the phytocoenosis: The forest of black alder with alder buckthorn is arranged in a mosaic pattern over a specific relief and in specific relief conditions. It usually occurs in old riverbeds and depressions, and less frequently in swamps, where the pioneering role of black alder has come to its full expression. When conditions are favourable, it inhabits old riverbeds and after several generations forms a normal forest soil and conditions for the growth and development of other tree species.

The association occurs exclusively on eugley soils, or on their sub types, epigley and amphigley, although it is slightly better represented on amphigley. It is rich in nitrogen and has a slightly acid reaction.

The phytocoenosis is subjected to long-lasting surface water about 20 to 70 cm in depth (sometimes more), which often indicates soil completely saturated with water.

Floral composition and vegetative structure: The floral composition, based on 10 phytocoenological recordings from various parts of the "Žutica", is shown in Table 10. A total of 79 species have been registered, of which 34 participate at a rate of over 20%.

The tree layer covers 30% of the area in Recording 3, and almost 90% in Recording 10. Of the characteristic species belonging to the association and alliance *Alno-Quercion*, black alder (*Alnus glutinosa*) is the most constant, while other tree species are almost non-existent, apart from a sporadic occurrence of narrow-leaved ash (*Fraxinus angustifolia*).

Stagnant surface water is responsible for the fact that black alder develops special conical roots, giving these forests an unusual aspect. Mud collecting around these cones forms soil, which enables black alder to vegetate despite stagnant surface water, since a part of its roots is above the water. Other tree species do not possess this ability. However, there are stands whose appearance does not correspond to this typical picture. These are the ones in which both the site and the association are at a higher level of development, so the humidity is lower, and the cones gradually disappear, although the floral composition is the same.

It is interesting that the phytocoenosis disposes of large quantities of organic matter through leaves and other waste material, which leads to a gradual progression of site conditions.

The coverage of the shrub layer ranges from 5 to 30%, with the exception of Recording 9, where it reaches 50%. This may be caused by conditions in the site hostile to the development of most trees and shrubs, and by the fact that black alder, when fully canopied, almost entirely shades the soil. Besides black alder, the shrub layer consists only of alder buckthorn (*Frangula alnus*) and grey willow (*Salix cinerea*) as characteristic species of the association and alliance *Alno-Quercion*, to which it belongs primarily in the diagnostic sense. Buckthorn (*Rhamnus cathartica*) is the only accompanying species that participates in the stand to a larger degree. It is characteristic that almost all shrubs, except grey willows, develop on the cones of black alder trees.

The layer of ground vegetation covers 90 - 100% of the area (the recordings show a range between 7 and 70%). *Carex riparia*, *Peudecanum palustre*, *Nephrodium spinulosum*, *Solanum dulcamara*, *Galuim palustre*, *Iris pseudacorus* and others are characteristic species of the association and alliance *Alno-Quercetum*. Of other species of wet and flooded sites, there is a slightly higher participation of *Myosotis scorpioides*, *Polygonum hydropiper* and *Euphorbia palustris*, and of ac-

companying species there are *Urtica dioica*, *Galeopsis tetrahit*, *Circaea lutetiana*, *Eupatorium cannabinum* and some others.

In most cases, two storeys (sinusions) can be distinguished in the layer of ground vegetation, of which one (mesophytic) grows on the already mentioned conical roots of black alders, that is, on the soil connected to the alder root system. This sinusion is made up of *Nephrodium spinulosum*, *Glechoma hederacea*, *Solanum dulcamara*, *Rubus caesius*, *Urtica dioica*, *Galium palustre*, *Circaea lutetiana*, and a smaller number of some other species.

The other sinusion (hygrophytic) of the ground vegetation occurs on the soil itself, between the cones of black alder, and is made up of distinct hygrophytes. Of characteristic species of the association and alliance, special mention should be made of *Carex riparia*, *Peucedanum palustre*, *Carex elongata*, *Lysimachia vulgaris* and *Lycopus europaeus*, while of accompanying species there are *Iris pseudacorus*, *Carex vesicaria*, *Sparganium erectum*, *Polygonum hydropiper*, *Lythrum salicaria*, *Stachys palustris*, and many others.

A detailed analysis of the recordings and the history of dieback in the Management Unit "Žutica" have led to the conclusion that the stands of black alder are in progression. Some stands are the result of site and association progression, while others originate from dieback of pedunculate oak and lowland elm and the associated water logging of the terrain, in other words, from regression processes. Recordings 1 and 2 are examples of waterlogged terrain with hygrophyllic vegetation in the place where the association of *Carpino betuli-Quercetum* roboris existed prior to pedunculate oak dieback. They are all characterised by poorly stocked stands, very hard conditions for the development of vegetation, the prevalence of swampy sedges, and the formation of cones.

Similar conditions are seen in Recordings 4, 5 and 6, where water remains on the surface over the whole year. Such specific ecological conditions have caused groups of black alders to grow on elevated cones, and often to develop from stumps. The poor-quality trunks are relatively low, have weak crowns, and are often forky.

Very well developed black alders are seen in Recording 7, and especially in Recording 8. Unlike previous recordings, these are not in the initial, but in the optimal stage of the development of black alder forests. The terminal stage is largely shown in Recording 9, with species such as *Quercus robur*, *Crataegus oxyantha* and *C. monogyna*, *Acer campestre*, *Corylus avellana*, *Ulmus carpinifolia*, *Cornus sanquinea*, *Carex remota*, *Carex brizoides*, *Cerastium silvaticum* and *Geum urbanum*. All these are mesophyllic elements of oak forests that indicate a transition of the association of black alder with alder buckthorn into a drier association of pedunculate oak and great green weed with remote sedge. A characteristic of this recording is a large participation of American ash (*Fraxinus americana*), brought into this site by man, probably as a consequence of certain changes in the site. However, as in other parts of the Management Unit "Žutica", in this one too, autochthonous elements prevail, so the American ash will gradually disappear from the floral composition.

Table 10. - *Tablica 10.*

Association:		*FRANGULO-ALNETUM GLUTINOSAE* Rauš 1968										Degree of part.	Biological form
Subassociation:		*typicum* Rauš 1971											
Number of recording:		1	2	3	4	5	6	7	8	9	10		
Area:		Žutica											
Department, compartment:		125d	112b	154c	197a	82d	95b	90c	44b	91a	114c		
Plot size (m^2):		400	400	400	400	400	400	400	400	400	400		
Date:		26.6.97.	27.6.97.	20.6.97.	6.6.97.	1.7.97.	1.7.97.	23.9.97.	27.8.97.	3.6.97.	27.8.97		
Cover (%):													
Tree layer		40	40	30	60	40	50	80	80	70	90		
Shrub layer		30	5	10	15	20	10	10	5	50	5		
Ground vegetation layer		100	90	100	100	100	100	70	100	100	90		
FLORAL COMPOSITON													
Characteristic species of the association and alliance (*Alno-Quercion*):													
Alnus glutinosa Gartn.	A	3	3	3	3	3	3	4	5	2	5	V	Ph
Fraxinus angustifolia Vahl		.	.	.	1	.	.	.	.	1	.	I	Ph
Frangula alnus Mill.	B	2	+	1	1	1	2	+	+	3	1	V	Ph
Salix cinerea L.		+	.	1	1	2	.	1	+	+	.	IV	Ph
Alnus glutinosa Gartn.		1	1	+	.	.	1	1	1	.	.	III	Ph
Sambucus nigra L.		.	.	.	.	1	.	+	.	.	.	I	Ph
Rubus caesius L.		.	.	.	+	.	.	.	.	+	.	I	H
Fraxinus angustifolia Vahl.		.	.	.	.	.	.	.	.	+	.	I	Ph
Viburnum opulus L.		.	.	.	.	.	.	.	.	+	.	I	Ph
Carex riparia Curt.	C	3	2	4	4	4	4	3	2	4	3	V	H
Peucedanum palustre (L.) Monch.		3	2	+	+	1	1	1	1	1	1	V	H
Nephrodium spinulosum (Mill.) Stemp.		2	.	+	2	1	2	2	+	1	1	V	H
Solanum dulcamara L.		3	3	1	2	.	2	2	+	+	1	V	H
Galium palustre L.		2	2	+	1	.	1	1	1	+	.1	V	H
Iris pseudacorus L.		.	3	.	.	+	1	+	+	+	2	IV	G
Carex vesicaria L.		3	.	4	3	3	3	.	2	.	.	III	H
Carex elongata L.		1	2	1	.	.	.	.	2	2	3	III	H
Lysimachia vulgaris L.		1	+	+	.	.	2	1	+	.	.	III	H
Rubus caesius L.		1	.	+	.	1	+	.	+	.	+	III	H
Sparganium erectum L.		3	3	1	.	1	2	.	1	.	.	III	H

Stachys palustris L.		+	1	.	.	.	1	+	+	.	+	III	H
Allisma plantago aquatica L.		.	1	.	.	+	.	.	.	.	.	I	H
Sium latifolium L.		.	1	.	.	.	.	.	.	.	.	I	H
Other species of wet and flooded sites:													
Myosotis scorpioides L.	C	.	.	1	+	2	1	+	.	.	+	III	H
Polygonum hidropiper L.		.	+	+	.	2	.	.	2	.	2	III	Th
Euphorbia palustris L.		1	+	.	.	1	.	.	.	+	.	II	H
Leucoium aestivum L.		.	1	+	+	.	.	.	.	+	.	II	G
Carex elata All.		2	.	.	4	.	.	3	+	.	.	II	H
Roripa amphibia (L.) Bess.		2	.	.	1	.	.	+	+	.	.	II	
Cardamine dentata L.		.	+	.	+	.	.	.	.	.	+	II	H
Lythrum salicaria L.		.	.	+	.	.	.	+	.	.	+	II	H
Caltha palustris L.		.	.	.	.	1	.	.	.	3	.	I	H
Deshampsia caespitosa (L.) Beaur.		.	.	.	.	.	.	.	.	1	2	I	H
Mentha aquatica L.		.	.	3	.	1	.	.	.	.	.	I	H
Rumex sanquineus L.		.	.	.	.	+	.	.	.	.	+	I	H
Lemna trilusca L.		.	+	.	+	.	.	.	.	.	.	I	H
Hottonia palustris L.		2	3	.	.	.	.	.	.	.	.	I	H
Ranunculus repens L.		.	.	.	.	1	.	.	.	.	+	I	H
Lemna minor L.		.	+	.	.	.	.	.	.	.	.	I	H
Symphytum officinale L.		.	+	.	.	.	.	.	.	.	.	I	H
Festuca gigantea (L.) Vill.		.	.	.	.	+	.	.	.	.	.	I	H
Juncus effusus L.		.	.	.	.	.	.	.	.	.	+	I	H
Senecio aquatica Huds.		.	.	.	.	1	.	.	.	.	.	I	H
Other species:													
Fraxinus americana	A	.	.	.	.	.	.	.	.	3	.	I	Ph
Quercus robur L.		.	.	.	.	.	.	.	.	1	.	I	Ph
Rhamnus cathartica L.	B	.	.	.	+	+	+	.	.	.	.	II	Ph
Quercus robur L.		.	.	.	.	+	.	.	.	+	.	I	Ph
Crataegus oxyacantha L.		.	.	.	.	.	.	.	.	+	+	I	Ph
Prunus spinosa L.		.	.	.	.	+	.	.	.	.	+	I	Ph
Fraxinus americana		.	.	.	.	.	.	.	.	2	.	I	Ph
Cornus sanquinea L.		.	.	.	.	.	.	.	.	+	.	I	Ph
Acer campestre L.		.	.	.	.	.	.	.	.	+	.	I	Ph
Corylus avellana L.		.	.	.	.	.	.	.	.	+	.	I	Ph
Crataegus monogyna Jacq.		.	.	.	.	.	.	.	.	+	.	I	Ph

Ulmus carpinifolia Gled.		.	.	.	.	.	.	.	.	+	.	I	Ph
Ulmus laevis Pall.		.	.	.	.	.	.	.	.	+	.	I	Ph
Pyrus pyraster (L.) Borkh.		.	.	.	.	.	.	.	.	+	.	I	Ph
Acer tataricum L.		.	.	.	+	.	.	.	.	.	.	I	Ph
Urtica dioica L.	C	+	1	+	2	2	+	2	.	.	1	IV	H
Galeopsis tetrahit L.		+	+	+	.	2	+	+	3	.	.	IV	Th
Circaea lutetiana L.		.	.	+	1	+	+	.	.	+	+	III	G
Lycopus europaeus L.		+	1	.	.	1	.	1	+	.	+	III	H
Eupatorium cannabinum L.		+	+	.	.	+	+	+	.	.	.	III	H
Aegopodium podagraria L.		.	.	+	.	1	.	.	.	.	+	II	H
Glechoma hederacea L.		.	.	.	.	1	.	+	.	.	1	II	Ch
Bidens tripartitus L.		.	.	.	.	.	.	+	3	.	2	II	Th
Galium silvaticum L.		.	.	.	.	.	+	+	+	.	.	II	H
Vitis silvestris Gmel.		.	.	2	.	.	.	.	.	+	.	I	
Impatiens noli tangere L.		.	.	.	.	+	.	.	.	+	.	I	Th
Lychnis flos cuculi L.		.	.	.	+	.	.	.	.	+	.	I	H
Humulus lupulus L.		.	.	+	.	1	.	.	.	.	.	I	H
Carex remota L.		.	.	.	.	.	.	.	.	+	.	I	H
Lysimachia nummularia L.		.	.	.	.	.	.	.	.	+	.	I	H
Carex brizoides L.		.	.	.	.	.	.	.	.	1	.	I	H
Cerastium silvaticum W.K.		.	.	.	.	.	.	.	.	+	.	I	Ch
Geum urbanum L.		.	.	.	.	.	.	.	.	+	.	I	H
Galium odoratum (L.) Scop.		.	.	.	+	.	.	.	.	.	.	I	G
Polygonatum multiflorum (L.) All.		.	.	.	+	.	.	.	.	.	.	I	G
Aristolochia clematitis L.		.	.	.	.	2	.	.	.	.	.	I	H
Moehringia trinervia (L.) Clairv.		.	.	.	.	+	.	.	.	.	.	I	
Melandrium rubrum Roehl.		.	.	.	.	.	.	.	+	.	.	I	H
Athyrium filix femina (L.) Roth.		.	.	.	.	.	.	.	.	.	2	I	H
Angelica silvestris L.		.	.	.	.	.	.	.	.	.	+	I	H

Explanation of abbreviations:
A - Tree layer
B - Shrub layer
C - Ground vegetation layer
+, 1, 2, 3, 4, 5 - Combined assessment of abundance and cover (Braun-Blanquet 1964)

Biological range: Biological forms according to Ranunkiaer (1905) on the basis of 10 phytocoenological recordings (Table 10) show the following structure in the association: phanerophytes (Ph) 29%, chamaephytes (Ch) 3%, hemicryptophytes (H) 57%, geophytes (G) 6%, and therophytes (Th) 5%, which means that the association of black alder with alder buckthorn is a distinctly hemicrypto-phanerophytic (57 - 29%) association.

Distribution of the phytocoenosis: Due to the fact that these associations occur both in drained sites (river terraces) and in extremely swampy sites (depressions), the basic association *Frangulo-Alnetum glutinosae* (Rauš 1968) is divided into two subassociations: the subassociation *typicum* (Rauš 1971), and the subassociation *ulmetosum laevis* (Rauš 1971). Both these associations are present in the lowland region of Croatia.

Syndynamics of the phytocoenosis: The syndynamic development of the forest of black alder with alder buckthorn is very interesting, primarily owing to the pioneering and meliorative role the black alder plays in the lowland region of Croatia. There are three stages in its development: in the initial stage, which begins in former river courses, only ground vegetation of sedges and other similar species develops, followed by grey willow, white willow, fragile willow, alder buckthorn, white poplar, narrow-leaved ash and black alder on micro-elevations.

The optimal stage of the forest development is marked by black alder originating from seeds and stumps, with or without conical roots. There are also some narrow-leaved ashes and spreading elms.

The terminal stage contains black alder, which gradually disappears and gives place to pedunculate oak. Some sporadic maples and common hornbeams also occur.

In the Management Unit "Žutica", forests of black alder are in various stages of development. Forests growing on micro-elevations along the existing canals and dried riverbeds are in the initial stage. On a slightly more elevated terrain the sinusion of cones with swampy vegetation and bushes (*Salix cinerea, Frangula alnus*) gradually disappears, to be replaced by pure forests of black alder (optimal stage). The boundary of the terminal stage is more difficult to determine due to a successive development in which alder abruptly penetrates the sites of pedunculate oak. In certain small places in the central part of the Management Unit, alder even penetrates hornbeam sites.

Stability of the phytocoenosis: By carrying out meliorative treatments and fellings, man has been influencing the development of forests of black alder for a very long time.

The consequence of man's activities and of specific ecological conditions in which forests of black alder grow is the following phenomenon: in the Management Unit "Žutica" black alder has spread from old riverbeds and canals onto surfaces covered with stagnant water remaining there after floods and heavy rains. In addition, the disappearance of pedunculate oak has meant the disappearance of a "pump" whose role was to take away large quantities of water from the soil. The re-

sult was a worsened hydrological regime, a change in the microclimate, and a deterioration of biological components in the soil. Since black alder is the only species capable of tolerating such extremely humid conditions, it quickly invaded these localities. Narrow-leaved ash occurs in less humid localities.

The large-scale expansion of black alder is also noticeable in the association *Genisto elatae-Quercetum roboris*, as well as in individual places on micro-elevations.

Black alder also grows along oil wells, which is not surprising since as a pioneering species it can more or less tolerate such unfavourable life conditions. However, extremely adverse conditions, such as oil slicks, cause its degradation and dieback.

A comparison between the distribution of forest vegetation in the Management Unit "Žutica" (Medvedović 1975) and the present state shows that black alder has aggressively penetrated into the site of pedunculate oak in compartments 54a and b, 78 (north), 92b and c, 132, 134 and 154c, and replaced the previous forest of pedunculate oak and great green weed with remote sedge, and in compartments 70c and d, 111d, 117b, 140b and 141b, previously inhabited by the forest of pedunculate oak and great green weed with remote sedge. Very drastic dieback of pedunculate oak, combined with the water logging of the terrain, has enabled black alder to inhabit micro-elevations in compartments 80b, 88a, 100b, 112b, 113d, 125 and 126c, where it has replaced the previous forest of pedunculate oak and common hornbeam.

Black alder has also spread over previously uninhabited areas in compartments 96, 97 and 124, and along the majority of oil wells. Progression has also taken place in compartments 84, 86 and 121a, where the forest of black alder with alder buckthorn has been replaced by the forest of pedunculate oak and great green weed with remote sedge, and in compartments 82a and c, and 90b, which are now inhabited by forests of pedunculate oak and great green weed with common hornbeam. However, this is open to question, since, under disturbed site conditions and dieback, black alder spreads into the site of common hornbeam much more readily than common hornbeam inhabits the site of black alder.

Forest-economic characteristics: Similar to narrow-leaved ash, black alder also displays a tendency to expand quickly into areas which are either desiccated or are in the process of desiccation. It is a promising species and should be given more attention. Its properties will be fully utilised when pedunculate oak forests desiccate and decline, and black alder takes up the place of the necessary "third" species in pedunculate oak forests. The development of black alder forests should be assisted with silvicultural measures. Together with pedunculate oak and narrow-leaved ash, black alder should remain the basic species to be introduced into desiccating and declining stands (Matić 1989). In degraded sites, pedunculate oak should be obtained indirectly by introducing pioneering tree species, particularly narrow-leaved ashes, black alders, willows and poplars.

More will be said about silvicultural measures in normally developed forests of black alder in the section on the forests of narrow-leaved ash, because the princi-

ples are almost the same. The rotation of black alder forests is a minimum of 60 years, and 30 years with coppice forests.

FOREST OF NARROW-LEAVED ASH WITH SUMMER SNOWFLAKE
ŠUMA POLJSKOGA JASENA S KASNIM DRIJEMOVCEM
(*Leucoio-Fraxinetum angustifoliae* Glav. 1959)

Research so far: The first to describe the forest of narrow-leaved ash with summer snowflake in Croatia was Glavač (1959), who also divided it into two subassociations: *typicum* and *alnetosum glutinosae* (1962), which was adopted by other researchers of forest vegetation in lowland regions in Croatia (Horvat, Rauš). The exceptions are E. Vukičević (1959) and Erdeši (1971), who considered such phytocoenoses facies or subassociations of forests of pedunculate oak and great green weed in their most humid sites.

Distribution of the phytocoenosis: The forest of narrow-leaved ash with summer snowflake inhabits the clayey alluvial terrain of the Croatian Posavina from Sisak to Spačva. The largest and the most beautiful of these forests are located in Lipovljani in Posavina, in Javička Greda near Jasenovac and in Kamare near Novska.

Site of the phytocoenosis: A typical forest of narrow-leaved ash is especially beautifully developed in the southern part of the studied area, where the river Česma joins the river Lonja (the lowest terrain), but it does not cover large areas. Flood tides beginning at this point extend into the interior towards Veliko and Málo Polje. In the lowest points, narrow-leaved ashes display circles left by floodwater and ice at heights of up to 2 m. Narrow-leaved ash is a monodominant species here, the trunks are curved, many trees have been blown down, and the shrub and ground layers are almost non-existent. It occurs in the area of willows and initial vegetation in general, and represents the initial stage in the development of ash forests (according to Glavač 1959). In the southernmost and north-western areas, the association is complemented with black alder and pedunculate oak, while the shrub and ground layers are much better developed. Since hydrological conditions are more favourable here than in a typical subassociation, trees have much better heights and forms. Apart from black alder, there are also *Frangula alnus*, *Nephrodium spinulosum*, *Peucedanum palustre*, and others. The forest of narrow-leaved ash is in its optimal and terminal stage of development here.

The most important factors in the development of the association are the relief and the related stagnant and groundwater. The association occurs exclusively on eugley soil, that is, on its sub-types epigley and amphigley (occurring more frequently on the former). The terrain is uneven, and the soils can be neutral to acid. The association is exposed to long-lasting surface water and high groundwater.

In terms of orography, the phytocoenosis inhabits depressions of different kinds (bogs and recessions).

Floral composition and vegetative structure: The floral composition of the association is shown in Table 11 with five recordings from a typical subassociation, and five recordings from a subassociation with black alder. A total of 65 species has been recorded in the former, and 58 species in the latter.

The tree layer covers 50 - 90% of the area, and is made up of narrow-leaved ashes in the dominant storey, with an occasional appearance of lowland elms, ashes and pedunculate oaks. The tree layer in the subassociation with black alder covers 50 - 80% of the association's area, and is characterised by a fairly large participation of black alder.

The shrub layer is rather poor, and covers 1 - 40% of the area in a typical subassociation (Recording 4 is an exception, as the coverage there is 70%), and 1 - 10% in a subassociation with black alder (Recording 9 - 30%). It is mostly made up of narrow-leaved ash, spreading elm (*Ulmus laevis*), dyers' greenweed (*Genista tinctoria* ssp. *elata*) grey willow (*Salix cinerea*) and lowland elm (*Ulmus carpinifolia*) as the characteristic species of the alliance and order *Populetalia*, and hawthorn (*Crataegus oxyantha*) of accompanying species. The situation is the same in both associations, while black alder (*Alnus glutinosa*) and alder buckthorn (*Frangula alnus*) are distinguishing species for the second subassociation.

In a typical forest of narrow-leaved ash with summer snowflake, the ground layer covers 70 - 100% of the area, with the exception of Recording 5, where the coverage is only 10%. In the subassociation with black alder, the coverage is 90 - 100%. As characteristic and distinguishing species of the association, both subassociations contain common-marsh bedstraw (*Galium palustre*), bladder-sedge (*Carex vesicaria*), greater pond sedge (*Carex riparia*), tufted sedge (*Carex elata*), summer snowflake (*Leucoium aestivum*), and *Cardamine dentata*. Bladder-sedge is better represented in the subassociation with black alder, while summer snowflake and *Cardamine dentata* are better represented in the subassociation *typicum*. As characteristic species of the alliance and order *Populetalia*, both subassociations are rich in gipsywort (*Lycopus europaeus*), yellow loosestrife (*Lysimachia vulgaris*), dewberry (*Rubus caesius*), yellow flag (*Iris pseudacorus*), marsh woundwort (*Stachys palustris*), wood dock (*Rumex sanguineus*), remote sedge (*Carex remota*) and others. In the subassociation *alnetosum glutinosae* the participation of remote sedge is considerably smaller than in the subassociation *typicum*.

Of other species of wet and flooded sites, the most numerous in both subassociations are *Polygonum hydropiper*, spurge (*Euphorbia palustris*), and purple loosestrife (*Lythrum salicaria*). In the subassociation typicum there is also sedge (*Carex vulpina*), giant fescue (*Festuca gigantea*), and tufted hair-grass (*Deschampsia caespitosa*). Of distinguishing species which divide the subassociation alnetosum glutinosae from typicum, the most numerous are common nettle (*Urtica dioica*), milk parsley (*Peucedanum palustre*), common hemp nettle (*Galeopsis tetrahit*), water forget-me-not (*Myosotis scorpioides*), bittersweet (*Solanum dulcamara*), Nephrodium spinulosum, marsh marigold (*Caltha palustris*), and soft rush (*Juncus effusus*).

A detailed analysis of individual phytocoenological recordings, combined with knowledge of the conditions in the terrain and changes in the past, show that Recording 1 represents a young ash forest. The conditions for the development of forest vegetation here are very hard, so that narrow-leaved ash is a mono-dominant species of very bad appearance (curved), while the shrub layer is very poorly developed. Recording 2 refers to the terrain which represents the initial stage in the development of narrow-leaved ash forests. The stand is characterised by a very poor appearance with badly curved ash trees and a poverty of species (*Leucoium aestivum*, *Polygonum hydropiper*, moss), but the recording itself represents a transition into the optimal stage, which is fully shown in Recording 3. Here, the ash is taller, straight and of good quality, and there is a much larger variety of species in all layers.

Recording 4 represents a typical example of a terminal stage in the development of forests of narrow-leaved ash and summer snowflake, as described by Glavač (1959). Apart from narrow-leaved ash, the tree layer displays pedunculate oak, the shrub layer is characterised by Genisto elatae, and the ground vegetation abounds in hygrophyllic species with occasional tufts of remote sedge (*Carex remota*). It is a perfect indicator of decreased humidity and a transition towards the association of pedunculate oak and great green weed with remote sedge (*Genisto elatae-Quercetum roboris caricetosum remotae*).

Recording 5 shows the area affected by pedunculate oak dieback. The terrain is waterlogged, and consequently the earlier association of pedunculate oak and great green weed with remote sedge has been replaced by the association of narrow-leaved ash and summer snowflake. A number of elements remaining from forests of pedunculate oak are further indicators of the case: *Acer campestre*, *Crataegus oxyantha*, *Euonymus europaea*, *Ulmus carpinifolia*, *Carex remota*, *Rubus caesius*, *Cerastium silvaticum*, *Stellaria media*. *Glechoma hederacea*, and others.

Recording 6 shows a characteristic subassociation with black alder, where the participation of narrow-leaved ash reaches 70% and black alder 30%. Species differentiating this subassociation from a typical forest of narrow-leaved ash with summer snowflake are also present: *Myosotis scorpioides*, *Solanum dulcamara*, *Caltha palustris*, *Urtica dioica*, *Peucedanum palustre* and *Nephrodium spinulosum*. Recording 7 is similar, except that the participation of alder is somewhat higher, while Recording 8 is characterised by the fact that it was made in the area where pedunculate oak has desiccated. The desiccation was followed by the introduction of EA poplar cultures, which were suppressed by narrow-leaved ash and black alder some thirty years later, as these were the only pioneering species capable of surviving in such a badly devastated site.

In contrast, Recordings 9 and 10 represent the driest variant of this subassociation with species such as *Quercus robur*, *Acer campestre*, *Crataegus oxyantha*, *Carex remota* and others, and indicate the progression of the site towards a forest of pedunculate oak and great green weed with remote sedge.

Table 11. - *Tablica 11.*

Association:		*LEUCOIO-FRAXINETUM ANGUSTIFOLIAE* Glavač 1959										Degree of floral part.	Biological form
Subassociation:		*typicum* Glavač 1959					*alnetosum glutinosae* Glavač 1959						
Number of recording:		1	2	3	4	5	6	7	8	9	10		
Area:		Žutica											
Department, compartment:		9a	194a	61b	198a	56b	160b	167c	129c	69a	77a		
Plot size (m^2):		400	400	400	400	400	400	400	400	400	400		
Date:		2.7.97.	6.6.97.	4.9.97.	4.6.97.	26.8.97.	17.6.97.	20.6.97.	26.6.97.	27.8.97	23.9.97.		
Cover (%):													
Tree layer		90	60	50	70	80	50	70	50	70	80		
Shrub layer		1	5	20	70	40	10	1	10	30	10		
Ground vegetation layer		70	100	90	100	10	90	90	100	90	90		
FLORAL COMPOSITON													
Characteristic and distinguishing species of the association:													
Fraxinus angustifolia Vahl	A	5	4	4	4	4	3	4	4	4	4	V	Ph
Fraxinus angustifolia Vahl	B	.	+	1	+	.	+	+	1	2	1	IV	Ph
Galium palustre L.	C	2	2	1	+	+	1	1	1	+	1	V	H
Carex vesicaria L.		2	1	1	+	.	4	3	2	2	4	V	H
Carex elata All.		2	+	3	2	.	.	3	3	2	2	IV	H
Carex riparia Curt.		.	+	4	1	.	4	.	.	1	3	III	H
Leucoium aestivum L.		3	2	.	2	.	+	+	.	.	.	III	G
Cardamine dentata L.		1	+	+	.	.	.	.	.	.	+	II	H
Characteristic and distinguishing species of the alliance and order (*Populetalia*):													
Quercus robur L.	A	.	.	.	+	.	.	.	.	.	+	I	Ph
Ulmus laevis Pall.	B	.	+	1	.	+	1	.	.	+	.	III	Ph
Genista tinc. ssp. *elata* A. et G.		+	+	.	4	.	+	.	.	.	.	II	Ph
Salix cinerea L.		.	.	1	+	.	.	.	1	.	+	II	Ph
Ulmus carpinifolia Gled.		.	.	.	+	.	.	.	+	.	.	I	Ph
Populus alba L.		+	.	.	.	.	.	.	.	.	.	I	Ph

Quercus robur L.		.	.	+	.	.	.	.	.	.	.	I	Ph
Lycopus europaeus L.	C	1	.	1	+	.	+	+	1	+	2	IV	H
Lysimachia vulgaris L.		+	+	1	1	.	.	+	+	+	1	IV	H
Rubus caesius L.		+	+	1	1	+	.	+	.	2	.	IV	H
Iris pseudacorus L.		+	2	.	+	.	+	+	1	+	+	IV	G
Stachys palustris L.		2	1	.	+	.	.	+	1	+	1	IV	H
Rumex sanquineus L.		+	1	.	+	.	+	1	+	.	.	III	H
Carex remota L.		3	+	.	+	+	.	.	.	1	.	III	H
Carex elongata L.		1	.	.	1	.	2	.	1	.	.	II	H
Quercus robur L.		.	.	.	+	+	.	.	.	+	.	II	Ph
Valeriana dioica L.		.	.	2	.	+	.	.	.	1	+	II	H
Glechoma hederacea L.		.	.	+	.	1	.	+	.	3	.	II	Ch
Ulmus carpinifolia Gled.		.	.	.	.	1	.	.	.	.	.	I	Ph
Viburnum opulus L.		.	.	+	.	.	.	.	.	.	.	I	Ph
Distinguishing species of the subassociation *alnetosum glutinosae*:													
Alnus glutinosa Gartn.	A	.	.	.	.	.	+	1	1	2	3	III	Ph
Alnus glutinosa Gartn.	B	.	.	1	.	.	1	+	1	.	+	III	Ph
Frangula alnus Mill.		.	.	.	+	.	.	.	+	.	1	II	Ph
Urtica dioica L.	C	.	.	1	.	1	2	2	+	1	1	IV	H
Peucedanum palustre (L.) Monch.		+	.	.	+	.	1	1	3	.	2	III	H
Galeopsis tetrahit L.		.	.	.	.	+	+	+	+	.	+	III	Th
Solanum dulcamara L.		.	.	1	.	.	1	1	.	1	.	II	H
Humulus lupulus L.		.	.	.	.	.	+	+	+	.	.	II	H
Nephrodium spinulosum (Mill.) Stemp.		.	.	+	.	.	+	+	+	.	.	II	H
Caltha palustris L.		.	.	+	.	.	3	1	.	.	.	II	H
Juncus effusus L.		.	.	.	.	.	.	+	+	+	.	II	H
Myosotis scorpioides L.		.	.	.	.	.	+	1	+	.	+	II	H
Lysimachia nummularia L.		.	.	.	.	.	.	1	.	+	.	I	H
Impatiens noli tangere L.		.	.	.	.	.	.	1	+	.	.	I	Th
Athyrium filix femina (L.) Roth.		.	.	.	.	.	.	+	+	.	.	I	H
Circaea lutetiana L.		.	.	.	.	.	.	.	+	+	.	I	G
Frangula alnus Mill.		.	.	.	.	.	+	.	.	.	.	I	Ph

Other species of wet and flooded sites:													
Polygonum hidropiper L.	C	2	4	+	1	.	+	1	+	+	.	IV	Th
Euphorbia palustris L.		1	+	+	+	.	+	.	1	.	3	IV	H
Lytrum salicaria L.		+	.	+	+	.	1	.	1	.	.	III	H
Ranunculus repens L.		1	+	+	1	.	+	1	.	.	.	III	H
Carex vulpina L.		1	2	.	.	.	.	.	.	.	.	I	H
Alisma plantago aquatica L.		.	.	.	+	.	1	.	.	.	.	I	H
Festuça gigantea (L.) Vill.		.	2	.	+	.	.	.	.	.	.	I	H
Deschampsia caespitosa (L.) Beaur.		1	+	.	.	.	.	.	.	.	.	I	H
Oenanthe fistulosa L.		.	+	+	.	.	.	.	.	.	.	I	H
Succisa pratensis Mch.		.	.	1	.	.	.	.	.	.	+	I	H
Mentha aquatica L.		1	.	.	.	.	.	.	.	.	.	I	H
Roripa amphibia (L.) Bess.		.	2	.	.	.	.	.	.	.	.	I	
Senecio aquatica Huds.		.	+	.	.	.	.	.	.	.	.	I	H
Thalictrum flavum L.		.	+	.	.	.	.	.	.	.	.	I	
Poa palustris L.		+	.	.	.	.	.	.	.	.	.	I	H
Symphytum officinale L.		.	.	.	.	.	.	.	2	.	.	I	H
Accompanying species:													
Acer campestre L.	A	.	.	.	.	1	.	.	.	.	.	I	Ph
Crataegus oxyacantha L.	B	.	.	1	.	3	.	+	.	+	.	II	Ph
Rhamnus cathartica L.		.	.	+	.	.	.	.	.	2	.	I	Ph
Pyrus pyraster (L.) Borkh.		.	.	+	.	.	.	.	.	.	+	I	Ph
Acer tataricum L.		.	.	.	+	.	1	.	.	.	.	I	Ph
Acer campestre L.		.	.	.	.	1	.	.	.	+	.	I	Ph
Fraxinus americana		.	.	.	1	.	.	.	.	.	.	I	Ph
Euonymus europaea L.		.	.	.	.	+	.	.	.	.	.	I	Ph
Amorpha fruticosa L.		.	+	.	.	.	.	.	.	.	.	I	Ph
Aegopodium podagraria L.	C	1	.	.	.	.	.	.	+	.	.	I	H
Galeopsis speciosa Mill.		.	.	1	.	+	.	.	.	.	.	I	Th
Stellaria media (L.) Mill.		.	.	.	.	+	+	.	.	.	.	I	Ch
Melandrium rubrum Roehl.		.	.	+	.	.	.	.	.	.	+	I	H

Lychnis flos cuculi L.	.	.	.	+	.	.	.	.	.	.	I	H
Milium effusum L.	.	+	.	.	.	.	.	.	.	.	I	H
Hedera helix L.	.	.	.	.	+	.	.	.	.	.	I	Ph
Brachypodium silvaticum (Huds.) R.S.	.	.	.	.	+	.	.	.	.	.	I	H
Acer campestre L.	.	.	.	.	+	.	.	.	.	.	I	Ph
Rhamnus cathartica L.	.	.	.	.	+	.	.	.	.	.	I	Ph
Cerastium silvaticum W.K.	.	.	.	.	+	.	.	.	.	.	I	Ch
Geum urbanum L.	.	.	.	.	.	.	+	.	.	.	I	H
Angelica silvestris L.	.	.	.	.	.	.	.	+	.	.	I	H
Filipendula ulmaria (L.) Maxim.	.	.	.	.	.	.	.	.	1	.	I	H
Ajuga reptans L.	.	.	.	.	.	.	.	.	.	+	I	H
Galium silvaticum L.	.	.	.	.	.	.	.	.	.	+	I	H

Explanation of abbreviations:
A - Tree layer
B - Shrub layer
C - Ground vegetation layer

+, 1, 2, 3, 4, 5 - Combined assessment of abundance and cover (Braun-Blanquet 1964)

Biological range: The biological range of biological (living) forms according to Ranunkiaer (1905) from 10 phytocoenological recordings (Table 11) show the following relationship of plant species: phanerophytes (Ph) 33%, chamaephytes (Ch) 4%, hemicryptophytes (H) 55%, geophytes (G) 4%, therophytes (Th) 5%. Such a structure points to a distinctly hemicrypto-phanerophytic (55 + 33%) association.

Division of the phytocoenosis: Glavač (1959) divides the association into two subassociations: *typicum* - in a flooded zone, and *alnetosum glutinosae* (forest of narrow-leaved ash and black alder with summer snowflake) - in depressions out of a flood zone or on its edges, and in relief depressions under the strong influence of groundwater.

Syndynamics of the phytocoenosis: According to research by this author, the forest of narrow-leaved ash with summer snowflake in "Žutica" is in all stages of development (from initial to terminal - according to Glavač 1959). Narrow-leaved ash itself also occurs in all kinds of stands inhabiting different forms of micro-relief (from swamps to micro-elevations). As humidity in the site decreases, the association allows a drier association of pedunculate oak and great green weed remote sedge to take its place. Under more humid conditions, not even narrow-leaved ash survives, and the site is taken by the initial vegetation of willows and various swampy plants.

Stability of the phytocoenosis: Due to a disturbed rhythm of floods and a waterlogged terrain intersected with roads, the association shows a tendency to expand into lower positions inhabited by the association of pedunculate oak and great green weed. Narrow-leaved ash shows outstanding aggression in conquering more humid sites, producing an ample seed crop, and spreading its seed fast by water and wind. A comparison of the current state with that described by Medvedović (1975) shows that the forest of narrow-leaved ash has expanded into compartments 15, 20, 56b, 61b, 62b, 64f, 164b, 194c, 195c, and 196a, which were previously inhabited by forests of pedunculate oak and great green weed with remote sedge, and into compartments 33b and 58b, e, and f, previously inhabited by the forest of pedunculate oak and great green weed with quaking sedge. The full extent of regression is seen in compartments 27d and 72f, where an ash forest has replaced the earlier forest of pedunculate oak and common hornbeam after the pedunculate oak desiccated and ecological conditions changed. Apart from these changes in the associations themselves, the onset of narrow-leaved ash and the accompanying elements is visible in many localities.

Besides a complex in the southern and south-western region, there are also several initial areas of a successive character, resulting from the water let into the Management Unit "Žutica" by the water authorities. This association is expected to expand in the future.

Likewise, the seed of narrow-leaved ash is successfully invading clearings and forming young ash stands within complexes of lowland forests (Matić 1981). This can be seen in many places in "Žutica", particularly in the north-west and south part of the Management Unit.

Under normal conditions, the processes of vegetation succession lead towards the transition of a forest of narrow-leaved ash into a less humid forest of pedunculate oak and great green weed with remote sedge. In the Unit under study this is a very rare occurrence, and can only be seen in compartments 23b and 75a. Progression is visible along river courses, where deposits of materials have elevated the terrain and decreased humidity. Elements of oak forests are gradually suppressing hygrophyllic elements of ash forests, thus forming associations occupying a higher place in a succession series *Leucoio-Fraxinetum angustifoliae* → *Genisto elatae-Quercetum roboris* → *Carpino betuli-Quercetum roboris*.

Forest-economic characteristics: The importance of narrow-leaved ash should be emphasised from several standpoints. It is important as a pioneering species, and succeeds in unfavourable, mostly swampy conditions where other species cannot grow and where it has no competition. Furthermore, when stands of pedunculate oak in the association *Genisto elatae-Quercetum roboris* desiccate and the biotop changes and becomes waterlogged, ash represents an indispensable species in the restoration of desiccated stands. In the first stage, together with black alder, it takes the main role until conditions for the return of pedunculate oak are established. This was proved in the restoration of the forests Kalje, Turopoljski Lug, the forests in Pokuplje, and others. Finally, ash is a highly appreciated economic species, which periodically achieves the same price as pedunculate oak.

In the natural regeneration of narrow-leaved ash stands (Dekanić, 1961), shelterwood felling is done in two cuts (seeding and final), as ash is the most heliophyllic species. The minimal rotation period is 80 years.

OTHER ASSOCIATIONS
OSTALE ZAJEDNICE

Apart from the above mentioned and described associations, there are initially developed associations of willows in the south-west of "Žutica". These are stands of white willow (*Salix alba*), goat willow (*Salix caprea*) and grey willow (*Salix cinerea*). The conditions for the development of forest vegetation in these localities are very hard, as the terrain is mainly covered with almost impenetrable high sedges, while bushes of goat willow and grey willow are sporadically dispersed in small groups. White willow grows in the form of trees, but its numbers are low. Small groups of white willow are also sporadically arranged over the area. The following species occur in the ground vegetation: *Carex riparia*, *Carex vesicaria*, *Carex elata*, *Polygonum hydropiper*, *Lysimachia vulgaris*, *Leucoium aestivum*, *Iris pseudocorus*, *Stachys palustris*, *Euphorbia palustris*, and others, mostly swampy species, indicating high humidity in the site. This is not surprising, since the area is under the strong influence of flood and groundwater.

Unlike cultures of spruce (*Picea abies*) and Weymouth pine (*Pinus strobus*) which inhabit very small areas in the "Žutica", artificially raised cultures of Eu-

ro-American poplars (*Populus* x *euroamericana*) are much more numerous, for example in compartments 42a, 49c, 131b, 133, 137a, 138b, 173c, 182c, 183b, 193b, and others. They were raised primarily in order to restore the area after pedunculate oak dieback (most were established in 1968). Recordings from compartments 42a, 49c, 114c and 137b show that Euro-American poplars are enriched with a large participation of black alder (*Alnus glutinosa*) in the tree layer, while alder buckthorn (*Frangula alnus*) occurs in the shrub layer. *Carex vesicaria*, *Carex elata*, *Peucedanum palustre*, *Deschampsia caespitosa*, *Urtica dioica*, *Polygonum hydropiper*, *Juncus effusus*, *Lycopus europaeus*, *Lytrum salicaria*, *Myosotis scorpioides*, *Lysimachia vulgaris*, *Galeopsis tetrahit*, *Stachys palustris*, *Iris pseudacorus*, *Glechoma hederacea* and *Galium palustre* appear in the ground layer. This is indication of the return of autochthonous vegetation, above all, of black alder and its accompaniments, as pioneering species capable of surviving in changed site conditions (water logging, full light). Unless new disturbances take place, this slow progression is expected to continue towards autochthonous natural vegetation, from black alder towards pedunculate oak.

DISCUSSION
RASPRAVA

FACTORS OF DESTABILIZATION IN THE "ŽUTICA" ECOSYSTEM
ČIMBENICI DESTABILIZACIJE EKOSUSTAVA ŽUTICA

The forest of "Žutica" represents an ecosystem which has dramatically changed its natural appearance and stability primarily owing to man's activity. Regions of lowland forests in Croatia are currently under strong human influence; however, this influence is nowhere so pronounced as in "Žutica".

The forests of Central Posavina were primeval forests as late as the 18th century. Virtually untouched by man, these forests were not affected by any human influence, so they retained a perfect ecological balance.

The original influence of man on the ecosystems in the "Žutica" forests was limited to his exploiting them by cutting, using more elevated positions for building houses and settlements, and keeping livestock in forests and in fields.

The first major shock for these forests came when man's extensive activities disrupted the balance between the biocoenosis and the site. As pedunculate oakwood achieved outstanding values on the European market, almost every virgin forest in Posavina was cut down. Large-scale felling caused the climate and the hydrological conditions in the forests and their surroundings to change. The microclimate and macroclimate changed, and humidity increased. The negative influence of man increased by his favouring pedunculate oak and establishing its monocultures. Since this monoculture could not achieve a biological balance, it was prone to frequent

attacks by harmful insects. Repeated defoliation, combined with mildew and floods during the growing period, led to tree and stand dieback.

In 1930, dieback of lowland elm caused by Dutch Elm disease assumed epidemic proportions. The disappearance of elm from the understorey resulted in a changed climate: there was more light, the forests became warmer and drier, and the ecological balance was disturbed even more.

At the end of the 19th and the beginning of the 20th century, regulations of the water regimes of the Sava, Lonja and Česma took place. These hydro-improvement treatments, continuing until the present day, have had a highly damaging impact on the "Žutica" forest ecosystem. The river courses of the Sava, Česma and Lonja have been regulated, the Lonja-Strug canal and the Deanovec canal dug; the Lonjsko Polje drained, a retention at a height of 98.4 m above sea level made, and agricultural land around the forest ammeliorated. All this has disturbed water relations in the forest. Groundwater levels have dropped and floods are either absent or reach the forest at an unsuitable time, that is, when water management authorities let the water into the forest. Combined with other negative factors, this has resulted in forest dieback and regression processes, both in the plant communities and in the site.

Dry periods during the growing season are becoming more frequent. As a result, there is either a shortage of water, or more frequently, a surplus of water. Again, the main culprit is man. In order to exploit oil from "Žutica", man has built as many as 76 km of hard roads through the forest, most of them without adequate draining systems. The resulting "slots" trap the water, so it cannot retreat as it does under a normal regime. The trapped water remains until it evaporates, which leads to water logging of the terrain. The consequences are a lack of oxygen in the soil, decreased microbiological activity, and a decline in vegetation not adapted to these new conditions.

It is very important to mention that the area of the forest "Žutica" has been very intensively exploited for oil since 1964. A highly complex system of exploitation with as many as 289 oil wells has been erected in large clearings. These wells are connected with roads for motor vehicles and underground oil and water transport systems. Two central buildings of INA-Naftaplin have also been built in the area. These facilities have broken up the stands in the "Žutica" and exposed them to adverse external influences, thus leading to general dieback. The most pronounced cases of dieback are precisely around the oil wells. Another problem is that old oil pipes often burst and the oil spills into the forest, while restoration of the damage is inadequate and untimely. The soil becomes polluted, and roots and useful fauna cannot carry out their function. This causes the physiological weakening and desiccation of trees.

A further highly negative impact on the forest communities is exerted by the river Sava and its tributaries, which are badly polluted with toxic mechanical waste, unhumified faecal matter, large amounts of chemical waste, acids and various other toxic substances.

The situation is further aggravated by polluted air (SO_2, NOx, heavy metals and other materials) whose origin is difficult to ascertain. A part undoubtedly comes from industrial centres (Zagreb, Sisak, Kutina), a part relates to car traffic (immediate vicinity of the motorway), while a considerable part is brought to the area from distant European industrial regions by air currents.

Felling activities carried out after dieback also destroy the structure of stands and further influence the forest climate.

Apart from all these abiotic factors, biotic ones also play an important role. In the beginning of forest research, these were considered primary factors of forest decline. Today, however, they are regarded to have a secondary role: a weakened tree resistance allows harmful entomofauna, above all gypsy moths and plant diseases (mildew), to attack.

The ground vegetation along the river Lonja is badly damaged by cattle (pigs, cows and horses), and the soil is trodden down or routed up.

In conclusion, the forest of "Žutica" is a very complex ecosystem marked by a multitude of various factors and their combinations. This contributes to the complexity of the problem of desiccation, since the effect of harmful factors is mostly synergistic.

THE HISTORY OF DESICCATION IN THE MANAGEMENT UNIT "ŽUTICA"
POVIJEST SUŠENJA ŠUMA U GOSPODARSKOJ JEDINICI ŽUTICA

The first instances of dieback in "Žutica" occurred in 1910. Since then, desiccation intensity has been changing, but the first particularly strong occurrences of dieback took place between 1924 and 1927.

The problem of oak dieback was dealt with in the "Forest Paper" as early as 1878, but it did not worry forest experts of the time until a catastrophic dieback of Žutica" in 1925 took place. According to Nenadić, the dieback was of such pro - portions that it was regarded as the biggest national economic catastrophe of the time. The wood mass of dead oaks in 1924 alone was about 50,000 m^3, and the situation grew even worse the following year. Different researchers gave different reasons for the occurrence, but what it known is that in that year the flood coincided with defoliation. The same situation was repeated in the spring of 1965 and 1966. In the short period of 1966 - 1973, about 300,000 m^3 of wood mass desiccated. Total dieback occurred almost exclusively in micro-depressions where water remained for longer periods. Stronger instances of desiccation on micro-elevations were only sporadic, and occurred only on small elevations situated in the middle of a low terrain. Despite the fact that stagnant water did not remain there long, a high level of groundwater, reaching almost to the soil surface, had almost the same effect on the area browsed clean by cattle. According to an analysis carried out in 1968, between 1958 and 1968 a total of 244,900 m^3 of pedunculate oak desiccated. During the half-period 1968 - 1977, a further 69,660 m^3 of dead oak trees

were cut down, which amounted to a total of 314,560 m³ for a 20-year period. Such catastrophic dieback in a relatively small area had never happened before, and initiated a detailed study of this problem.

PRESENT CONDITION IN THE "ŽUTICA" ECOSYSTEM
SADAŠNJE STANJE EKOSUSTAVA ŽUTICA

The intensity of dieback is lower today, but the desiccation process, above all of pedunculate oak, is still continuing. The consequences of earlier disastrous dieback cases are still felt today, so that the proportion of sanitary fellings in the period 1988 - 1995 amounted to 25,259 m³, or 13.8%. At present, this is a very unstable ecosystem that requires careful handling and the application of silvicultural treatments aimed at restoring its lost ecological balance.

Each change in the intensity and dynamics of wetting (surplus or shortage of water) causes changes in the forest ecosystem. This is largely reflected in desiccation, as is the case here. Conditions causing catastrophic dieback have an impact on young, middle-aged, mature and old stands. The intensity of dieback is higher in older stands.

In order to assess the present condition of forests, the phytocoenology of all communities in the Management Unit "Žutica" was recorded in detail, and special attention was given to the consequences of pedunculate oak dieback in the last thirty years. The condition was compared with research by Rauš (1967 - 1973, 1980) and with Medvedović's vegetation map of the "Žutica" on a scale 1 : 50,000, also dating from 1975. The results of pedological research, as well as those of research into lowland forests in the areas affected by pedunculate oak dieback (Kalje, Turopoljski Lug, Pokuplje Basin), were also used.

From a phytocoenological standpoint, the condition is regarded normal when no significant changes in site conditions and in the structure of forest associations have occurred in the last thirty years, or when a progressive successive change towards a climatozonal association has taken place. In this respect, the presence of various successive processes linked primarily to anthropogenic (stressful) influences has been established.

The Forest of pedunculate oak and common hornbeam (*Carpino betuli-Quercetum roboris*) is relatively the most stable association of pedunculate oak in Croatia. In the last thirty years, its total surface area in "Žutica" has slightly increased. This is the result of progression, that is, of the syndynamic development of more humid associations, which has occasionally been accelerated by a drop in the groundwater level caused by hydro-meliorative activities (the best example is the locality of Žalkovo). The total area in progression is slightly over 300 ha; however, this association, too, was subjected to regression processes. Almost 60 ha of the association's sites are currently inhabited by black alder or narrow-leaved ash, and as many as 200 ha by forests of pedunculate oak and great green weed (80 ha is

the subassociation with quaking sedge, and 120 ha is the subassociation with remote sedge).

It should be stressed that the association of pedunculate oak and common hornbeam, being a terminal association in the development of forest vegetation of lowland Croatian regions, proved to be stable and resistant to dieback in other localities affected by pedunculate oak dieback (Kalje, Turopoljski Lug, Pokuplje Basin). This stable character was also confirmed by research in "Žutica" (Rauš 1980).

For the first time in this region, an association of pedunculate oak and great green weed with common hornbeam, or the so-called humid micro-elevation, was established in an area of about 150 ha. Of this, about 100 ha were the result of progression in the areas previously inhabited by the described subassociations of the association with quaking sedge and remote sedge. However, about 50 ha were established as a consequence of regression processes in the association of pedunculate oak and common hornbeam.

The biggest changes, regardless of whether they related to positive or negative succession, took place in the association of pedunculate oak and great green weed (*Genisto elatae-Quercetum roboris*). About 50 ha of the subassociation with quaking sedge (*caricetosum brizoides*) are inhabited by the forest of black alder, about 30 ha by a forest of narrow-leaved ash, while over 120 ha are covered by a more humid subassociation with remote sedge.

Site progression is visible on a very small area of about 40 ha (20 ha has turned into a subassociation with common hornbeam and about 20 ha into an association of pedunculate oak and common hornbeam). Therefore, this subassociation has considerably decreased its area.

Its floral composition has also undergone changes, so that an increased participation of plants of humid terrain is complemented with *Frangula alnus*, *Salix cinerea*, *Juncus effusus*, *Peucedanum palustre*, *Cirsium palustre* and others, while mesophyllic elements are gradually disappearing. All this indicates that the biotop is now waterlogged.

Rauš, studying the forest vegetation of "Žutica" in the period 1969 - 1973, confirmed that the forest of pedunculate oak and great green weed with quaking sedge was in a relatively stable condition and did not show any disturbances in its development and floral composition connected to small-scale pedunculate oak dieback. According to him, the subassociation was then in a state of progression.

However, research in other localities of pedunculate oak dieback shows almost identical results to those found and described in "Žutica" by this author, where serious consequences of stress and indiscriminate sites are visible. Floral compositions and the physiognomy and structure of stands have completely lost their character of typically developed subassociations in many places. Non-typical plants indicating a waterlogged biotop are dominant.

A more humid subassociation with remote sedge (*caricetosum remotae*) has also undergone considerable changes. Regression was recorded in as many as fifteen departments or compartments (about 200 ha), and the site was invaded by more

humid associations, of which 70 ha by the association of black alder, and 130 ha by the association of narrow-leaved ash. Currently, slightly over 50 ha are still under the association of pedunculate oak and great green weed with common hornbeam, while about 130 ha are under the association of pedunculate oak and common hornbeam; however, these are progression processes.

On the other hand, the area of this association has increased at the expense of the association of pedunculate oak and common hornbeam, mostly owing to increased terrain humidity and related regression processes. Slightly more than 120 ha are taken by this association, and about 120 ha by the association of pedunculate oak and great green weed with quaking sedge. In addition, as a consequence of the mainly natural succession of associations and their transition into drier ones, this subassociation has expanded over a further 80 ha of the previous forest of black alder and over about 50 ha of the previous forest of narrow-leaved ash.

All this indicates very intensive changes despite the fact that the association has more or less retained its surface area of thirty years ago.

On the basis of his research in "Žutica" (1980), Rauš concluded that this subassociation was in regression, because its stability was largely disturbed by the dieback of lowland elm, followed by the sudden and mass dieback of pedunculate oak. Such conditions led to the development of ample weed vegetation, a surplus of stagnant water and water logging of the terrain.

This situation, although on a smaller scale, is confirmed by current research. Today, regression processes in the subassociation with quaking sedge are somewhat larger, which coincides with the results of vegetation research in Kalje, Turopoljski Lug and the Pokuplje basin.

In the meantime, pioneering species of black alder and narrow-leaved ash have filled bare land and empty areas left after dieback, which has had a positive effect on the gradual stabilisation of these stands.

Thus, the total area under the association of black alder with alder buckthorn (*Frangulo-Alnetum glutinosae*) has been enlarged by about 80 ha in relation to 1975, (Medvedović). However, this was rather difficult to establish, since black alder grows very intensively around the majority of the 289 oil wells existing in the area, developing the association of black alder with alder buckthorn. Therefore, it can be concluded that the size of the area under this association is much larger than mentioned above. Next, some 25 ha refers to the entrance of black alder into the previously bare land, while the second expansion of black alder relates to regression processes in the site and stands in "Žutica". Black alder took over 70 ha of the area which, according to Medvedović (1975), was under the association of pedunculate oak and great green weed with remote sedge, and 40 ha under the association of pedunculate oak and common hornbeam.

However, changes in site conditions and the progression of vegetation caused black alder to diminish by almost 80 ha in favour of the association of pedunculate oak and great green weed with remote sedge, by 50 ha in favour of the association of pedunculate oak and great green weed with quaking sedge, and by about 30 ha

in favour of the association of pedunculate oak and great green weed with common hornbeam.

The results of the current research were compared with the situation in 1975 (Medvedović). It can be seen shown that the penetration of narrow-leaved ash and the related association of narrow-leaved ash and summer snowflake (*Leucoio-Fraxinetum angustifoliae*) into the previously bare land and the area inhabited by other associations is even stronger than was the case with black alder. The negative factors mentioned earlier have led to pedunculate oak dieback and caused abrupt changes in ecological site conditions, which have resulted in more humid conditions and the possibility of narrow-leaved ash, being a pioneering, fast-growing species with light seed, expanding into smaller or bigger areas under different associations. These include swampy areas, micro-depressions and micro-elevations.

The same pattern emerges as with black alder: the higher the terrain and the drier the association, the weaker the onset of narrow-leaved ash. Thus, the association of narrow-leaved ash with summer snowflake covers over 120 ha of the land previously inhabited by the association of pedunculate oak and great green weed with remote sedge. About 30 ha of the sites belonging to the association of pedunculate oak and great green weed with quaking sedge, and 15 ha of the sites of the association of pedunculate oak and common hornbeam are covered by forests of narrow-leaved ash.

All these forests of narrow-leaved ash were formed through regression processes. A normal site progression and a transition of forests of narrow-leaved ash into drier associations occurred over only 70 ha. The association of narrow-leaved ash with summer snowflake passed into the association of pedunculate oak and great green weed with remote sedge on 50 ha, and the association of pedunculate oak and common hornbeam on about 20 ha. It should be stressed that over 100 ha of the previously bare soils are now covered with forests of narrow-leaved ash with summer snowflake in various stages of development. These forests were created either naturally, or with the help of man (by planting seedlings), but they are mostly in the initial stage that frequently passes into the optimal one.

In conclusion, all this confirms that over 700 ha of the most interesting and valuable forests of pedunculate oak underwent intensive and abrupt external and internal influences during dieback some thirty years ago. The principal tree species desiccated, the site conditions and forest communities changed, and a negative succession of forest vegetation took place. In order to obtain the final picture and a complete syndynamic development in "Žutica", the results should be complemented with those of pedological research.

The results of all research have been used to draw up a vegetation map on a scale 1:25,000 of forest associations in the Management Unit "Žutica". The mapping was based on the instructions from the "Manual of typological research and vegetation mapping" (Horvat et al. 1950). A total of eight vegetative units (associations and subassociations) was presented, including the association of pedunculate oak and great green weed with common hornbeam for the first time in this area.

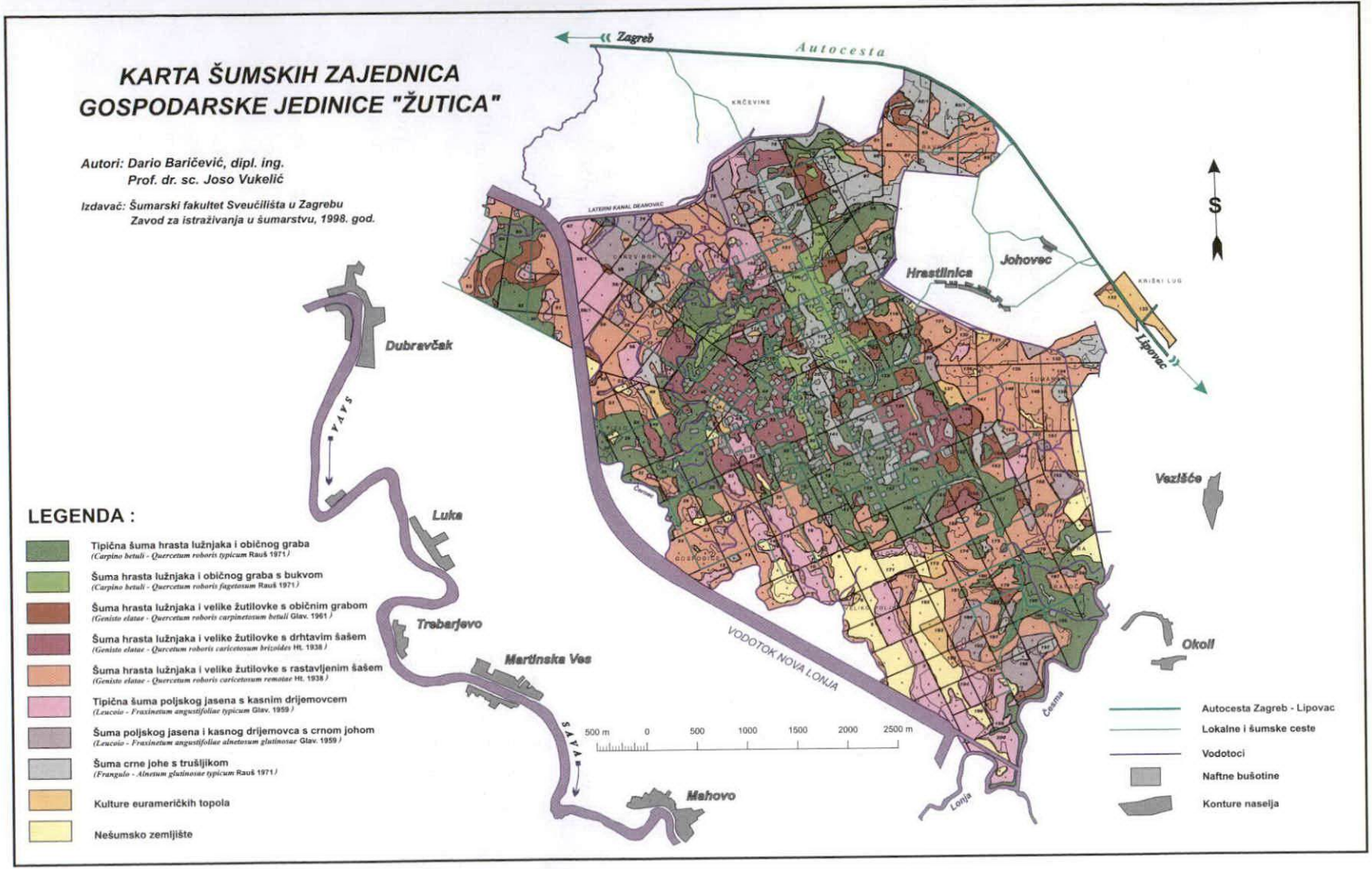


Figure 2. Map of forest associations in the Management Unit "Žutica"

The phytocoenological map shows the real state of forest phytocoenoses in the studied area, as well as the development dynamics of vegetation. It can be used as a starting point in planning and carrying out all the activities within the ecosystem (management, tending and other tasks). Next, it can also be used in climatological, pedological, economic, management and other research.

In general, it is hard to predict the direction of vegetation development in the studied area. It mostly depends on man's influence on the ecosystem. Degradation processes should be stopped with various meliorative and silvicultural measures. Natural principles should be followed, taking into account each case as it is. Areas under more humid associations are expected to expand, especially in the south, south-west and north-west part of the Management Unit under the forest of narrow-leaved ash, and in the north-east area of black alder forests around oil wells and in "slots". However, despite the considerable negative influence of various factors on the ecosystem, natural succession and the development of forest associations will continue their normal course in many places, that is, there will be a change from more humid towards drier associations.

SILVICULTURAL TREATMENTS IN STANDS WITH DAMAGED STRUCTURES AND SITES
UZGOJNI POSTUPCI U STRUKTURNO I STANIŠNO OŠTEĆENIM SASTOJINAMA

The ecosystem of the Management Unit "Žutica" has largely altered its natural appearance, and is in various stages of site and association degradation. As a result, the situation in the area of the Management Unit is highly varied in terms of conditions in forest associations. Therefore, in choosing proper silvicultural procedures, the existing situation should be taken into account. The Management Unit has a variety of forms. There are degraded flat areas with stagnant surface water, non-forested areas thickly covered with weeds, stands in one of the stages of degradation (thicket, brushwood), low silvicultural forms or coppices, and areas where natural or artificial regeneration with pedunculate oak have failed, and are consequently waterlogged or covered with weeds and subject to the succession of pioneering species. On the other hand, there are bigger or smaller areas with unbroken horizontal and vertical structures of good appearance and well-preserved soil, and areas where regeneration with pedunculate oak has been very successful.

Before these stands are regenerated and reconstructed, a thorough review of the area should be made, and a detailed forest management plan made, prescribing silvicultural treatments for each particular case.

Next, all accessible causes of degradation should be eliminated, and degraded areas put into progression by first restoring the most threatened areas, and then those with a lower degree of degradation. The preservation of forest soil from degradation should be given priority in establishing the sequence of treatments.

In applying silvicultural procedures to stands with damaged structures and sites, we should follow the principles set down by Matić (1989), Matić & Skenderović (1993), Matić et al. (1994), Matić (1996), Matić et al (1996), which have proved successful in other areas afflicted with similar ecological disturbances (Kalje, Turopoljski Lug, the Pokuplje basin).

Old oak stands in the central part of "Žutica", which have retained their coherence, adequate growing stock, mixture ratio and other structural and site properties, should be further tended and supported for the production of wood mass and use of trees as natural water pumps, and for gradual natural regeneration. Other healthy stands should also be tended and formed into coherent smaller or bigger stands, which will continue their production under new conditions in the soil.

Stands should also be regenerated in compartments 64a, 70b, 107a, 113b, 119b, 126d, 131c, 179b and others, where desiccation has reduced the growing stock by over 30%, leaving incoherently covered areas, but site conditions have not changed so much as to prevent the survival of pedunculate oak seedlings. Along with natural regeneration with the existing and newly formed young growth of the principal tree species, artificial regeneration should also be applied by introducing acorns or seedlings of pedunculate oak on the principle of shelterwood felling.

Natural and artificial regeneration, combined with the shelterwood method in small areas or circles should be the main principle of regenerating these stands.

In compartments 25d, 37, 63a, 103a, 104d, 122b, 155b and others, the desiccation of pedunculate oak and elm occurred in larger proportions, so that groups of oaks alternate with groups of ashes and alders, there are bigger or smaller gaps, and the forest cover has been halved. However, the remaining trees have good chances of survival, so these stands should be restocked with black alder or narrow-leaved ash. In this manner, the continuity of the still immature pedunculate oak stand will be ensured by establishing a stand of pioneering species which will protect the soil, form storeys, maintain a favourable stand climate, and gain good increment.

In areas with a higher degree of degradation, such as compartments 27d, 36b, 63a, 72f, 104b, 179e, 187b and some others, causes of degradation should first be eliminated from the terrain. In these compartments, conditions for the development of vegetation are very difficult. They are mostly covered with pedunculate oak stands heavily afflicted by large-scale desiccation. The ecological balance is disturbed, the canopy is permanently broken in many places, the terrain is waterlogged, the shrubs are thick and rich, and narrow-leaved ashes and black alders are appearing. In some extreme cases (for example, in compartment 117), even black alders are desiccating, leaving only weed-covered areas. Prior to planting such areas with pioneering species, weeds should be destroyed by mechanical means. Black alder, narrow-leaved ash and other pioneering tree species should be planted, bearing in mind the conditions in every site and the ecological requirements of each

particular tree species. In order to prepare the site for planting pioneering tree species, it is necessary to drain the surface by digging shallow canals or vents in places where water stagnates in artificially formed "slots".

In degraded sites, pedunculate oak should be obtained indirectly by introducing pioneering tree species, especially narrow-leaved ashes, black alders, willows, poplars and others. It should be stressed that pedunculate oak is not and cannot be a pioneering tree species (Matić 1996), because it does not tolerate degraded soil.

In 1970, Professor Dekanić began an experiment in "Žutica" (compartment 114) aimed at determining the most favourable tree species and methods of regeneration in devastated areas resulting from pedunculate oak dieback. The results show that it is practically very difficult, if not almost impossible, to immediately regenerate degraded areas with autochthonous tree species, except for black alder. Black alders, white willows and Euro-American poplars can be used as pioneering, or transitional tree species, which will, in combination with silvicultural and other measures, form conditions for the arrival of more valuable tree species. Further research in these same experimental plots after twenty years (Oršanić, Matić, Anić 1996), confirmed that pedunculate oak was not suitable for planting in dieback-affected areas. Black alder, narrow-leaved ash, poplar and white willow are recommended. The best quality of trees and wood mass were achieved in the cultures of black alder and Euro-American poplar, clone I-154. It should be pointed out that a period of 25 years is not long enough for pioneering species to play their meliorative role.

To sum up, we could say that the measures applied to forests are aimed at maintaining the biological balance in the ecosystem. Each member of the community, from the living world in the soil to the dominant trees and every site factor, should be paid due attention. Judging by the situation so far, it is clear that better-organised and stronger forestry policy is needed in relation to the co-users of the same area, first of all the water management and the oil industry. Forestry experts are the most knowledgeable about forest ecosystems, and without their say when important decisions related to interventions into the ecosystem are made, little progress can be made.

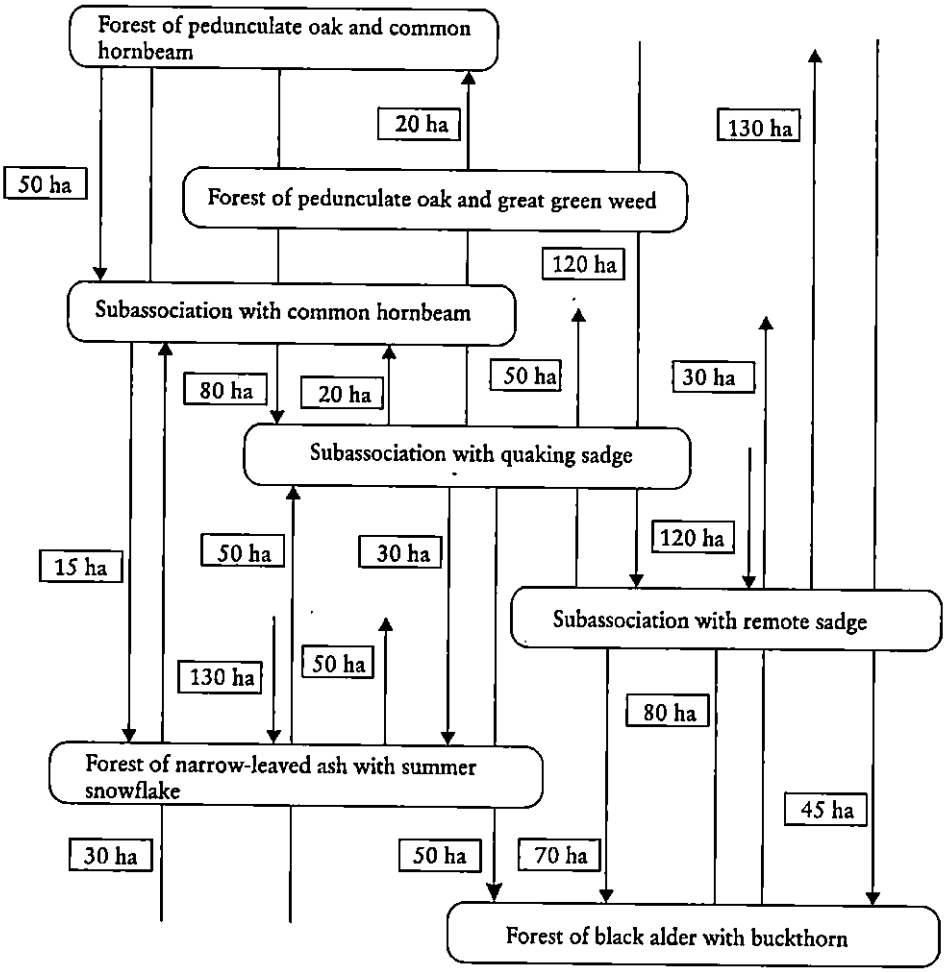
CONCLUSIONS
ZAKLJUČCI

1. The author established and described eight forest associations over an area of 5,107 ha, of which the association of pedunculate oak and great green weed with common hornbeam was described for the first time in this area. A disturbed ecosystem was detected in most of them.
   The systematic position of the studied and described communities is as follows:

Class: *Querco-Fagetea* Br.-Bl. et Vlieg. 1937
Order: *Fagetalia sylvaticae* Pawl. 1928
Alliance: *Carpinion betuli* Ht. 1956
Association: *Carpino betuli-Quercetum roboris* (Anić 1959) emend. Rauš 1969
Subass: *typicum* Rauš 1971
Subass: *fagetosum* Rauš 1971

Class: *Alno-Populetea* Fk. et Fb. 1964
Order: *Populetalia albae* Br.-Bl. 1931
Alliance: *Alno-Quercion roboris* Ht. 1938
Association: *Genisto elatae-Quercetum roboris* Ht. 1938
Subass: *caricetosum remotae* Ht. 1938
Subass: *caricetosum brizoides* Ht. 1938
Subass: *carpinetosum betuli* Glav. 1961
Association: *Frangulo-Alnetum glutinosae* Rauš 1968
Subass: *typicum* Rauš 1971
Association: *Leucoio-Fraxinetum angustifoliae* Glav. 1959
Subass: *typicum* Glav. 1959
Subass: *alnetosum glutinosae* Glav. 1959

2. The first instances of dieback in these forests occurred in 1910, and have continued with higher or lower intensity until today. At present, the desiccation intensity is lower, but the participation of sanitary fellings in the period 1988 - 1995 was 13.8%, or 25,259 m^3.
3. The causes of aberrations from normal forest associations of lowland regions, as well as of the overall destabilization of the "Žutica" forest ecosystem, have a synergistic nature. The principal causes include badly conducted regulations of waterways and melioration, and the related drop in groundwater levels and changes in the natural rhythm of floods, as well as the terrain being turned into waterlogged "slots" by a network of hard roads with inadequate draining systems. Normal relations among synecological factors have been disturbed, leading to changes in the participation of principal tree species, floral compositions and forest associations, as well as to the instability of forest stands and other problems.
4. The progression and regression scheme of forest associations in the studied area in the last twenty-five years is as follows:



5. All this confirms that over 700 ha of the most interesting and valuable forests of pedunculate oak suffered very intensive and abrupt external and internal influences during dieback some thirty years ago. The principal tree species desiccated, the site conditions and forest associations changed, and a negative succession of forest vegetation took place. The final picture and complete syndynamic development can only be obtained in correlation with pedological and other research in "Žutica".
6. A vegetation map of forest associations in the Management Unit "Žutica" on a scale 1:25,000 was drawn up on the basis of phytocoenological and other research. The map, providing the real situation in the forest phytocoenoses of the studied area and pointing to the dynamics of vegetation development, can serve as a starting point for planning and carrying out

various activities within the ecosystem (tending, management, and other tasks).

In general, it is difficult to predict the future development of vegetation in the studied area as it mostly depends on the influence of man on the ecosystem. Areas under more humid associations are expected to continue expanding, particularly in the south, south-west, and north-west part of the Unit inhabited by forests of narrow-leaved ash, and in the north-east part under forests of black alder, mainly in the "slots" and around oil wells. However, despite the large negative influence of various factors on the ecosystem, natural succession and the development of forest associations in many places will continue their normal course, that is, will go from more humid to drier associations.

7. The biological spectrum of life forms according to Ranunkiaer (1905) shows that all the associations in the studied area are hemicryptophytic-phanerophytic. This places them into the Central European region, shows their resistance to winter colds, and indicates very warm summers.
8. The processes of degradation can be stopped, and sites and associations put into their normal condition and progression, only by applying a multidisciplinary approach.
9. The silvicultural principles set down by Matić (1989), Matić and Skenderović (1993), Matić *et al.* (1994), Matić (1996), Matić *et al.* (1996) should be applied to treat the damaged structures and stands in the forest of "Žutica". These principles have proved very successful in other areas affected by similar ecological disturbances (Kalje, Turopoljski Lug, the Pokuplje basin).
10. The field monitoring of water movement on and in the soil with piezometers (permanent monitoring), already conducted in some other lowland ecosystems, is the best way of arriving at exact data on the water regime in the forest. It is also one of the principal indicators for managing forest ecosystems of lowland regions. With reǵard to significant changes and desiccation caused mainly by changes in the water regime, this system should also be introduced into the area of "Žutica".
11. Man and his activities in the field of water management and the oil industry have always been the main destabilising factor in the "Žutica" ecosystem. Better-organised and stronger forestry policy is needed in relation to other co-users of the same area. Forestry experts are those who know best about forest ecosystems, and without their equal participation in important decisions relating to treatments in the ecosystem, little progress can be made.

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EKOLOŠKO-VEGETACIJSKE ZNAČAJKE ŠUME ŽUTICA

SAŽETAK

Nizinska šumska područja u Hrvatskoj u drugoj su polovici ovoga stoljeća pod jakim meliorativnim, tehnološkim i drugim antropogenim utjecajima, što je u jednom sinergističkom djelovanju izazvalo mjestimične promjene i nestabilnosti šumskih ekosustava. Ti su utjecaji uzrokovali u pojedinim dijelovima savskoga toka u zapadnom dijelu Hrvatske značajno sušenje šuma, a u drugim područjima različite sindinamske promjene vezane uz povlačenje ili pak širenje pojedinih vrsta drveća ili šumskih zajednica.

U tom je smislu poglavito značajna šuma Žutica, u kojoj se promijenio normalan odnos sinekoloških čimbenika, što je imalo za posljedicu promjenu udjela glavnih vrsta drveća, flornoga sastava i pridolaska šumskih zajednica, nestabilnost šumskih sastojina i drugo. Zbog toga je šuma Žutica vrijedan i zanimljiv objekt znanstvenih vegetacijskih istraživanja.

Žutica je šumski kompleks između autoceste Zagreb – Lipovac na sjeveru, rijeke Save na jugu, rijeke Lonje na zapadu i rijeke Česme na istoku.

Ukupna površina gospodarske jedinice iznosi 6 116, 68 ha, od čega je obraslo šumskim sastojinama 5 107,41 ha, a neobraslo i neplodno 1 009,27 ha.

U tri godine istraživačkoga rada završen je fitocenološki opis, snimanje, sistematizacija i kartiranje šume Žutice. Osim toga, uspoređeno je sadašnje stanje sa stanjem ovih šuma u prošlosti (Dekanić 1962, Medvedović 1975, Rauš 1980) i s rezultatima istraživanja nizinskih šuma u kojima se suši hrast lužnjak (Kalje, Turopoljski lug, Pokuplje).

Šuma Žutica predstavlja ekosustav koji je djelovanjem čovjeka uvelike promijenio svoj prirodni izgled i prirodnu stabilnost.

Šume srednje Posavine još su u 18. stoljeću bile prašume, gotovo netaknute od čovjeka, ritam njihova razvoja nije bio ničim ometan te je u njima vladala savršena ekološka ravnoteža.

Izravni utjecaj čovjeka u ekosustav Žutice svodio se prošlih razdoblja na iskorištavanje šuma sječom, boravak na povišenijim dijelovima te držanje stoke u šumi i na poljima.

No, prvi veći šok za ove šume nastao je čovjekovim naglim zahvatima koji su unijeli nesklad u ravnotežu biocenoza – stanište. Zbog vrijednosti lužnjakova drva na europskom tržištu u 19. stoljeću posječene su gotovo sve nekadašnje prašume u Posavini. Velike sječe izazvale su promjenu klime i hidroloških prilika u šumama i njihovoj okolici. Promijenila se mikroklima i makroklima te se povećala vlažnost. Negativni se utjecaj čovjeka nastavio forsiranjem hrasta lužnjaka i stvaranjem monokultura hrasta lužnjaka. U monokulturama nije uspostavljena biološka ravnoteža pa su šumu češće napadali štetni kukci. Ponovljeni golobrst te pepelnica, zajedno s poplavama tijekom vegetacijskoga razdoblja izazvali su sušenje stabala i sastojina.

Godine 1930. započelo je i epidemijsko ugibanje nizinskoga brijesta koje uzrokuje holandska bolest. Nestankom brijesta iz podstojne etaže promijenila se klima, u šumi je postalo svjetlije, toplije i suše, što je još više poremetilo ekološku ravnotežu.

Do početka 20. stoljeća veliki su prostori u Posavini bili izloženi poplavama, no hidrotehnički zahvati tijekom ovoga stoljeća uvelike su smanjili poplavne površine.

Već od kraja 19. stoljeća pa do danas planiraju se i provode veliki radovi na uređenju vodnih režima naših rijeka. Zbog toga su se promijenili vodni odnosi u staništu šume, snizila se razina podzemne vode, poplave ili izostaju ili poplavna voda dolazi u šumu u nepogodno vrijeme, tj. kada je vodoprivreda pušta u šumu. Sve je to, uz druge negativne čimbenike, utjecalo na slabljenje otpornosti pojedinih stabala, sušenje šuma i na regresijske procese i biljnih zajednica i staništa.

Čovjek je za svoje potrebe izgradio velik broj tvrdih cesta i nasipa kroz šumske ekosustave u GJ Žutica, koji nažalost uglavnom nemaju adekvatno riješene propuste za vodu, pa se teren kazetira, a voda koja dođe na određeno područje ne može se povući kao kod normalnoga režima, već ostaje zarobljena dok ne ispari, zbog čega se zemljište zamočvaruje. Na taj se način stanište degradira, nestaje kisika u tlu, smanjuju se mikrobiološke aktivnosti i propada vegetacija neprilagođena na takve uvjete.

Utjecaj je čovjeka na GJ Žutica i režim njezinih voda velik, pa je u vodoprivrednim planovima dobila ulogu retencijskoga prostora za visoke vode rijeke Save, Česme i Lonje, te je tako u potpunosti, osim predjela Žalkovo, okružena novim riječnim tokovima i nasipima. Nažalost sve to nije usklađeno s prirodnim odnosima pa su nastali vrlo veliki poremećaji ekosustava.

Vrlo je važno istaknuti da je Žutica pojačano eksploatirano naftno područje još od 1964. godine. Razvijen je složeni sustav ekploatacije sa čak 289 naftnih bušotina na velikim čistim proplancima, povezanim putovima za motorna vozila s proširenim stazama za podzemni odvod nafte i dovod vode te s dva velika središnja objekta INA-Naftaplina. Ti su, za šumu strani objekti razbili kompaktnost šume Žutice, čime su sastojine razbijene i izložene nepovoljnim vanjskim utjecajima, što je uzrokovalo i ubrzalo opće sušenje. Moramo naglasiti da su danas najbolje vidljiva sušenja upravo oko naftnih postrojenja. Veliku štetu čini pucanje dotrajalih naftovoda i izlijevanje nafte, uz neadekvatnu sanaciju. Tlo se onečišćuje, onemogućava se funkcija korijenja i korisne faune u tlu, što pak izaziva fiziološko slabljenje i odumiranje stabala.

Vrlo negativan utjecaj na šumske zajednice imaju i zatrovane i onečišćene vode rijeke Save i njezinih pritoka, u koje se slijeva mehanički otpad, nehumificirane fekalije, velika masa kemijskoga otpada, kiseline te razne druge otrovne supstancije.

Šuma je uz to sve više opterećena onečišćenim zrakom (SO_2, NO_x, teški metali i dr.), čije je porijeklo teško utvrditi. No, sigurno jedan dio potječe iz naših industrijskih središta (Zagreb, Sisak, Kutina), dio se odnosi na automobilski promet (neposredna blizina autoceste), dok značajan dio otpada na daljinski transport onečišćenoga zraka, koji zračnim strujanjima dolazi do naše zemlje iz udaljenijih europskih industrijskih područja.

Zasigurno se i sječom nakon znatnih sušenja narušava struktura sastojina, što utječe na promjenu šumske klime.

Uza sve spomenute abiotske čimbenike ne treba isključiti ni biotske, koji su se u prvo vrijeme istraživanja smatrali primarnim čimbenicima propadanja šuma, dok u današnje vrijeme prema većini autora imaju sekundarnu ulogu.

Iz svega izrečenoga može se reći da je šuma Žutica jedan vrlo složen ekosustav uvjetovan mnoštvom raznolikih čimbenika te njihovim kombinacijama, tako da je i problem sušenja vrlo kompleksan, posebno znajući da je djelovanje štetnih čimbenika uglavnom sinergetičko.

Sušenje je u šumi Žutici prvi put uočeno 1910. godine. Otada do danas nekada je veće, nekada manje. Prvo je osobito jako sušenje bilo od 1924. do 1927. godine.

Obujam hrastovih sušaca samo u 1924. godini iznosio je oko 50 000 m^3, a stanje se sljedeće godine još i pogoršalo. Uzroci tomu su prema pojedinim istraživačima različiti, ali se zna da je tih godina poplava koincidirala s defolijacijom, kao što se to dogodilo i u proljeće 1965. i 1966. godine. U kratkom razdoblju od 1966. do 1973. godine posušilo se oko 300 000 m^3 drveta. Potpuna su sušenja gotovo isključivo nastala u nizama gdje se voda duže zadržavala. Na gredama je jačeg sušenja bilo samo mjestimično. Takvo katastrofalno sušenje na relativno maloj površini nije se nikada ranije dogodilo te je bilo povodom da se istraživanja ovoga problema nakon dugoga vremena ponovno pojačaju.

Danas je sušenje slabije, ali i dalje traje sušenje ponajprije hrasta lužnjaka, a uvelike se osjećaju i posljedice prijašnjih katastrofalnih sušenja, tako da je udio sanitarnih sječa od 1988. do 1995. godine 13,8 %, što iznosi 25 259 m^3. Možemo reći da je ovo sada jedan vrlo labilan ekosustav kojim je potrebno vrlo pažljivo gospodariti težeći uzgojnim postupcima koji će ekosustav dovesti u što veću ekološku ravnotežu.

Svaka promjena u jačini i dinamici vlaženja u svezi sa suviškom ili manjkom vode izaziva i promjene u šumskom ekosustavu. One se najčešće, kako je to i ovdje slučaj, očituju u sušenju. Uvjeti koji izazivaju katastrofalno sušenje djeluju na mlade, srednjodobne, starije i stare sastojine, s tim da se starije sastojine više suše.

Na obrasloj površini od 5 107 ha utvrđeno je i opisano 8 šumskih zajednica, od kojih je zajednica hrasta lužnjaka i velike žutilovke s običnim grabom (*Genisto elatae-Quercetum roboris carpinetosum betuli* Glav. 1961) prvi put opisana na ovome području.

Sistematski položaj istraženih i opisanih zajednica je sljedeći:

Razred: *Querco-Fagetea* Br.-Bl. et Vlieg. 1937
red: *Fagetalia sylvaticae* Pawl. 1928
sveza: *Carpinion betuli* Ht. 1956
as.: *Carpino betuli-Quercetum roboris* (Anić 1959) emend. Rauš 1969
subas.: *typicum* Rauš 1971
subas.: *fagetosum* Rauš 1971

Razred: *Alno-Populetea* Fk. et Fb. 1964
red: *Populetalia albae* Br.-Bl. 1931
sveza: *Alno-Quercion roboris* Ht. 1938
as.: *Genisto elatae-Quercetum roboris* Ht. 1938
subas.: *caricetosum remotae* Ht. 1938
subas.: *caricetosum brizoides* Ht. 1938
subas.: *carpinetosum betuli* Glav. 1961
as.: *Frangulo-Alnetum glutinosae* Rauš 1968
subas.: *typicum* Rauš 1971
as.: *Leucoio-Fraxinetum angustifoliae* Glav. 1959
subas.: *typicum* Glav. 1959
subas.: *alnetosum glutinosae* Glav. 1959

Prisutne su još inicijalne vegetacije vrba i šaševa te kulture euroameričkih topola (*Populus* x *euramericana*) u koje ulaze prirodne, pionirske vrste poljski jasen i crna joha, kao i na vrlo maloj površini kulture smreke (*Picea abies*) i borovca (*Pinus strobus*).

Biološki spektar životnih oblika po Ranunkiaeru (1905) pokazuje da su sve zajednice istraživanoga područja hemikriptofitsko-fanerofitske, što opredjeljuje ove zajednice u srednjoeuropsku oblast, pokazuje njihovu otpornost protiv zimske hladnoće te indicira vrlo toplo ljeto.

S fitocenološkoga gledišta normalnim smatramo stanje kada u tridesetak godina nema značajnih promjena u stanišnim uvjetima i građi šumskih zajednica ili kada je pak došlo do progresivnoga sukcesivnoga pomaka u smjeru klimatskozonalne zajednice nekoga područja.

Analiza vlastitih fitocenoloških snimaka te usporedba karte rasprostiranja šumskih zajednica u GJ Žutica (Medvedović 1975) i današnjega stanja pokazuje da je šuma hrasta lužnjaka i običnoga graba, relativno najstabilnija zajednica hrasta lužnjaka u Hrvatskoj, u proteklih trideset godina donekle povećala svoju ukupnu površinu. To je rezultat progresije, tj. sindinamskoga razvitka vlažnijih zajednica, koji je na pojedinim lokalitetima ubrzan sniženjem razine podzemnih voda zbog hidromelioracijskih radova (najljepši je primjer lokalitet Žalkovo). Ukupna površina na kojoj se događala i događa progresija nešto je preko 300 ha, no unatoč tomu i ova je zajednica bila podložna regresivnim procesima. Gotovo na 60 ha staništa ove zajednice danas su sastojine crne johe ili poljskoga jasena, a čak na 200 ha šuma hrasta lužnjaka i velike žutilovke (80 ha subasocijacija s drhtavim šašem i 120 ha subasocijacija s rastavljenim šašem).

Važno je napomenuti da se zajednica hrasta lužnjaka i običnoga graba na drugim lokalitetima sušenja hrasta lužnjaka (Kalje, Turopoljski lug, Pokuplje), kao terminalna zajednica u razvoju šumske vegetacije nizinskoga područja Hrvatske, pokazala stabilnom i otpornom na sušenje, a to su stabilno stanje pokazala i istraživanja u Žutici (Rauš 1980).

Na površini od oko 150 ha prvi je put na ovom području izdvojena i zajednica hrasta lužnjaka i velike žutilovke s običnim grabom ili tzv. vlažna greda. Od toga je

oko 100 ha nastalo kao posljedica progresije na površinama gdje su prije bile opisane subasocijacije ove zajednice s drhtavim šašem i s rastavljenim šašem. No, oko 50 ha nastalo je kao posljedica regresijskih procesa u zajednici hrasta lužnjaka i običnoga graba.

Najveće promjene, bilo da se radi o pozitivnoj ili negativnoj sukcesiji, doživjela je zajednica hrasta lužnjaka i velike žutilovke s drhtavim šašem. Tako na staništu ove subasocijacije danas na više od 50 ha imamo šumu crne johe, na 30 ha šumu poljskoga jasena, dok je na više od 120 ha danas vlažnija subasocijacija s rastavljenim šašem.

Pregledom svih ovih odjela mogu reći da na istraživanom području drhtavi šaš (*Carex brizoides*) sve intenzivnije ulazi na grede u stanište graba gdje ga ima više nego u tipski opisanoj šumi, što upućuje na zaključak da mu je na pojedinim mjestima previše vlažno te da traži suša staništa. Sušenje hrasta lužnjaka dosta je primjetno, a subasocijacija je također izložena regresiji. Na manjim površinama vidljiv je prodor crne johe i poljskoga jasena u svim slojevima.

Progresija se staništa primjećuje na mnogo manjoj površini, i to na približno 40 ha (20 ha je prešlo u subasocijaciju s običnim grabom i oko 20 ha u zajednicu hrasta lužnjaka i običnoga graba) pa je ova subasocijacija znatnije smanjena po svojoj površini.

U njezinu flornom sastavu također su uočljive promjene pa uz povećani udio biljaka vlažnih terena rastu: *Frangula alnus, Salix cinerea, Juncus effusus, Peucedanum palustre, Cirsium palustre* i dr., dok mezofilni elementi polako iščezavaju. Sve to upućuje na zamočvarenost biotopa koji nije bio takav.

Važno je napomenuti da je Rauš, istražujući šumsku vegetaciju GJ Žutica u razdoblju od 1969. do 1973. godine, ustvrdio da se šuma hrasta lužnjaka i velike žutilovke s drhtavim šašem nalazi u relativno stabilnom stanju i da ne pokazuje nikakve poremećaje u razvoju i flornom sastavu vezano uz sušenje hrasta lužnjaka, koje je bilo neznatno. Subasocijacija se po njemu u GJ Žutica tada nalazila u progresiji.

S druge strane, istraživanja na ostalim lokalitetima sušenja hrasta lužnjaka pokazuju rezultate koji su gotovo istovjetni stanju koje sam zatekao i opisao u GJ Žutica. Dakle, zbog stresa i neizdiferenciranosti staništa nastaju teške posljedice. Florni sastav sastojina, njegova fizionomija i struktura na mnogim lokalitetima potpuno su izgubili karakter tipski razvijene subasocijacije, a prevladavaju netipične biljke koje indiciraju zamočvarenost biotopa.

Druga, vlažnija subasocijacija s rastavljenim šašem (*caricetosum remotae*) doživjela je također veće promjene, tako da je čak u petnaest odjela ili odsjeka (oko 200 ha) zabilježena regresija pa su stanište ove zajednice zauzele vlažnije zajednice, i to na 70 ha zajednica crne johe i 130 ha zajednica poljskoga jasena. Danas je još nešto više od 50 ha pod zajednicom hrasta lužnjaka i velike žutilovke s običnim grabom i oko 130 ha pod zajednicom hrasta lužnjaka i običnoga graba, no ovdje se radi o progresijskim procesima.

S druge strane, površina se ove zajednice povećala uglavnom zbog povećane vlažnosti terena i s tim povezanim regresijskim procesima, i to na račun zajednice hrasta lužnjaka i običnoga graba na nešto preko 120 ha i zajednice hrasta lužnjaka i velike žutilovke s drhtavim šašem na oko 120 ha. Nadalje, kao posljedica uglavnom prirodne sukcesije zajednica i prijelaza u suše zajednice, ova se subasocijacija proširila na još 80 ha bivše šume crne johe i oko 50 ha bivše šume poljskoga jasena.

Sve to govori o vrlo velikim promjenama unatoč tomu što je ova zajednica više-manje zadržala površinu od prije tridesetak godina.

Još je Dekanić (1962) proveo istraživanja vodnoga režima u šumi Žutici radi utvrđivanja uzroka sušenja hrasta lužnjaka. Pri tom je utvrdio da je u šumi hrasta lužnjaka i velike žutilovke s rastavljenim šašem nepovoljan vodni režim. Podaci pokazuju da je u sastojini, uz ostalo, došlo do poremećaja u zoni rizosfere nakon izgradnje nasipa, cesta i kanala.

Prema Rauševim istraživanjima (1980) gospodarske jedinice Žutica ova se subasocijacija nalazila u stanju regresije, jer je stabilnost subasocijacije uvelike poremećena prvobitno sušenjem nizinskoga brijesta, a potom naglim i masovnim sušenjem hrasta lužnjaka. Takvi su uvjeti omogućili nagli razvoj korovne vegetacije i višak stagnirajuće vode pa se teren zamočvaruje.

To i današnja istraživanja potvrđuju, no u manjem opsegu nego prije. Danas je nešto veća regresija u subasocijaciji s drhtavim šašem, što koindicira s rezultatima istraživanja vegetacije s područja Kalja, Turopoljskoga luga i iz Pokuplja.

U međuvremenu su pionirske vrste crna joha i poljski jasen popunili dio praznina nastalih sušenjem i dio neobrasloga zemljišta, što je pozitivno utjecalo na postupnu stabilizaciju ovih sastojina.

Kao posljedicu toga te specifičnih ekoloških uvjeta u kojima se razvija šuma crne johe, danas u GJ Žutica imamo pojavu da se crna joha širi iz korita starih vodotoka i kanala na površine gdje stoji voda, koja se u manjim ili većim kazetama zadržava nakon poplava i većih oborina. Također je nestajanjem hrasta lužnjaka nestala i "crpka" koja je crpila velike količine vode iz tla. To je izazvalo pogoršanje hidrološkoga režima, izmjenu mikroklime i pogoršanje bioloških komponenata tla. Na tim i takvim lokalitetima naglo se širi crna joha kao jedina vrsta koja se može održati u tako ekstremno vlažnim uvjetima, dok na nešto manje vlažnim lokalitetima dolazi i poljski jasen.

Tako se ukupna površina pod zajednicom crne johe s trušljikom (*Frangulo-Alnetum glutinosae*) u odnosu na 1975. god. (Medvedović) povećala za oko 80 ha, što je vrlo teško odrediti jer se crna joha dosta intenzivno razvija oko velike većine naftnih bušotina, pa možemo zaključiti da je povećanje površina pod ovom zajednicom mnogo veće. Nadalje, nekih 25 ha otpada na prodor crne johe na ranije neobraslo zemljište, dok se drugo širenje crne johe odnosi na regresijske procese u staništu i sastojinama GJ Žutica. Tako je crna joha zauzela 70 ha površina koje su prema Medvedoviću (1975) bile pod zajednicom hrasta lužnjaka s velikom žutilovkom i rastavljenim šašem i 40 ha pod zajednicom hrasta lužnjaka i običnoga graba.

S druge strane, površine pod crnom johom su se smanjile gotovo 80 ha u korist zajednice hrasta lužnjaka i velike žutilovke s rastavljenim šašem, 50 ha u korist za-

jednice hrasta lužnjaka i velike žutilovke s drhtavim šašem te oko 30 ha u korist zajednice hrasta lužnjaka i velike žutilovke s običnim grabom kao posljedica promijenjenih stanišnih uvjeta i progresije vegetacije.

Prema vlastitim istraživanjima te usporedbom sa stanjem iz 1975. god. (Medvedović) može se zaključiti da je prodor poljskoga jasena i s tim povezano zajednice poljskoga jasena s kasnim drijemovcem (*Leucoio-Fraxinetum angustifoliae*), kako na prije neobraslo zemljište tako i na područje rasprostranjenosti drugih zajednica, još snažniji nego što je to bio slučaj kod crne johe. Zbog nabrojenih negativnih čimbenika najprije se osušio hrast lužnjak te su se dosta naglo promijenili ekološki uvjeti staništa pa je ono većinom postalo vlažnije i tako pogodno za širenje poljskoga jasena, kao pionirske, brzorastuće vrste lakoga sjemena, na veće ili manje površine pojedinih zajednica, od bare, preko nize, pa sve do grede.

I ovdje vrijedi ista zakonitost kao kod crne johe: što je teren viši i zajednica suša, to je prodor poljskoga jasena slabiji. Tako na čak više od 120 ha bivšega staništa zajednice hrasta lužnjaka i velike žutilovke s rastavljenim šašem danas uspijeva zajednica poljskoga jasena s kasnim drijemovcem, nadalje na oko 30 ha staništa zajednice hrasta lužnjaka i velike žutilovke s drhtavim šašem i 15 ha staništa zajednice hrasta lužnjaka i običnoga graba sada raste šuma poljskoga jasena.

Normalna progresija staništa i prelazak šuma poljskoga jasena u suše zajednice prisutna je samo na oko 70 ha, i to prelaskom zajednice poljskoga jasena s kasnim drijemovcem u zajednicu hrasta lužnjaka i velike žutilovke s rastavljenim šašem na približno 50 ha te zajednicu hrasta lužnjaka i običnoga graba na oko 20 ha. Važno je napomenuti da je i preko 100 ha bivšega neobrasloga zemljišta, bilo prirodnim putem, bilo uz pomoć čovjeka (sadnja sadnica), danas obraslo šumom poljskoga jasena s kasnim drijemovcem u raznim fazama razvitka. No, najčešće je to inicijalna faza koja na mnogim mjestima prelazi u optimalnu.

Većinom kao posljedica sušenja hrasta lužnjaka te sanacije posušenih površina (uglavnom 1968. god.) podignute su kulture euroameričkih topola (*Populus* x *euroamericana*), npr. odjeli 42a, 49c, 131b, 133, 137a, 138b, 173c, 182c, 183b, 193b i dr., u kojima se danas uz euroameričke topole u sloju drveća s velikim udjelom javlja crna joha (*Alnus glutinosa*), a u sloju grmlja trušljika (*Frangula alnus*). U sloju prizemnoga rašća najveći udio imaju: *Carex vesicaria, Carex elata, Peucedanum palustre, Deshampsia ceaspitosa, Urtica dioica, Polygonum hydropiper, Juncus effusus, Lycopus europaeus, Lytrum salicaria, Myosotis scorpioides, Lysimachia vulgaris, Galeopsis tetrahit, Stachys palustris, Iris pseudacorus, Glechoma hederacea* i *Galium palustre*. Sve to upućuje na povratak autohtone vegetacije, u prvom redu crne johe i njezinih pratilica, kao pionirske vrste koja može opstati u tako promijenjenim stanišnim uvjetima (zamočvarenost, puno svjetlosti). Treba očekivati da će se, ako ne dođe do novih poremećaja, ova polagana progresija nastaviti i dalje k autohtonoj prirodnoj vegetaciji, od crne johe prema hrastu lužnjaku.

Zaključno se može reći da sve to potvrđuje da je više od 700 ha nama najzanimljivijih i najvrednijih šuma hrasta lužnjaka u vrijeme sušenja prije tridesetak godina pretrpjelo vrlo intenzivne i nagle vanjske i unutarnje utjecaje. U njima su se

osušile glavne vrste drveća, promijenile su se stanišne prilike i šumske zajednice te je nastala negativna sukcesija šumske vegetacije.

Na osnovi fitocenoloških i drugih istraživanja izrađena je vegetacijska karta šumskih zajednica gospodarske jedinice Žutica u mjerilu 1: 25 000. Ona prikazuje stvarno stanje areala šumskih fitocenoza istraživanoga područja te pokazuje dinamiku razvoja vegetacije ovoga područja i može poslužiti kao dobra osnova za planiranje i izvođenje svih radova u ekosustavu (uzgoj, uređivanje i dr.).

No, općenito je teško reći u kojemu će smjeru ići dalji razvitak vegetacije istraživanoga područja, što većinom ovisi o djelovanju nas samih na ekosustav. Može se očekivati da će se površine pod vlažnijim zajednicama i dalje povećavati, posebno u južnom, jugozapadnom i sjeverozapadnom dijelu gospodarske jedinice šume poljskoga jasena te u sjeveroistočnom dijelu, na mnogim mjestima gdje je teren kazetiran i oko bušotina šume crne johe. No, usprkos velikom negativnom utjecaju raznih čimbenika na ekosustav prirodna sukcesija i razvitak šumskih zajednica na mnogim će mjestima ići normalnim putem, tj. od vlažnijih zajednica prema sušim.

U uzgoju se u strukturno i stanišno oštećenim sastojinama GJ Žutica možemo pridržavati načela koja su odredili Matić (1989, 1996), Matić i Skenderović (1993), Matić i dr. (1994, 1996) i koja su se pokazala uspješnim na drugim područjima u kojima je došlo do sličnih ekoloških poremećaja (Kalje, Turopoljski lug, Pokuplje).

Tako stare hrastove sastojine središnjega dijela GJ Žutica, koje su zadržale suvislost, primjernu drvnu zalihu, omjer smjese i druga strukturna i stanišna svojstva, treba i dalje uzgajati i podržavati radi proizvodnje drva i radi korištenja stabala kao prirodnih crpki za vodu te radi postupnoga prirodnoga pomlađivanja. Potrebno je također pristupiti njezi i formiranju ostalih neosušenih sastojina u suvisle manje ili veće sastojine koje će u novim uvjetima u tlu nastaviti proizvodnju.

U odjelima 64a, 70b, 107a, 113b, 119b, 126d, 131c, 179b i drugim, gdje je sušenje smanjilo drvnu zalihu preko 30 % i gdje su nakon toga ostale nesuvislo obrasle površine, no stanišni uvjeti se nisu promijenili u tolikoj mjeri da pomladak hrasta lužnjaka ne bi mogao opstati, potrebno je pristupiti obnovi sastojina. Uz prirodnu obnovu postojećim i novonastalim pomlatkom glavne vrste drveća treba primijeniti umjetnu obnovu unošenjem žira ili sadnica hrasta lužnjaka po načelima oplodnih sječa.

Prirodno i umjetno pomlađivanje uz oplodne sječe na malim površinama ili krugovima treba i u ovoj situaciji biti glavno načelo obnove ovih sastojina.

U odjelima 25d, 37, 63a, 103a, 104d, 122d, 149b, 155b te drugim, gdje je bilo nešto veće sušenje lužnjaka i brijesta pa se sada skupine hrasta smjenjuju sa skupinama urasloga jasena i johe te većim ili manjim plješinama, a obrast se smanjio do polovice ili neznatno niže, no stabla koja su ostala imaju povoljan izgled za dalji opstanak, potrebno je podsaditi takve sastojine crnom johom ili poljskim jasenom. Na taj ćemo način osigurati kontinuitet još nezrele lužnjakove sastojine uz formi-

ranje sastojine pionirskih vrsta koja će štititi tlo, razviti slojeve, održavati povoljnu sastojinsku klimu i koja će dobro prirašćivati.

Na površinama koje su u još većem stupnju degradirane, kao što su to odjeli 27d, 36h, 38b, 63a, 72f, 93a, 104b, 179e, 187b i neki drugi, potrebno je prvo na terenu ukloniti uzroke degradacije. U tim su odjelima vrlo teški uvjeti za razvitak vegetacije. To su većinom lužnjakove sastojine pogođene velikim sušenjem, narušena je ekološka ravnoteža, na mnogim mjestima trajno je prekinut sklop, teren je zamočvaren, bujno je razvijeno grmlje, urašta poljski jasen i crna joha, dok se u ekstremnim slučajevima suši i crna joha (npr. odjel 117), pa imamo samo zakorovljene površine. Na takvim površinama treba saditi pionirske vrste drveća uz prethodnu mehaničku pripremu staništa uništavanjem korova. Potrebno je saditi crnu johu, poljski jasen i ostale pionirske vrste drveća, imajući na umu uvjete koji vladaju na konkretnom staništu i ekološke zahtjeve pojedine vrste. Površinska odvodnja kopanjem plitkih kanala sisavaca ili izrada propusta na mjestima stagniranja vode u umjetno stvorenim kazetama preduvjet je pripremi staništa i sadnji pionirskih vrsta drveća.

Na degradiranim staništima do lužnjaka treba doći posredno unošenjem u ta staništa pionirskih vrsta drveća, posebno poljskoga jasena, crne johe, vrba, topola i drugih. Važno je naglasiti i to da hrast lužnjak nije i ne može biti pionirska vrsta drveća (Matić 1996), jer ne prihvaća degradirano tlo za svoj razvoj.

Samo multidisciplinaran pristup rješavanju ovoga i sličnih problema može zaustaviti degradaciju staništa i zajednica te ih dovesti u normalno stanje i progresiju.

Terensko praćenje kretanja vode na tlu i u tlu pijezometrima (trajni monitoring), koje se provodi u nekim drugim nizinskim ekosustavima, najbolji je način dolaska do točnih podataka vodnoga režima u šumi, a to je ujedno i jedan od glavnih pokazatelja za gospodarenje šumskim ekosustavima nizinskoga područja pa ga je potrebno uvesti i u šumu Žuticu zbog velikih promjena i sušenja koja su uglavnom uvjetovana promjenama vodnoga režima.

Najsnažniji čimbenik destabilizacije ekosustava Žutice bio je i ostao čovjek, ponajprije djelovanjem preko vodoprivrede i naftne industrije. Potrebna je puno organiziranija i snažnija šumarska politika u odnosu na sudjelitelje istoga prostora. Šumarski su stručnjaci najbolji poznavatelji šumskih ekosustava i bez njihova jednakopravnoga sudjelovanja u donošenju važnih odluka, u svezi s ovakvim i sličnim velikim zadiranjima u ekosustav, nikakva napretka ne može biti.

Ključne riječi: Žutica, sinekološko-vegetacijsko istraživanje, šumske zajednice, narušeni ekosustavi, sinergizam, vegetacijska karta, multidisciplinarno istaraživanje

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FOREST FIRE-PREVENTION ROADS AS A SPECIAL CATEGORY OF FOREST ROADS AND FACTORS THAT INFLUENCE THEIR DISTRIBUTION IN SPACE

ŠUMSKE PROTUPOŽARNE CESTE KAO POSEBNA KATEGORIJA ŠUMSKIH CESTA I ČIMBENICI KOJI UTJEČU NA NJIHOV RAZMJEŠTAJ U PROSTORU

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Forest fire-prevention roads (FFPR) are a special category of forest roads connected to the Mediterranean and Submediterranean area, i.e. to the area where forest fires represent the greatest danger of total biotic and abiotic factors harmful to the existence of forest ecosystems. Research on the most important factors which influence the spatial distribution of the network of forest fire-prevention roads of high quality, as an important factor in preventive measures against forest fires, was carried out in the management unit Senjska Draga in the area of the Forest Management, Senj. The results of the research showed that one third of the existing forest fire-prevention roads were laid with a higher longitudinal gradient than permitted. An average geometrical distance determined by a centroidal method, and by the application of the personal computer is 244.79 m, and its real equivalent is 287.15 m. Using the relative openness and the new method of bordered areas, it has been established that the researched management unit is satisfactorily open for the average geometrical distance of access to the forest area from 250 m and more. On the theoretical model, due to various influences of factors, it has been shown that forest fire-prevention roads should be designed at a distance of 300 to 600 m apart. In order to choose the most acceptable costs for forest fire-prevention roads, the computer programme COST has been created, and calculations are based on the derived mathematical expressions. Costs of excavations depend on many factors that have been analysed in detail, and according to the rese-

arch of the normal transversal profile, the more economic method of building forest fire-prevention roads has been suggested.

Key words: forest fire-prevention roads, forest fires, the karst area, digital terrain model, relative openness, excavation costs

INTRODUCTION
UVOD

According to the data of the Public Enterprise "Croatian Forests" (1997) the area of forests on karst, i.e. forests that are on the islands and the coastal area of the Republic of Croatia, which are managed by "Croatian Forests", amounts to 873,148 ha. Wood reserves of the state seaside forests are only 46 m^3/ha, and the annual growth is 1.35 m^3/ha. The annual felling according to management plans is 387,580.00 m^3, but the plan cannot be fulfilled due to inaccessibility, the high costs of felling and the lack of a market for conifer trees.

The mentioned indicators, as well as others, if taken into account only from the point of view of timber mass production, could lead to the wrong conclusion, namely, that seaside forests, as they are, are not an important factor in the Croatian forestry and economy at this moment. However, if we take into account their production potential, which can be far better used and improved by intensive and professional management, and particularly if we take into account the *secondary functions* that they have, these forests represent a significant factor in Croatian forestry and in the economy in general. Apart from that, the development of tourism as a significant segment of the Croatian economy is closely connected to the existence of these forests. Without them, particularly due to their secondary functions, this area would not be what it is.

Forest fires as an abiotic destabiliser of the ecosystem of the Mediterranean, i.e. the karst area of the Republic of Croatia, have been jeopardising the vegetation of this area more and more lately. In the coastal area and on the islands of our country, forest fires represent the greatest danger in compared to any other damaging factors. Therefore, forest fires represent a problem characteristic of the Mediterranean region, a problem that has to be faced, fought against and whose solution has to be carefully planned.

According to Vajda (1974) measures of fighting against forest fires can be divided into three larger groups: *preventive measures, preparatory measures for fire extinguishing, and measures for fire extinguishing.*

We are primarily interested in the preventive measures by which, theoretically, the accurrence of all forest fires can be prevented (whose direct or indirect cause is man), and in the Republic of Croatia the proportion of total annual number of fires caused by man is 95 % (Španjol 1996).

According to Bilandžija (1988) preventive measures are: legal, educational, continuous advertising in the media, the education and organised engagement and training of the local population in activities of protection against fire, a well-organised observation-informational service, and measures which are biological (forest-growing and forest-arranging), and technical (the building and maintenance of fire-prevention straight clearings, the building and maintenance of forest fire-prevention roads and the building and maintenance of storage reservoirs and pumping sites).

In the period before Croatian independence, in former Yugoslavia, for various reasons, the organisation of protection against forest fires was not performed purposefully and successfully. The main drawbacks of the previous organisation lay in the lack of financial means, in the insufficient care taken by the state at that time and in the frequent changes in the system of organisation and in the policy of managing forestry and fire-fighting. This particularly refers to the system of carrying out preventive measures, and within these measures, there was aparticularly difficult situation with the technical component, i.e opening up Mediterranean forest areas with fire-prevention roads.

Pičman & Pentek (1996) wrote: "Forest fire-prevention roads are such forest roads that are primarily designed and built in order to prevent forest fires and in the case of the emergence of fire they have to enable conditions for its extinguishing. These are forest roads that are not called economic forest roads, as at the time of their realisation the raw base of the Mediterranean forests was uneconomical for exploitation, so the primary task of the built roads was fire-prevention."

Naturally, fire-prevention roads have other functions which arise in managing forests, so these roads can be with good reason called *multifunctional forest roads* (Pičman & Pentek, 1996).

As the Mediterranean area is the most jeopardised by forest fires and at the same time the most attractive to tourists, and as the total economy of the Republic of Croatia is particularly interested in this area, all necessary steps which will lead to the radical decrease of forest fires should be taken. One of the big steps which leads to the realisation of this aim is the optimum openness of the Mediterranean karst zone in terms of the accessibility of the jeopardised areas to intervening fire-engines.

THE AIM OF THE RESEARCH
CILJ ISTRAŽIVANJA

The main aims and lines of direction of this research are conceived in the following steps:

- defining and clearly distinguishing forest fire-prevention roads as a special category of forest roads,
- making a digital terrain model of the researched area,

- determining the terrain gradients and the classification of categories of gradients,
- calculating the longitudinal gradient of the existing forest fire-prevention roads and classifying of the categories of the longitudinal gradients,
- determining the optimum quantity of fire-prevention roads regarding the tactical demands of the fire-brigades while extinguishing forest fires,
- including of data received from the previous step into knowledge of foresty science about the necessary openness of forest ecosystems and about the largest allowed surface of forest roads on a forest area and finding best solutions,
- taking account of the openness of the researched area due to various average optimum geometrical and real distances of accessibility to the area in a classical way and applying the size of the relative openness of the area,
- determining the costs of excavations for forest fire-prevention roads of the proper normal transversal profile with various transversal terrain gradients, various planum widths and various categories of materials,
- the elaboration of the programme COST which can be chosen in a short time, for the most acceptable variant of forest fire-prevention roads from the point of view of the minimum excavation costs,
- using the so-called "buffer" method to determine the relative openness of the area and the efficacity of forest fire-prevention roads, and of the programme COST, in choosing the most acceptable variant of the route of the future forest fire-prevention road.

RESEARCH PROBLEMS
PROBLEMATIKA ISTRAŽIVANJA

Forest fire-prevention roads in the classification of forest roads in our country have not been mentioned as a separate category, so it is necessary to start by elaborating on the models of classification of forest roads in Croatia and in some other European countries, so that we can determine in which category forest fire-prevention roads can be included in line with different classification criteria. Alternatively, it can be seen whether they make up a separate category.

THE CLASSIFICATION OF FOREST ROADS AND THEIR BASIC TECHNICAL CHARACTERISTICS
RAZREDBA ŠUMSKIH CESTA I NJIHOVA OSNOVNA TEHNIČKA OBILJEŽJA

According to *Tehnički uvjeti za gospodarske ceste* (1989) the network of economic roads in forestry can be classified according to:

- its significance,
- traffic load (gross tons/24h),
- the configuration of the terrain,
- its size and the frequency of timber mass transport.

Regarding the frequency of use and the necessity of maintenance, according to Pičman and Pentek (1996), roads can be classified into *primary roads*, which are used during the whole year and require regular maintenance, and *secondary roads*, which are used from time to time, according to the need, so their maintenance is periodical.

In Austria, forest roads are classified according to the building standard, so Trzesniowski (1988) classifies them into: *main forest roads, subordinate forest roads, formed paths,* and *main and subordinate skid trails.* A more detailed classification within the mentioned categories has not been made.

In Slovakia, Jurik et al. (1984) offer a classification in eight categories of high quality according to technical traits within two classes.

In Germany (Dietz et al. 1984), there is a classification of forest roads according to the number of lanes, the width of a roadway, allowed load, minimum radius of horizontal curves and allowed longitudinal gradient. Taking these elements into consideration the above mentioned authors have divided forest roads into: *main forest roads, primary forest roads, secondary forest roads, tractor paths and tractor haulages.*

Potočnik in Slovenia (1996) uses as a criterion for the classification of forest roads their multifunctional use and classifies them into three categories: *category 1: symbol GI/1, category 2: symbol GI/2, category 3 where he distinguishes: GII - main export roads and GIII - subordinate forest roads.*

THE OPENNESS OF FOREST AREA
OTVORENOST ŠUMSKOGA PODRUČJA

According to the statements in *Tehnički uvjeti za gospodarske ceste* (1989) in the calculation of the degree of forest openness, the following is taken into account:

- a road (or a part of it) which goes through a forest - for the total length (100 %)
- a road which goes through the edge of a forest or at a distance from the edge of a forest up to 300 m, and enables loading - for 50 % of its length,
- a road which comes vertically to the edge of a forest and stays there - for a length of 500 m, and
- a navigable water current which goes through the edge of a forest and is used for loading forest assortments - for 50 % of its length.

The openness of a certain forest area by forest roads or the density of forest roads over a certain area is a quantity usually expressed in m/ha or km/1 000 ha.

The percentage relationship of the forest area which is opened by forest roads and the total surface of a gravitational area is called a relative openness, a percentage openness of forests or a degree of forest openness and is expressed as a percentage. According to such expressed openness, i.e. the accessibility of a terrain, Jurik et al. (1984) mention five basic categories of openness. They are: up to 65 % - insufficient openness, 65-70 % - barely satisfactory openness, 70-75 % - satisfactory openness, 75-80 % - higly satisfactory openness, and more than 80 % - very good openness.

Dundović (1996) determines the efficacity of a forest transport network as a percentage. Here, he uses a formula:

$$Z_s = \frac{D_{st}}{D_{sg}} \cdot 100 \qquad (1)$$

where:
Z_s is the efficacity of the network of transport roads, %
$D_{st.}$ is an average theoretical distance of skidding, m,
D_{sg} is an average geometrical distance of skidding, m.

When a certain forest area is open, the final aim is always an optimum openness of the forest area. Various areas have determined the optimum density of the network of forest roads in various ways, but they are essentially similar - *to determine such a distance between forest roads where total costs will be minimum.*

Particularly when speaking about forest fire-prevention roads, all the factors that influence total costs have to be carefully determined. Cost factors have to be analysed in detail.

THE OPENNESS OF FORESTS IN THE REPUBLIC OF CROATIA WITH THE EMPHASIS ON THE MEDITERRANEAN
OTVORENOST ŠUMA U REPUBLICI HRVATSKOJ S NAGLASKOM NA MEDITERAN

Dealing with the openness of forests in the Republic of Croatia, it is necessary to start by mentioning which is the least regulated openness for certain areas due to the condition of the development of forestry in Croatia.

Table 1. The least openness of forests of a certain area of the Republic of Croatia according to *Tehnički uvjeti za gospodarske ceste* (1989)
Tablica 1. Najmanja otvorenost šuma određenoga područja Republike Hrvatske prema Tehničkim uvjetima za gospodarske ceste (1989)

Forest area of the Republic of Croatia *Šumsko područje Republike Hrvatske*	The least openness m/ha *Najmanja otvorenost* m/ha
Lowland region *Nizinsko područje*	7.00
Foothill-highland region *Prigorsko-brdsko područje*	12.00
Mountain region *Planinsko područje*	15.00

Table 2. Planned openness of forests of the Republic of Croatia in certain areas in 2010 (Izvješće o problematici gradnje i održavanja šumskih prometnica i stanju otvorenosti šuma, 1997)
Tablica 2. Planirana otvorenost šuma Republike Hrvatske u određenim područjima 2010. godine (Izvješće o problematici gradnje i održavanja šumskih prometnica i stanju otvorenosti šuma, 1997.)

Forest area of the Republic of Croatia *Šumsko područje Republike Hrvatske*	Planned openness in 2010 m/ha *Planirana otvorenost 2010. godine* m/ha
Lowland region *Nizinsko područje*	15
Foothill region *Prigorsko područje*	20
Highland and mountain region *Brdsko i gorsko područje*	25
Karst region *Krško područje*	10

The forest management authorities of Delnice, Senj, Gospić, Buzet and Split are in the karst region. These forest management authorities manage approximately 44 % of the total area managed by the Public Enterprise "Croatian Forests".

Table 3. The quantity of roads and forest openness according to the forest management authorities on 01.01.1996.
Tablica 3. Količina prometnica i otvorenost šuma po upravama šuma 1.1.1996. godine

The forest management authority *Uprava šuma*	The quantity of roads km *Količina cesta*, km	The openness in proportion to the total area m/ha *Otvorenost s obzirom na ukupnu površinu*, m/ha	The openness in proportion to overgrown area m/ha *Otvorenost s obzirom na obraslu površinu*, m/ha
Buzet	609.40	9.31	11.45
Delnice	52.70	7.37	7.47
Gospić	566.90	3.07	3.87
Senj	940.90	14.41	37.64
Split	3,442.10	6.25	10.42
Total *Ukupno*	5,612.00	6.43	9.99

THE USE OF A PERSONAL COMPUTER IN THE PLANNING, DESIGNING AND BUILDING OF FOREST ROADS
UPORABA OSOBNOGA RAČUNALA PRI PLANIRANJU, PROJEKTIRANJU I GRADNJI ŠUMSKIH CESTA

Personal computers started to be used in forestry as a highly efficient device for designing forest roads in the 1970s. In the very beginning, personal computers were only a replacement for a classical way of making project documentation like general plans, longitudinal sections, normal sections, drawn cross-sections, cubic volume of ground masses and cost estimates. But today personal computers are used much more widely and, particularly by the application of new GIS (geographical informational system) technology and methods, comprehensive and complete solutions for opening forest areas are made.

GEOGRAPHICAL AND GROUND INFORMATIONAL SYSTEM
GEOGRAFSKI I ZEMLJIŠNI INFORMACIJSKI SUSTAV (GIZIS)

The geographical and ground informational system is an informational system of the whole Earth area and is intended for successful management. It includes the lithosphere, hydrosphere, biosphere and atmosphere (Brukner 1994).

The geographical and ground informational system can be divided into two separate systems: *GIS* - geographical informational system and ground informational system.

GIS is more important to us for solving tasks within forest roads, as it is directly connected with *a digital terrain model (DTM)*. Together with this name, some other names are used in practice, like *digital relief model (DMR)* or *digital elevation model (DEM)*. Regardless of the used name, the same methodology of research is used.

DIGITAL TERRAIN MODEL (DTM)
DIGITALNI MODEL TERENA (DTM)

The beginning of the development of the Digital Terrain Model is connected to the names Miller & Laflamme (1958) who described theoretical statements for making DTM and the wide possibilities of its use.

Stefanovič et al. (1977) described DTM as a digital account of the surface of the Earth suitable for computer processing, which consists of a set of points of that same surface determined by x, y, z co-ordinates and a suitable programme for their processing.

Generally speaking, it can be said that DTM is a set of points of a part of the surface of the Earth whose co-ordinates are organised and stored in a medium which enables computer processing. A programme which enables entry and organising, processing, analysis and a display of data is necessary for handling DTM.

For the practical use of DTM, it is necessary to have special computer programmes which can be purchased individually or within GIS or CAD programme products.

DTM AS A MEANS OF WORK IN SOLVING PROBLEMS CONNECTED WITH FOREST ROADS
DTM KAO SREDSTVO RADA PRI RJEŠAVANJU PROBLEMA VEZANIH UZ ŠUMSKE CESTE

In opening forest areas and in the making of an optimum distribution of forest roads, Dietz et al. (1984) use a digital terrain model *(DGM - digitale Geländemodel)* as a cartographic base and a perspective account of forest terrain. They also simulate terrain circumstances with the use of a *digital terrain simulator (DGS)*. They use a topographic map with contour lines and a basic distribution of forest roads as entry data.

Shiba & Loffler (1990) use a digital terrain model (DTM) in planning the optimum spatial distribution of forest roads. They use a programme named TERDAS and do their research in the private forests "Schonsee-Drechselber" in an area of 210 ha in east Bavaria.

Shenglin (1990) uses an IBM-xt personal computer with a programme package made in the programme language FORTRAN to determine the most acceptable position of forest roads, and to determine costs by a cost-benefit method.

Knežević (1990) uses a personal computer with a peripheral unit digitiser to make an optimum distribution of forest roads in unevenly-aged forests.

Shiba (1992) uses a computer simulation of a terrain which was used in the work of Shiba & Loffler (1990) and in the same way determines four possibilities of opening, as well as establishing the optimum density of a network of forest roads.

Knežević & Sever (1992) use a personal computer to determine the optimum density of tractor haulages. As a model for data processing, they took Arnautović's formulas (1975) and they completely solved the whole problem on a personal computer.

Dürrstein (1992) considers the opening of forests with the use of a personal computer and the programme FOREST. In order to use completely the necessary electronic equipment and electronic devices in opening forests, the author starts by distinguishing two levels of forest opening.

Session (1992) calculates the minimum cost with the highest value of a network of forest roads by the use of the programme NETWORK.

Pičman (1993) determines the existing and optimum openness of the management unit Bistranska Gora by forest roads and tractor haulages using a personal computer and a peripheral unit digitizer *CalComp 9100*.

Pičman & Tomaz (1995) determine the most acceptable of four variants of the spatial distribution of tractor wood haulage ways by the use of a computer due to their longitudinal gradient of 12.5 %, 15.0 %, 17.0 % and 20.0 % in the department of the management unit Južna Garjevica.

Pičman & Pentek (1996) determine the most acceptable variant of a network of tractor haulages by the use of a personal computer taking into consideration the longitudinal gradient of tractor haulages.

The methods of determining the optimum spatial distribution of forest roads in a certain forest area by the use of personal computers and other electronic equipment represent a new approach and way of solving these problems. It can be presumed that in future, data processing will be much more precise, faster and of higher quality. Programme packages related to forest roads will offer more varied possibilities, while the account of processed data and DTM will be reliable and exact.

FACTORS WITH A DOMINANT INFLUENCE ON THE DISTRIBUTION OF A NETWORK OF FOREST ROADS
ČIMBENICI S DOMINANTNIM UTJECAJEM NA RASPORED MREŽE ŠUMSKIH CESTA

According to Pičman (1993) the following basic factors influence the spatial distribution and quality of built forest roads: *the morphology of microrelief (terrain), geological relationships, climatic relationship, the condition of components and forest soil survey.*

Generally speaking, factors that mostly influence the spatial distribution of a network of forest roads can be divided into the following groups: *factors that are directly connected with a forest terrain which is opened by a network of forest roads, factors of standardised technical features of a certain category of forest roads, factors of forest ingredients on the opened area, climatic factors, ecological factors, factors by which forest roads influence man, and other factors.*

WORKING METHODS
METODE RADA

TERRAIN RESEARCH
TERENSKA ISTRAŽIVANJA

After having examined a map of a management unit with all roads drawn in, forest roads are distinguished from public roads, as only forest roads are to be surveyed. They were surveyed in such a way that the gradients of grade lines were surveyed by a slope meter, while distances between breaks of grade lines were measured by a measuring tape, 30 m long. The gradients of grade lines were expressed in percentages. The total width of a forest road was surveyed at the points of break of a grade line.

DIGITALISATION OF FOREST-MANAGEMENT MAPS
DIGITALIZACIJA ŠUMSKO-GOSPODARSKIH KARATA

All the roads on the research area and which were not previously included on the map of the management unit Senjska Draga were first drawn onto it. A map with contour lines, with a drawn border of the management unit, with drawn borders of compartments and subcompartments, and with roadsi ncluded, was digitised with the use of a personal computer Pentium 100 MHz and 16 Mb Ram, and with the use of a digitiser CalComp 9100 for paper size A0. The digitalisation of maps was made by the programme *AutoCAD*. A digital terrain model (DTM) was

obtained by the processing of the digitised map of the management unit, using the programme *ArcInfo* and the programme *Surfer*.

THE CLASSIFICATION OF TERRAIN GRADIENTS IN VARIOUS CATEGORIES
RAZREDBA NAGIBA TERENA U VIŠE KATEGORIJA

DTM was used as the basis for the classification of the terrain gradient in several categories. The terrain was classified according to Löffler's classification from 1991. Various categories of the terrain gradient were coloured in various colours; smaller gradients with lighter, and larger ones with darker colours.

GRAPHICAL AND MATHEMATICAL DETERMINATION OF THE RELATIONSHIP BETWEEN THE NECESSARY EARTHWORKS AND THEIR COST FOR FOREST FIRE-PREVENTION ROADS LAID ON VARIOUS TERRAIN GRADIENTS
GRAFIČKO I MATEMATIČKO UTVRĐIVANJE ODNOSA IZMEĐU POTREBNIH ZEMLJANIH RADOVA I CIJENE NJIHOVE IZVEDBE ZA ŠUMSKE PROTUPOŽARNE CESTE POLOŽENE NA RAZLIČITIM NAGIBIMA TERENA

If a zero-line is taken over various terrain gradients, but in the same category, the necessary quantities of excavation and embankment at the normal transversal profile will be different. The results will be shown graphically and by a mathematical expression which will show a dependence of the quantity of earthworks on the terrain gradient. By introducing the costs of the earthworks in the above mentioned relation, a cost function of the dependence of a spatial location of a forest road on the terrain gradient will be obtained.

DETERMININATION OF AN AVERAGE GEOMETRIC AND A REAL DISTANCE OF THE APPROACH TO THE AREA BY THE USE OF THE CENTROIDAL METHOD
ODREĐIVANJE SREDNJE GEOMETRIJSKE I STVARNE UDALJENOSTI PRISTUPA POVRŠINI PRIMJENOM TEŽIŠNE METODE

The average geometrical distances of the approach to the area are determined by the centroidal method, using a personal computer. On a digital terrain model, each geometric average of distance of the approach to the area is corrected by a factor of the vertical correction of the terrain, which is determined from the avera-

ge gradient of average geometric distances of the approach to the area laid across DTM. Values from literature for certain categories of terrain were taken as a factor of the horizontal bypassing of obstacles and adapted to the existing circumstances and the primary task of forest fire-prevention roads.

DETERMINING THE STANDARD AND RELATIVE OPENNESS OF THE RESEARCHED AREA AND THE EFFICACITY OF THE LAID NETWORK OF FOREST ROADS FOR VARIOUS VARIANTS OF THE OPTIMUM AVERAGE REAL DISTANCE OF THE APPROACH TO THE AREA
UTVRĐIVANJE STANDARDNE I RELATIVNE OTVORENOSTI ISTRAŽIVANOGA PODRUČJA TE UČINKOVITOSTI POLOŽENE MREŽE ŠUMSKIH PROMETNICA ZA RAZLIČITE INAČICE OPTIMALNE SREDNJE STVARNE DALJINE PRISTUPA POVRŠINI

Around the existing roads, surfaces were laid which, for the chosen values of the optimum average geometric distance of the approach to the area, were on all their edges equally far from the roads. Correcting the average geometric distance of the approach to the area, the values of the average real distance of the approach to the area for the chosen optimum values were obtained. By an analysis of the differently coloured areas of the management unit, it can easily be determined which areas are not within the borders of the chosen optimum average real distance of the approach to the area. In the same way, so-called dead zones of individual forest fire-prevention roads can be observed.

DETERMINING THE AVERAGE OPTIMUM DISTANCE OF THE APPROACH TO THE AREA ACCORDING TO THE REQUESTS OF MEMBERS OF FIRE BRIGADES AND KNOWLEDGE OF FORESTRY EXPERTS
ODREĐIVANJE SREDNJE OPTIMALNE DALJINE PRISTUPA POVRŠINI NA TEMELJU ZAHTJEVA DJELATNIKA VATROGASNIH POSTROJBA I SPOZNAJA ŠUMARSKIH STRUČNJAKA

The basic presumption is that the unevaluated values of the generally useful functions of the forests in the karst region are large enough to cover the costs of opening these forests. From the point of view of the members of fire brigades, there are demands for a maximum optimum and minimum optimum distance between forest fire-prevention roads. These requests were corrected with the knowledge of domestic and foreign forestry experts in connection with the maximum areas allowed under the roads on 1 ha and in connection with the allowed quantities of roads in the forest ecosystem in such a way as not to endanger and not to disturb its stability and balance.

MAKING A COMPUTER PROGRAMME "COST"
DIZAJNIRANJE RAČUNALNOGA PROGRAMA "TROŠAK"

This simple programme was made in the programme language C++. The intention of the programme was to choose the most acceptable variant of forest fire-prevention roads from the point of view of the lowest cost of earthworks. Through the careful entry of basic parameters, we can obtain the cost of earthworks for all forest fire-prevention roads 1000 m long in only five minutes.

THE RESEARCH AREA
ISTRAŽIVANO PODRUČJE

INTRODUCTION
UVOD

The forest management authority Senj, i.e. Forestry Senj, manages the management unit Senjska Draga.

The total area of this management unit is 2,515.03 ha, and is divided into 43 compartments and 100 subcompartments.

Geographic location
Zemljopisni položaj

The management unit Senjska Draga is located between 44°55' and 45°00' of the northern latitude and between 14°55' and 15°05' of the eastern longitude.

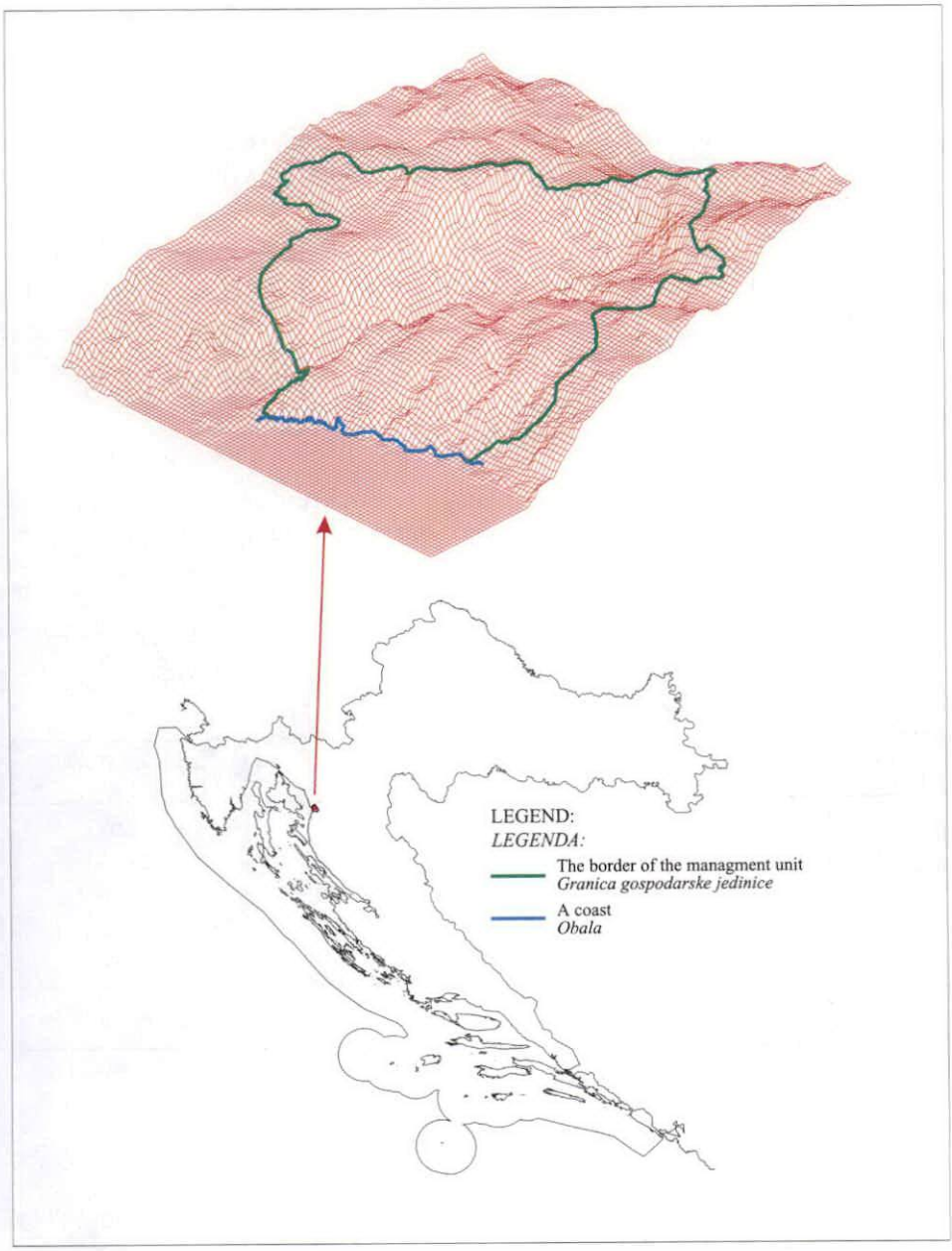
Climatic conditions
Klimatske prilike

According to Köppen's classification, the area of the management unit Senjska Draga is in the continental variant of the Mediterranean climate, of the symbol Cfsax". It is a moderately warm rainy climate, where summers are hot, with an average monthly temperature above 22 °C. A rainy period is widely distributed in a spring (from April to June) and autumn-winter maximum (October, November). The driest part of the year is in the warm season.

Vegetative features
Vegetacijska obilježja

In Senjska Draga two vegetative zones can be distinguished with the following forest zones:

Map 1. The geographic location of the management unit Senjska Draga with a 3D account of the terrain
Karta 1. Zemljopisni položaj GJ Senjska draga s 3D prikazom terena



1. the zone of submediterranean, xerothermophilous forests and copsewoods of hop and oriental hopbeam (link *Ostryo-Carpinion orientalis* Ht.) which spreads from the sea to an altitude of 700 m, and within it two high-altitude zones:
   - a zone of oriental hopbeam forest *(Carpinetum orientalis adriaticum* H-ić), which spreads from 0 to 300 m in altitude,
   - a zone of hop hopbeam forest *(Seslerio-Ostryetum* Ht. et H-ić) which can be found on altitudes from 300 to 700 m and includes two subassociations. In the zone of hop hopbeam forest, there are several extra-zone communities like: *Cotoneastero-Pinetum nigrae* Ht., *Luzulo-Quercetum petrae* Hill and *Luzulo-Fagetum syvaticae* Meusel.

2. the zone of moderately humid (mesophyte) forests (link *Fagion illyricum* Ht.);
   - beech forests and autumn moorgrass forests (*Seslerio-Fagetum sylvaticae* Ht.).

Orographic relations
Orografski odnosi

The average gradient of the terrain in the researched management unit differs widely. In the following table, categories of the terrain gradients are given according to Löffler's (1991) classification.

Table 4. Categories of the terrain gradient in the management unit Senjska Draga according to Löffler's (1991) classification of gradient (terrain data)
Tablica 4. Kategorije nagiba terena u GJ Senjska draga prema Löfflerovoj (1991) kategorizaciji nagiba (terenski podaci)

Gradient groups no. *Grupe nagiba*, br.	Gradient° *Nagib*, °	Area ha *Površina*, ha	Percentage share % *Postotni udio*, %
1	0.....< 6	92.71	3.69
2	6.....< 11	566.80	22.54
3	11.....< 18	591.12	23.50
4	18.....< 27	837.22	33.29
5	27+	427.18	16.98
Total *Ukupno*		2,515.03	100.00

Forest roads
Šumske ceste

In the management unit Senjska Draga there are three types of roads. They are: main roads, local roads and forest roads.

Table 5. Classification of roads in the management unit Senjska Draga (Katastar prometnica JP "Hrvatske šume" 1997)
Tablica 5. Podjela cesta u GJ Senjska draga (Katastar prometnica JP "Hrvatske šume" 1997)

The road type *Vrsta ceste*	Number of roads *Broj cesta*, br.	The length of roads m *Duljina cesta*, m	The superstructure *Gornji stroj*		
			Asphalt *Asfalt*	Broken stone *Tucanik*	Earth *Zemlja*
			m		
Main *Magistralna*	2	16,000	16,000	0	0
Regional *Regionalna*	0	0	0	0	0
Local *Lokalna*	2	8,450	1,500	6,950	0
Total *Ukupno*	4	24,450	17,500	6,950	0
Forest *Šumska*	16	21,219	0	20,535	684
Total *Ukupno*	20	45,669	17,500	27,485	684
%	100.00	100.00	38.3	60.2	1.5

On the whole area of the researched management unit there are 45,669 m of roads, among which 27,485 m are those whose upper layer is made of broken stone, 17,500 m are asphalt roads, while 684 m of roads have an earth upper layer. From the mentioned data it can be seen that, due to the quality, roads with a broken stone upper layer have the greatest influence on the opening of this management unit.

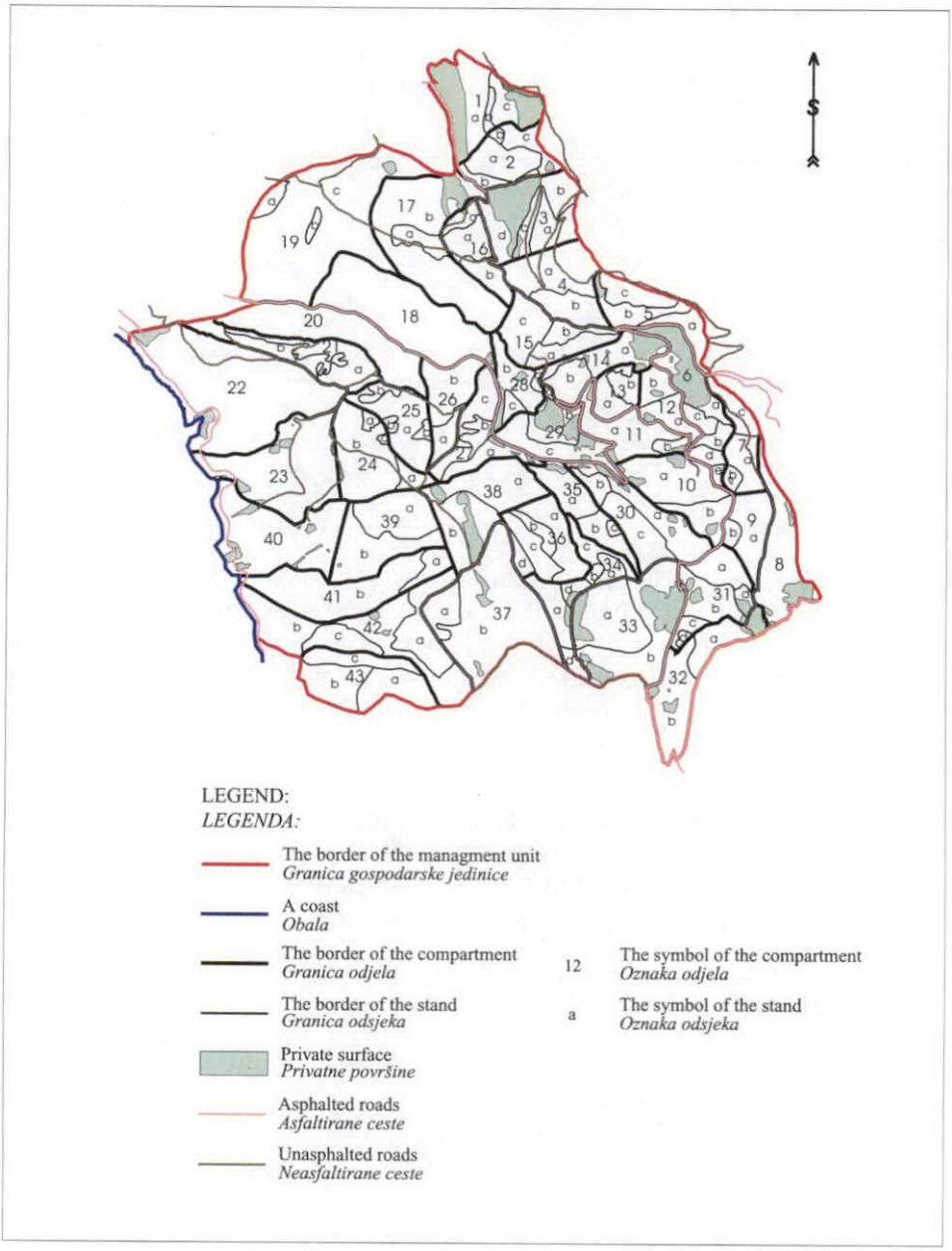
ECOLOGICAL ECONOMIC TYPES OF FORESTS AND THE DANGER OF FOREST FIRES
EKOLOŠKO-GOSPODARSKI TIPOVI ŠUMA I OPASNOST POJAVE ŠUMSKOGA POŽARA

According to the map of forest communities and forest soils and according to the ecological characteristics of a certain type of forest, the following ecological-economic types of forests have been distinguished and adapted to the real condition on the terrain: III-H-10, III-H-20, III-E-20, III-J-10, III-J-21.

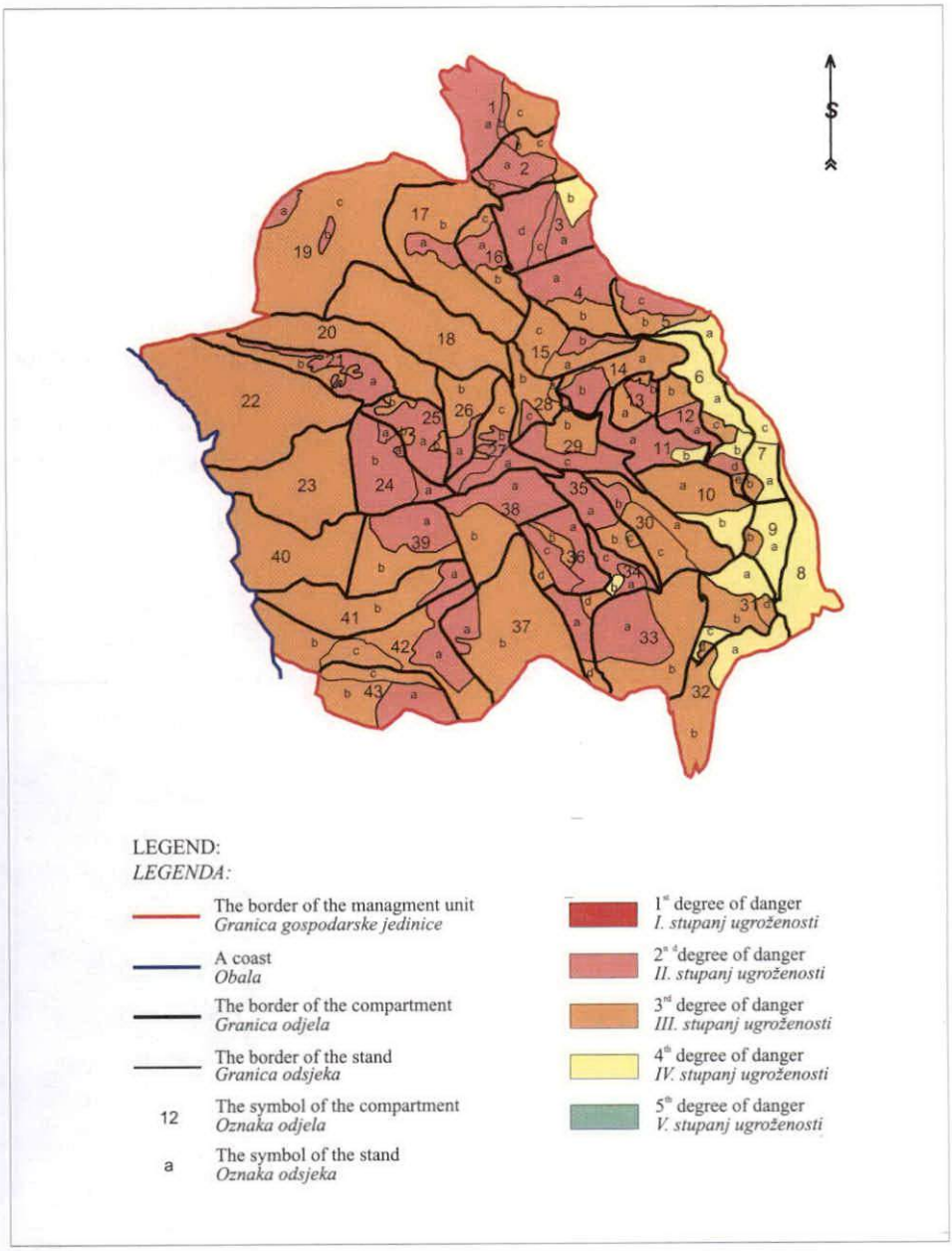
The order of endangerment of certain ecological-economic types of forests of the management unit Senjska Draga from forest fires, starting from the most endangered to the least endangered communities, is as follows: III-1-21, IIIJ-10, III-E-20, III-H-20, III-H-10.

The degree of endangerment from forest fires on the greatest part of 1,564.75 ha (62.20 %) of the area of the management unit Senjska Draga is moderate. A

Map 2. The map of the existing roads in the management unit Senjska Draga
Karta 2. Karta postojećih cesta u gospodarskoj jedinici Senjska draga



Map 3. Map of danger from fires in the management unit Senjska Draga
Karta 3. Karta opasnosti od požara u GJ Senjska draga



small danger of forest fires is characteristic of only 198.41 ha, i.e. less than 8 % of the area. However, it has to be emphasised that 751.87 ha of the total area of Senjska Draga, i.e. almost 30 %, is in a great danger of fires.

THE RESEARCH RESULTS
REZULTATI ISTRAŽIVANJA

THE LONGITUDINAL GRADIENT OF FOREST FIRE-PREVENTION ROADS IN THE RESEARCHED AREA
UZDUŽNI NAGIB ŠPPC NA ISTRAŽIVANOME PODRUČJU

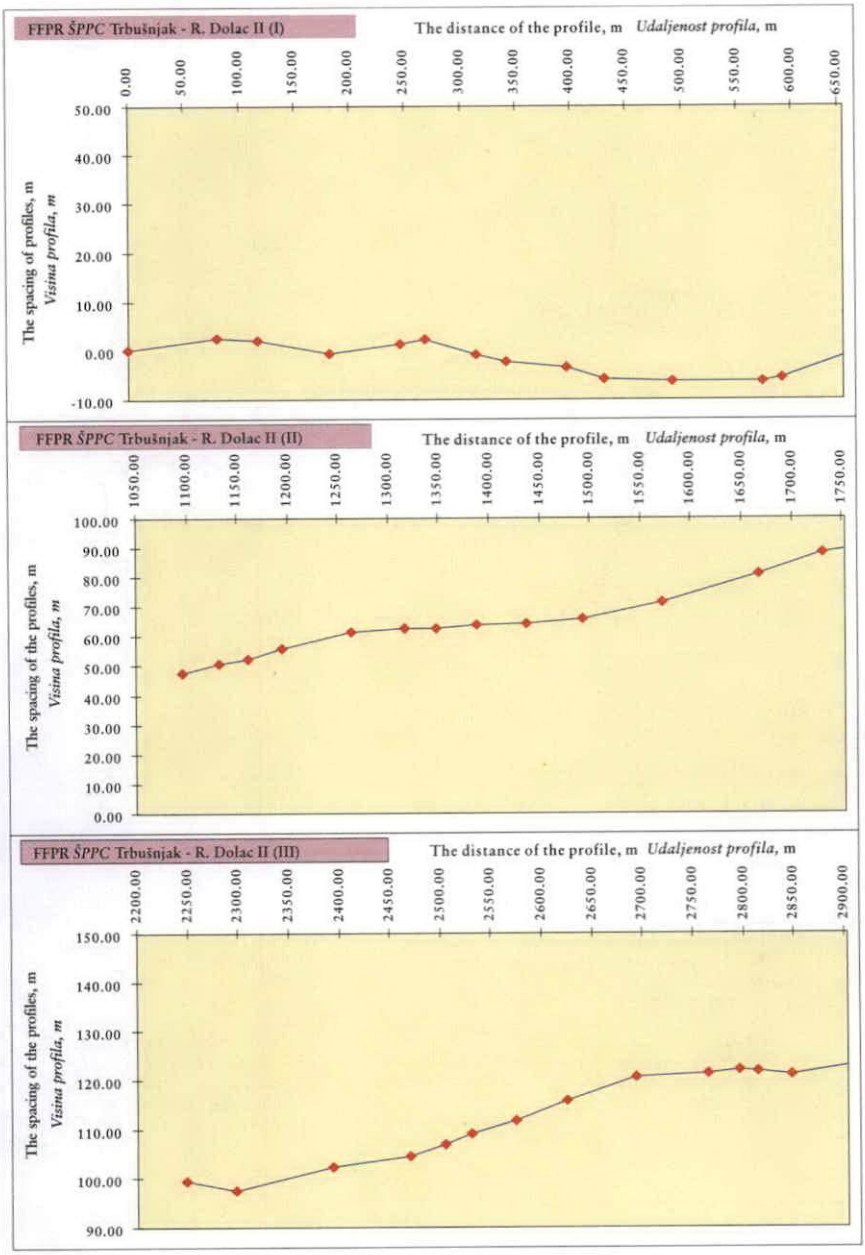
From the data measured on the terrain and according to the measured forest fire-prevention roads which are shown on Map 4, the longitudinal gradients of forest fire-prevention roads are examined. An account of a forest fire-prevention road is given in Figure 1. The position of the fraction points of a grade line, in which also a planum width is measured, is denoted on the abscissa, while a relative altitude of each fraction point is on the ordinate.

In the following tables data for all forest fire-prevention roads in the area of the management unit Senjska Draga are shown.

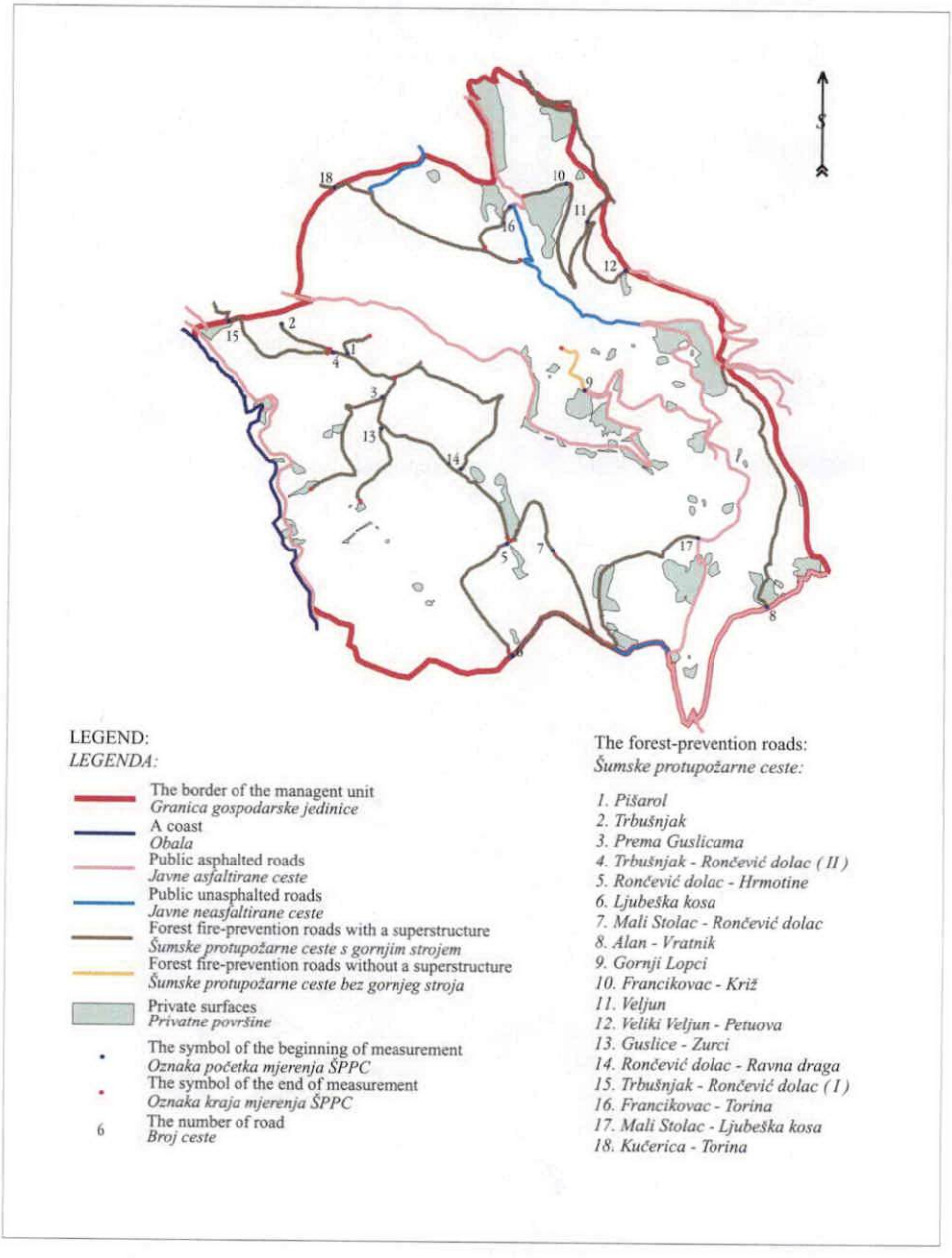
Table 6. All FFPR on the researched area
Tablica 6. Zbirna tablica svih ŠPPC na istraživanome području

Ordinal number no. *Redni broj*	The name of the road *Naziv ceste*	Total number of recorded profiles *Broj snim. profila*	Total length of a road m *Ukupna dulji-na ceste*, m	The length of the allowed gradient m *Duljina dopušt. nagi-ba*, m	The length of not allowed gradient m *Duljina nedo-pušt. nagiba*, m	The average planum width m *Prosječna širina planuma*, m	The total area under FFPR m^2 *Ukupna površina pod ŠPPC*, m^2
1	Pišarol	9	496.50	159.80	336.70	5.96	2,959.14
2	Trbušnjak	9	608.25	608.25	-	5.88	3,576.51
3	prema Guslicama	38	1,819.10	778.90	1,040.20	3.93	7,149.06
4	Trbušnjak-R.dolac II	61	3,374.25	2,700.45	673.80	3.91	13,193.32
5	R.dolac-Hrmotine	24	1,552.55	1,452.75	99.80	3.97	6,163.62
6	Ljubeška kosa	21	1,290.90	885.70	405.20	4.65	6,002.69
7	M.stolac-R.dolac	22	1,422.00	1,037.45	384.55	3.99	5,673.68
8	Alan-Vratnik	49	3,000.20	1,159.65	1,840.55	4.78	14,340.96
9	Gornji Lopci	16	683.95	683.95	-	3.63	2,482.74
10	Francikovac-Križ	16	704.20	362.90	341.30	3.53	2,485.83
11	Veljun	9	484.30	418.70	65.60	4.31	2,087.33
12	V.veljun-Petuova	42	3,048.00	1,561.50	1,486.50	4.19	12,771.12
13	Guslice-Zurci	15	1,129.60	701.50	428.10	3.59	4,055.26
14	R.dolac-Ra.draga	23	2,484.00	1,234.00	1,250.00	3.74	9,290.16
15	Trbušnjak-R.dolac I.	21	1,786.80	913.90	872.90	3.63	6,486.08
16	Francikovac-Torina	10	789.10	789.10	-	3.86	3,045.93
17	M.stolac-Lj. kosa	41	3,495.50	3,133.40	362.10	3.67	12,828.49
18	Kučerica-Torina	38	3,194.50	2,321.90	872.60	4.92	15,716.94
Total *Ukupno*	–	464	31,363.70	20,903.80	10,459.90	–	130,308.76

Figure 1. The longitudinal section of the forest fire-prevention road Trbušnjak - Rončević Dolac II
Slika 1. Uzdužni presjek ŠPPC Trbušnjak–Rončević dolac II



Map 4. Recorded forest fire-prevention roads
Karta 4. Snimljene šumske protupožarne ceste



The total length of forest fire-prevention roads is 31,363.70 m. Of the total length of forest fire-prevention roads 10,459.90 m (33.35 % of all fire-prevention roads) were laid with a higher longitudinal gradient than allowed. The total area under forest fire-prevention roads is 130,308.76 m^2 (13.03 ha).

Table 7. Lengths of certain categories of longitudinal gradient of forest fire-prevention roads
Tablica 7. Duljine pojedinih kategorija uzdužnoga nagiba ŠPPC

The name of the road *Naziv ceste*	The length of the category of the longitudinal gradient of FFPR m *Duljina kategorije uzdužnog nagiba ŠPPC*, m								
	Acclivity +% *Uspon*, +%					Declivity -% *Pad*, -%			
	13-16	9-12	5-8	1-4	0	1-4	5-8	9-12	13-16
Pišarol	-	126.20	54.20	61.20	-	44.40	- -	70.35	140.15
Trbušnjak	-	-	-	117.35	-	86.20	404.70	-	-
prema Guslicama	-	-	-	64.10	-	37.40	678.30	714.45	324.85
Trbušnjak-R.dolac I	71.50	602.30	941.25	1,061.15	113.00	476.90	108.15	-	-
R.dolac-Hrmotine	-	99.80	905.90	293.30	-	169.35	84.20	-	-
Ljubeška Kosa	-	52.60	198.00	389.20	-	46.80	251.20	254.90	97.70
M.stolac-R.dolac	-	-	-	91.55	59.10	264.05	622.75	384.55	-
Alan-Vratnik	-	-	120.40	330.60	18.00	244.80	446.85	1,746.85	92.80
Gornji Lopci	-	-	46.80	251.00	30.90	271.95	83.30	-	-
Francikovac-Križ	81.30	260.00	297.20	19.10	-	46.60	-	-	-
Veljun	-	-	-	-	-	-	418.70	65.60	-
V.veljun-Petuova	-	-	-	-	-	376.00	1,185.50	1,486.50	-
Guslice-Zurci	-	-	76.70	-	-	73.00	551.80	330.30	97.80
R.dolac-Ra.draga	-	-	250.00	228.90	-	440.10	315.00	1,250.00	-
Trbušnjak-R.dolac II	-	-	-	-	-	-	-	913.90	872.90
Francikovac-Torina	-	-	250.00	-	-	61.50	477.60	-	-
M.stolac-Lj. kosa	-	192.80	654.30	749.50	541.20	564.40	624.40	169.30	-
Kučerica-Torina	-	188.50	277.70	483.10	-	776.30	738.90	730.00	-
Total *Ukupno*	152.80	1,522.20	4,072.45	4,140.05	762.20	3,979.75	6,990.45	8,116.70	1,626.20

A total of 31.53 % of forest fire-prevention roads are in acclivity, among which 13.21 % of roads in the category of a longitudinal gradient 1-4 %, 12.98 % in the category 5-8 %, 4.85 % in the category of the longitudinal gradient from 9 to 12 % and 0.49 % of forest fire-prevention roads in the category of a longitudinal gradient from 13 to 16 %. 66.04 % of forest fire-prevention roads were built in declivity, mostly in the category of a longitudinal gradient of 9 to 12 % (25.88 %), slightly fewer in the category of a gradient from 5 to 8 % (22.29 %), with fewer forest fire-prevention roads in the category of a longitudinal gradient from 1 to 4 % (12.69 %) and the least, barely 5.18 % of forest fire-prevention roads, grouped in the category of a gradient of 13-16 %. In the total quantity of measured roads, 2.43 % of the forest fire-prevention roads have a longitudinal gradient which equals zero.

DETERMINING THE AVERAGE OPTIMUM DISTANCE OF APPROACH TO A FOREST AREA OF CLASSICAL AND RELATIVE OPENNESS
ODREĐIVANJE SREDNJE OPTIMALNE DALJINE PRISTUPA ŠUMSKOJ POVRŠINI, KLASIČNE I RELATIVNE OTVORENOSTI

Despite the fact that the intensive building of forest fire-prevention roads in the Republic of Croatia started in 1990 and that there are more than justified reasons for this, even today forest fire-prevention roads have not yet been accepted as a special category of forest roads. There are no regulated theoretical distances between FFPR, there is no recommended or optimum openness of forest fire-prevention roads, and there are no general limits for the average distance of the approach to the area. This has led to the necessity of defining and establishing certain values which should be taken into consideration in the planning, designing and building of FFPR.

After consultations with commanders of professional fire-brigades in Rijeka and voluntary fire brigades on the island of Rab regarding the tactics for extinguishing forest fires that have been used successfully for years in these areas and which are obligatory by law todayf or the whole area of the Republic of Croatia, it has been realised that the actual area which can be žcovered' in the first rush by intervening fire-engines is only an area 50 metres away from the forest fire-prevention road in all directions, while in the second rush, this service area is a maximum of 300 metres from the forest fire-prevention road in all directions.

As these are optimum values from the point of view of the fire brigade, by the use of computers, so-called "buffers" were laid around previously digitised existing roads on the research area, which extended at a uniform distance from the edges of the roads, which represented an average optimum geometrical distance of approach to the area. The variants of that parameter were 50, 100, 150, 200, 250 and 300 metres.

The obtained areas were screened and transferred into a digital terrain model on which, according to the made histogram, the average terrain gradient was determined in each variant and which was used for finding factors of vertical correction of the terrain. Each variant of the average optimum geometric distance of approach to the area was multiplied by this factor, and then divided by the factor of horizontal bypassing, which was 1.10 for the whole research area. This was done in order to obtain an average optimum real distance of approach to the area.

These expressions were used:

$$S_{PS} = \frac{S_{PG}}{k_H} \cdot k_V \tag{2}$$

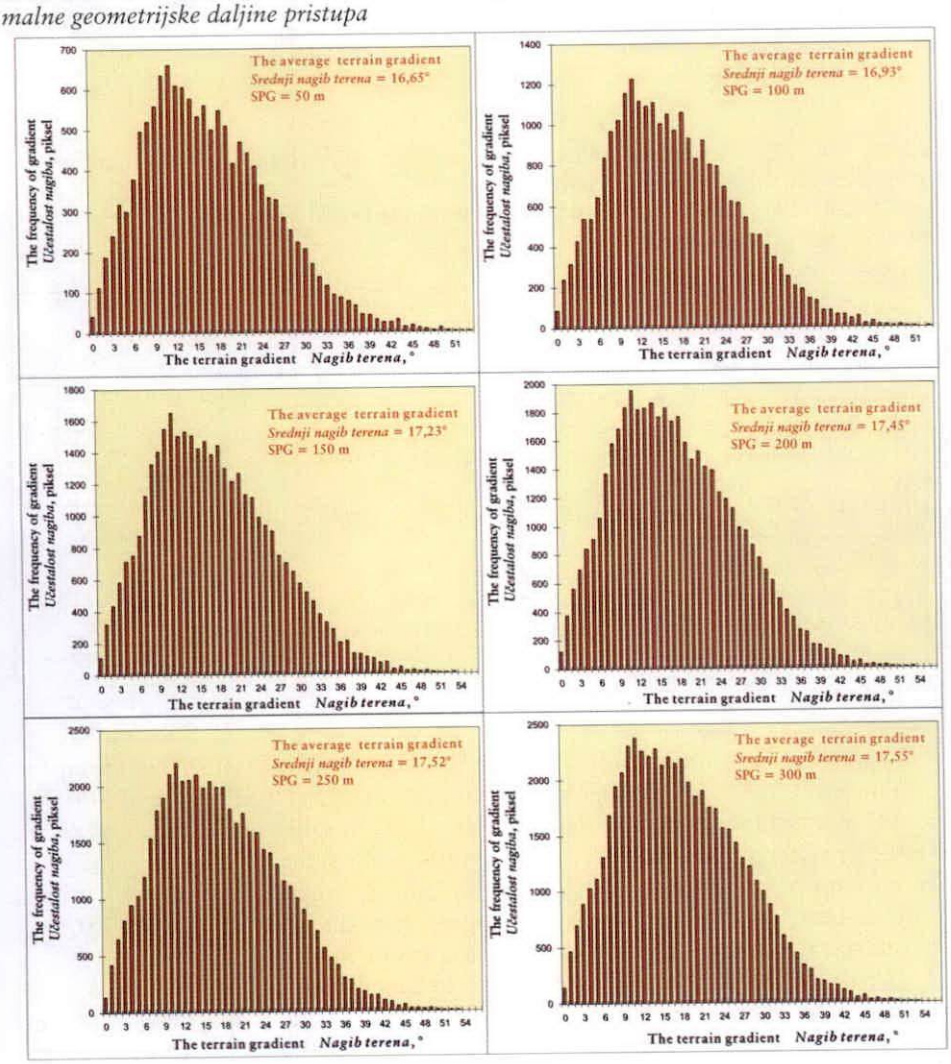
$$k_H = 1.10 \tag{3}$$

$$k_V = \cos \alpha \tag{4}$$

where:

S_{PG} is an average geometric optimum distance of the approach to the area, m,
S_{PS} is an average real optimum distance of the approach to the area, m,
k_H is a factor of horizontal bypassing,
k_V is a factor of vertical correction,
α is an average terrain gradient °.

Figure 2. An account of the participation of various terrain gradients for areas with different variants of the average optimum geometric distance of approach
Slika 2. Prikaz udjela različitih nagiba terena za površine s različitim inačicama srednje optimalne geometrijske daljine pristupa



Determining an area which is open regarding the choice of an individual variant of an average approach to the area and the total area of the management unit (together with private enclaves within the areas managed by the Public Enterprise "Croatian Forests", the relative openness for each variant was obtained, according to the formula:

$$O_R = \frac{P_O}{P_U} \cdot 100 \qquad (5)$$

where:
O_R is the relative openness of the area, %,
P_O is the open area, ha,
P_U is the total area, %.

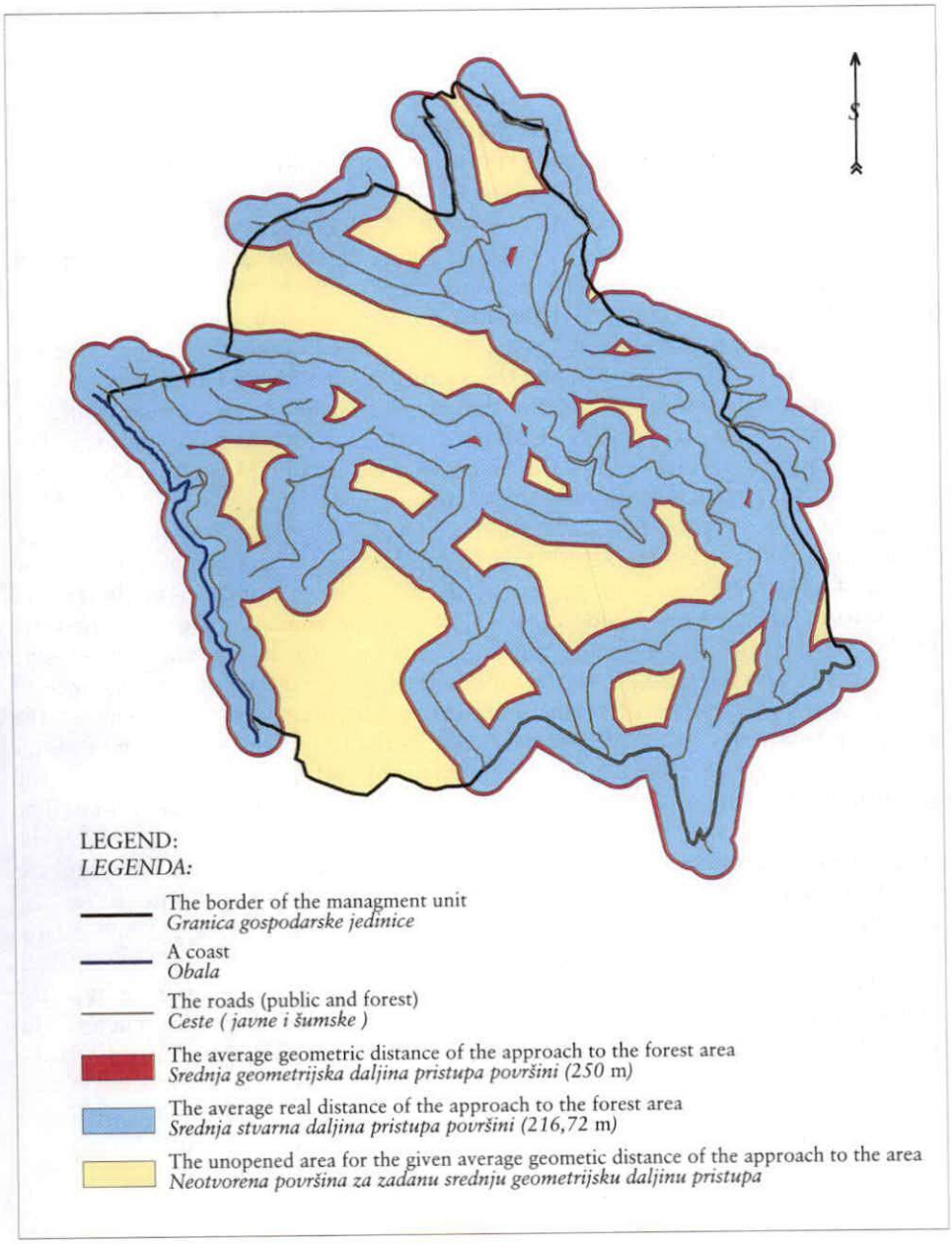
Table 8. The relative openness of the research area according to the various variants of the average real distance of approach to the area
Tablica 8. Relativna otvorenost istraživanoga područja prema različitim inačicama srednje stvarne daljine pristupa površini

S_{PG} m	α °	k_V	k_H	S_{PS} m	P_O ha	P_U ha	O_R %	Openness *Otvorenost* (Jurik et al. 1984)
50	16.65	0.95807	1.10	43.54	483.41	2,807.83	17.22	unsatisfactory *nedovoljna*
100	16.93	0.95666	1.10	86.97	912.41	2,807.83	32.50	unsatisfactory *nedovoljna*
150	17.23	0.95512	1.10	130.24	1,289.95	2,807.83	45.94	unsatisfactory *nedovoljna*
200	17.45	0.95398	1.10	173.45	1,632.32	2,807.83	58.13	unsatisfactory *nedovoljna*
250	17.52	0.95631	1.10	216.72	1,878.21	2,807.83	66.89	hardly satisfactory *slabo zadovoljavajuća*
300	17.55	0.95345	1.10	260.04	2,073.67	2,807.83	73.85	satisfactory *zadovoljavajuća*

Therefore, we can conclude that the openness of the area of the management unit Senjska Draga, at an average real distance of approach to the area of 300 metres, i.e. at a distance between roads of 600 metres, is satisfactory, as it is possible to intervence from one fire-prevention road on both sides. At an average real distance of approach to the area of 250 metres, the openness of the research area is hardly satisfactory. For variants of the approach to the area of 50, 100, 150 and 200 metres, the openness of the forest area is insufficient.

The described method of laying down so-called "buffers", which are equally far away everywhere from a forest fire-prevention road, i.e. roads that can be used as fire-prevention ones, is the ideal method by which the openness of a certain fo-

Map 5. An account of the method of limited areas for the average geometric distance of approach to the area of 250 m
Karta 5. Prikaz metode "buffera" za srednju geometrijsku daljinu pristupa površini 250 m



rest area can clearly be presented with the chosen optimum average distance of approach. In the same way, by using this method, unopened areas can be seen, which should particularly be taken into consideration in the further opening of the forest area. The "buffer" method is also efficient in the planning and further branching out of a forest fire-prevention roads network: a buffer of a specific size is laid around possible variants of routes of future forest fire-prevention roads, which are represented by a ground centre line and digitised as such. The variant of forest fire-prevention roads which opens the greatest part of the unopened forest area and at the same time includes the smallest area of the so-called dead zones, i.e. areas which, for the chosen average optimum distance of the approach to the area, are open with two or more roads, is the most efficient and the best.

The openness of the management unit Senjska Draga determined by the centroidal method was to be observed. For this purpose, by the use of a personal computer and suitable programmes, the centre of gravity of each subcompartment was found and drawn into a digitised map. The shortest distance from the centre of gravity of each subcompartment to the nearest road which can be used as a fire-prevention road was measured and defined as an average geometric distance of the approach to the area of the subcompartment. These lines of normal fire brigade intervention were drawn into the maps. In order to obtain the average real distances of the approach to the area of the subcompartment, a factor of the vertical correction of the terrain had to be found, as well as the factor of the horizontal bypassing of obstacles. The factor of the vertical terrain correction was established in such a way that the average geometric distances of the approach to the area of the subcompartment were laid across DTM and the values of the gradient were read at four points. Then, the average value in degrees was found and the cosine (cos) of that average gradient was established. The average geometric distance of the approach to the area of a subcompartment was divided by the cosine of the average gradient and multiplied by the factor of the horizontal bypassing of obstacles in order to obtain its real equivalent. A value of 1.10 was used as a factor of the horizontal bypassing of obstacles for the area of the whole management unit. The average geometric and the average real distance of the approach to the area of the whole management unit were calculated as the arithmetic mean of these values for each section, and the values of the section area were taken into consideration. The average geometric distance of the approach for the management unit Senjska Draga is 244.79 m and its real equivalent is 287.15 m.

The question is: what is the openness of the forest area expressed in m/ha for the mentioned variants of the average geometric distance of the approach to the area ? To obtain the answer, the model of the forest area of the dimension 1 200 x 1 000 m was taken and that model was opened by parallel forest fire-prevention roads on the mutually equal distance of 1 ($1 = 2S_{PG}$).

The following mathematical expressions were used in the calculation:

$$l = 2\,S_{PG} \quad d = \frac{Pu}{l} \quad O = \frac{d}{Pu} \qquad (6), (7), (8)$$

where:
S_{PG} is an average optimum geometric distance of the approach to the area, m,
l is the distance between roads, m,
d is the total quantity of roads on the whole area, m,
P_U is the total area that is opened, ha,
O is the openness of the forest area m/ha.

The obtained results are shown in Table 9.

Table 9. The quantity of roads and the openness of forest areas depending on the chosen variant of the average real optimum distance of the approach to the area
Tablica 9. Količina cesta i otvorenost šumskoga područja u ovisnosti o odabranoj inačici srednje stvarne optimalne daljine pristupa površini

S_{PG} m	l m	d m	P_U ha	O m/ha
50	100	12 000	120	100.00
100	200	6 000	120	50.00
150	300	4 000	120	33.33
200	400	3 000	120	25.00
250	500	2 400	120	20.00
300	600	2 000	120	16.67

According to the criterion of the openness of the forest area and according to knowledge on openness in the leading world forest countries, it can be concluded that an openness of 100.00 m/ha, which was obtained for the average optimum real distance of approach to an area of 50 m, cannot be considered, at least for building forest fire-prevention roads. An openness of 50 m/ha which was obtained for the variant S_{PG} = 100 m, is also very high and can hardly be justified in practice.

Therefore, according to the criterion of the openness of the forest area by forest fire-prevention roads, it is possible to open forest areas endangered by fires from an average optimum geometric distance of approach from 150 meters and above.

One of the criteria for determining the largest quantity of roads permitted in a particular ecosystem without disturbing its balance and without exceeding the allowed limits of dangers from damage caused by erosion is also the amount of the forest area under forest roads. This can be obtained by dividing the forest area under roads by the total area which is to be opened and expressed as a percentage. According to Pičman (1994), that quantity for forest roads is 3 %. The area under forest fire-prevention roads is calculated for various variants of the average optimum real distance of the approach on the previously used theoretical forest area. The various planum widths of forest fire-prevention roads were used as entries.

Table 10. The relation of the forest area under forest fire-prevention roads with various variants SPG and various planum widths
Tablica 10. Odnos šumske površine pod šumskim protupožarnim cestama kod različitih inačica SPG i različite širine planuma

	The average geometric distance of the approach to the area *Srednja optimalna geometrijska daljina pristupa površini*					
	50	100	150	200	250	300
	m					
The planum width *Širina planuma*	The area under forest fire-prevention roads *Površina pod šumskim protupožarnim cestama*					
m	%					
3.00	3.00	1.50	1.00	0.75	0.60	0.50
3.50	3.50	1.75	1.17	0.88	0.70	0.58
4.00	4.00	2.00	1.33	1.00	0.80	0.67
4.50	4.50	2.25	1.50	1.13	0.90	0.75
5.00	5.00	2.50	1.67	1.25	1.00	0.83

According to the factor of the percentage share of the area under forest roads, in the total surface of the area that is to be opened, the obtained results are in accordance with previous considerations. The network of forest fire-prevention roads in which the mutual distance of roads is 100 m, even with the minimum planum width of 3.00 m, reaches the maximum values of 3 % of the area under forest roads. Such a network of forest roads, although being considered the optimum by members of fire-brigades, is absolutely unacceptable from the forestry point of view and untenable in forest ecosystems. The area values under forest roads for a road distance of 200 m are acceptable, but are close to the allowed upper maximum. As we are dealing with fire-prevention roads in karst areas where there are great dangers of erosion and where vegetation, as the basic factor which prevents erosion, is not rich and not exuberant, it is better to plan and design networks of forest roads with larger distances which will also decrease the area under forest fire-prevention roads.

DETERMINING AREAS AND VOLUMES OF EXCAVATIONS AND EMBANKMENT IN FFPRS OF THE NORMAL TRANSVERSAL PROFILE DESIGNED ON VARIOUS TRANSVERSAL TERRAIN GRADIENTS
ODREĐIVANJE POVRŠINE I VOLUMENA ISKOPA I NASIPA KOD ŠPPC NORMALNOGA POPREČNOGA PROFILA PROJEKTIRANIH NA RAZLIČITIM POPREČNIM NAGIBIMA TERENA

The final cost of execution is very important when choosing a particular variant of a FFPR. The main source of expenses are the costs of earthwork which can be influenced in planning the future route of a fire-prevention road. The position of a FFPR was presented by ground centre lines of various gradients, depending on

the terrain gradient. The characteristic of each ground centre line is that the level of the grade line in the axis of the future road is equal to the level of the terrain at points obtained by designing ground centre lines on the digitised map (points which are on contour lines).

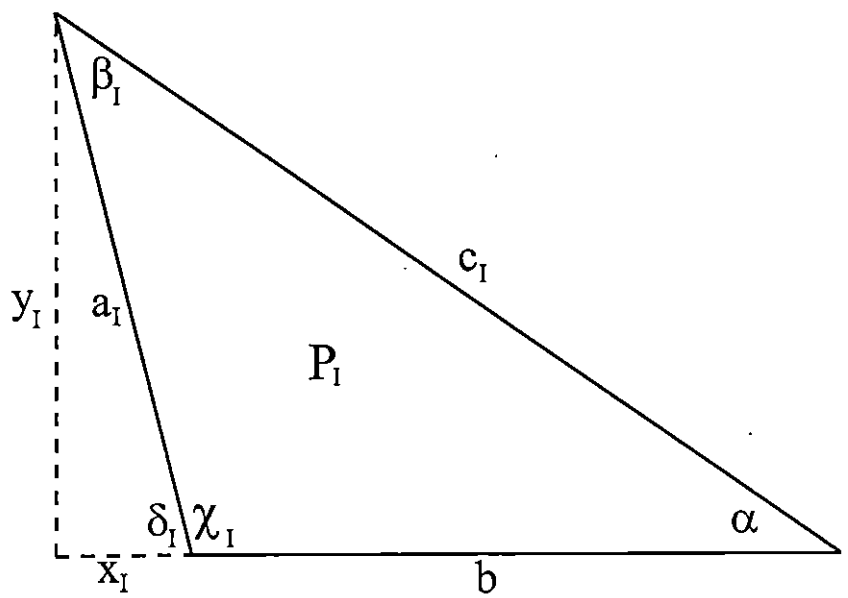
As the normal transversal profile of a forest fire-prevention road is known and a ground centre line which approximates the future situation on the terrain is laid, it is possible to determine in a very short period parallel costs of more variants of future routes of forest fire-prevention roads. The presumption is that the terrain gradient vertical on the ground centre line is constant for the whole planum width of the FFPR, which is 4.00 m.

While deriving mathematical expressions to calculate surfaces of excavation and embankment, which are necessary to obtain the volume of earthwork, and finally to obtain the approximate costs of the earthwork, we will use triangles of the surface P_I (the surface of the excavation) and P_N (the surface of the embankment).

The angle a is the terrain gradient angle which can be read from the digital terrain model. The quantity b is calculated from the total planum width of forest fire-prevention roads:

$$b = \frac{P}{2} \tag{9}$$

Figure 3. An account of the basic components for the calculation of the excavation surface
Slika 3. Prikaz osnovnih sastavnica za izračun površine iskopa



From the planned straight clearing gradient marked with m, a smaller angle between the straight clearing gradient and the horizontal (δ_I) will be calculated:

$$\delta_I = arctg(m) \tag{10}$$

From Figure 3 we can see that the following relation is valid:

$$\chi_I + \delta_I = 180° \Rightarrow \chi_I = 180° - \delta_I \tag{11}$$

The following mathematical expressions are also valid:

$$\frac{\sin\alpha}{a_I} = \frac{\sin\beta_I}{b} \Rightarrow \alpha_I = \frac{\sin a \cdot b}{\sin\beta_I} \tag{12}$$

$$P_I = \frac{a_I \cdot b}{2} \cdot \sin\chi_I \tag{13}$$

where:
α is a terrain gradient angle vertical on the ground centre line, °,
β_I is an angle between the straight clearing gradient and the terrain, °,
x_I is a bigger angle between the straight clearing gradient and the horizontal, °,
δ_I is a smaller angle between the straight clearing gradient and the horizontal, °,
P is a planum width, m,
b is half of the planum width, m,
m is a designed straight clearing gradient,
a_I is the length of the excavation gradient, m,
P_I is the excavation surface, m^2.

The procedure of derivation of necessary patterns for the calculation of the embankment surface is the same as in the derivation of formulas for the calculation of the excavation surface. The obtained formulas differ only in the indexes next to the symbols and quantities. The final expressions are:

$$b = \frac{P}{2} \tag{14}$$

$$\delta_N = arctg(n) \tag{15}$$

$$\chi_N = 180 - \delta_N \tag{16}$$

$$\beta_N = 180 - \alpha - \chi_N \tag{17}$$

$$\frac{\sin\alpha}{a_N} = \frac{\sin\beta_N}{b} = \frac{\sin\chi_N}{c_N} \Rightarrow a_N = \frac{\sin\alpha \cdot b}{\sin\beta_N} \tag{18}$$

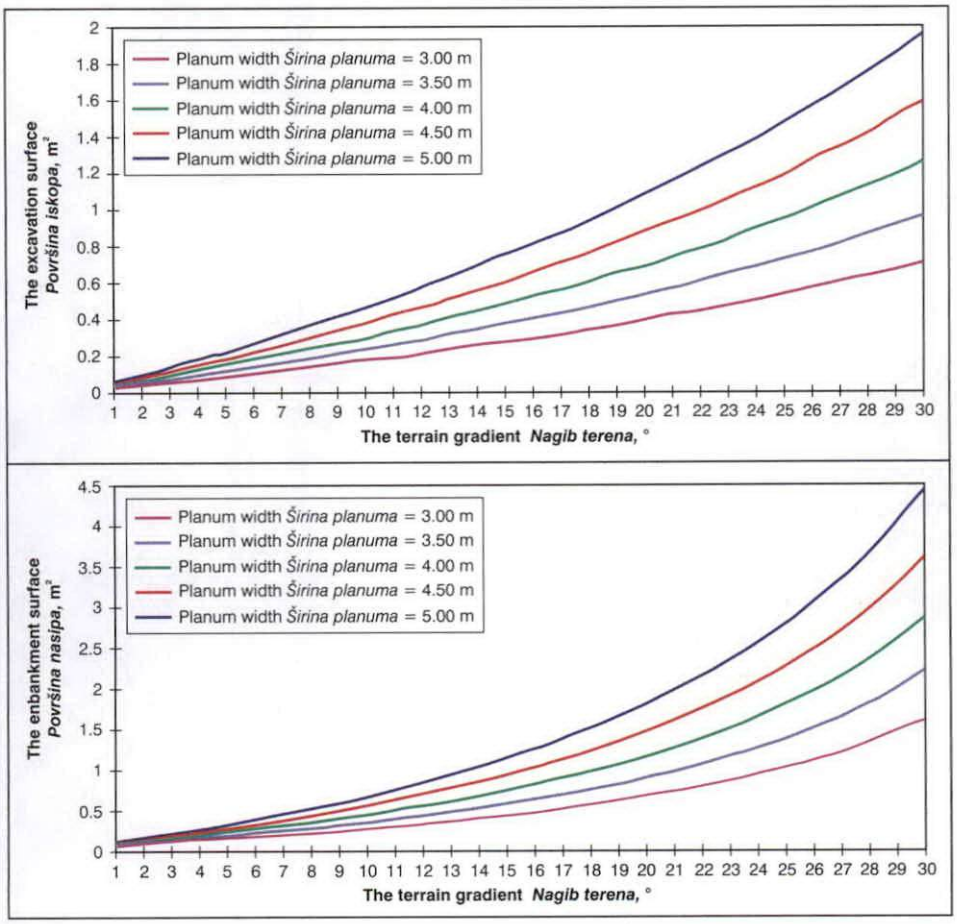
$$P_N = \frac{a_N \cdot b}{2} \cdot \sin \chi_N \tag{19}$$

The excavation surfaces as well as the embankment surfaces for a FFPR of a constant planum width increase proportionally to the increase of the transversal terrain gradient.

From Figure 4 the lack of earth for building an embankment for a FFPR is obviously in relation to the existing earth excavated in making a straight clearing

Figure 4. A graphical account of the dependence of the excavation and embankment surface on the characteristic transversal profile of a FFPR at various transversal terrain gradients and planum widths

Slika 4. Grafički prikaz ovisnosti površine iskopa i nasipa na karakterističnom poprečnom profilu ŠPPC pri različitom poprečnom nagibu terena i širini planuma



with the increase in the transversal terrain gradient and with the increase in the planum width. This means that the lack of material for embankment building should be solved in the most economic way.

An idea on how to solve this problem lies in the use of building technology of the so-called side compensation of earth masses.

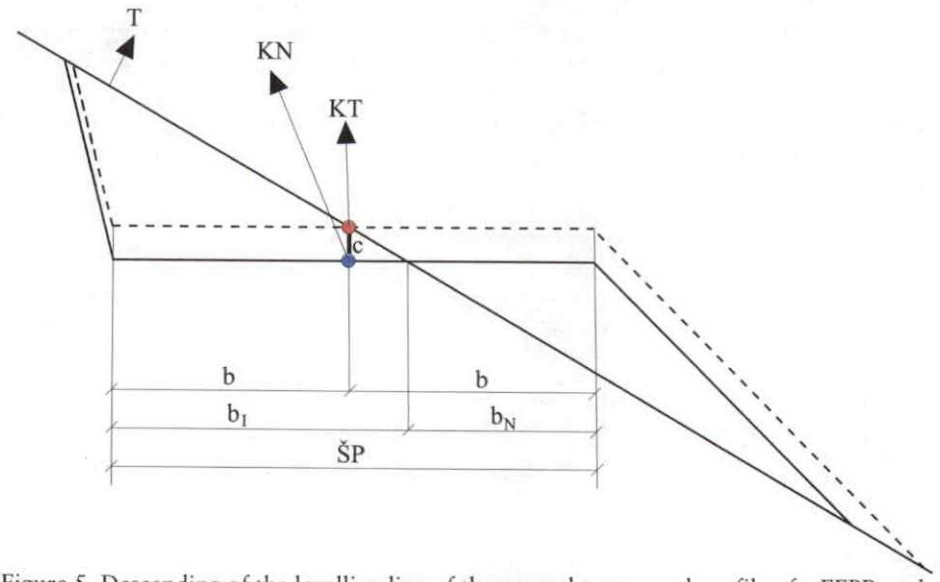


Figure 5. Descending of the levelling line of the normal transversal profile of a FFPR under the terrain level

Slika 5. Spuštanje kote nivelete normalnoga poprečnoga profila ŠPPC ispod kote terena

where:

gdje je:

ŠP is planum width, m; *širina planuma,* m

b is half planum width, m; *pola širine planuma,* m

b_I is planum width in the excavation for which the surface of excavation is the same as the surface of the embankment, m; *širina planuma u iskopu za koju je površina iskopa jednaka površini nasipa,* m

b_N is planum width of the embankment for which the excavation surface is the same as the embankment surface, m; *širina planuma u nasipu za koju je površina iskopa jednaka površini nasipa,* m

c is the difference between the terrain level and the levelling line, m; *razlika između kote terena i kote nivelete*, m

KT is terrain level, m; *kota terena,* m

KN is levelling line, m; *kota nivelete*, m

T is terrain; *teren*

Two changes which appear in moving the levelling line under the terrain level should be noted. They are important for further work: the excavation surface is equal to the embankment surface and the relation of the planum width in the straight clearing and the embankment is no longer 1:1. For this reason it was necessary to find a new ratio of the planum width of the FFPR in the excavation and the embankment.

Excavation and embankment surfaces are expressed depending on b_I and B_N and depending on the transversal terrain gradient:

$$P_I = \frac{\sin\chi_I \cdot b_I^2 \cdot \sin\alpha}{2 \cdot \sin\beta_I} \qquad P_N = \frac{\sin\chi_N \cdot b_N^2 \cdot \sin\alpha}{2 \cdot \sin\beta_N} \qquad (20), (21)$$

For the planned excavation gradient m = 4:1 and the planned embankment gradient n = 1:1, we will get:

$$P_I = \frac{0.970 \cdot b_I^2 \cdot \sin\alpha}{2 \cdot \sin(75.95 - \alpha)} \qquad P_N = \frac{0.707 \cdot b_N^2 \cdot \sin\alpha}{2 \cdot \sin(45 - \alpha)} \qquad (22), (23)$$

As there is a case of side compensation, this should be:

$$P_I = P_N \Rightarrow \frac{b_I}{b_N} = \sqrt{\frac{0.707 \cdot \sin(75.95 - \alpha)}{0.970 \cdot \sin(45 - \alpha)}} \qquad (24)$$

If we mark the expression under the root with k and if we know the total planum width, it follows:

$$b_I + b_N = P \qquad b_N = \frac{P}{k+1} \qquad (25), (26)$$

Solving two equations with two unknowns (b_I and b_N), we can easily calculate the planum width in the straight clearing and the planum width in the excavation. The difference between the terrain level and the levelling line (c) will be calculated by the expression:

$$\operatorname{tg}\alpha = \frac{c}{b_I - b} \Rightarrow c = \operatorname{tg}\alpha \cdot (b_I - b) \qquad (27)$$

When we know the excavation and the embankment surfaces which are equal for each segment of the ground centre line and are determined in the middle of the segment, it is possible to determine the volume of the earthwork of the excavation and the embankment for each segment of the ground centre line, as each segment of the ground centre line is of the same length, by these expressions:

$$V_I = P_I \cdot l \qquad V_N = P_N \cdot l \qquad (28), (29)$$

while for the whole FFPR, the volume of necessary excavations and embankments will be calculated according to the formulas:

$$V_{IUK.} = \sum_{i=1}^{n} V_{Ii} \qquad V_{NUK.} = \sum_{i=1}^{n} V_{Ni} \qquad (30), (31)$$

and if we want to find out the total cost of the execution of excavations and embankments on the FFPR, the following patterns will be used:

$$T_{IUK.} = V_{IUK.} \cdot C_I \quad T_{NUK.} = V_{NUK.} \cdot C_N \qquad (32), (33)$$

where:

V_I is an excavation volume of each segment of the ground centre line, m^3,
V_N is an embankment volume of each segment of the ground centre line, m^3,
P_I is the excavation surface calculated on the half segment of the ground centre line, m^2,
P_N is the embankment surface calculated on the half segment of the ground centre line, m^2,
l is the length of segments of the ground centre line, m,
V_{IUK} is the total volume of the excavation earthwork for the whole forest fire-prevention road, m^3,
V_{NUK} is the total volume of the embankment earthwork for the whole forest fire-prevention road, m^3,
i is the ordinal number of the ground centre line segment,
T_{IUK} are total costs of excavation earthwork for the whole forest fire-prevention road, kn
T_{NUK} are total costs of the embankment earthwork for the whole forest fire-prevention road, kn
C_I is the execution price of 1 m^3 of the excavation, kn,
C_N is the execution price of 1 m^3 of the embankment, kn.

CALCULATION OF THE COSTS OF EARTHWORK OF A FFPR FOR THE VARIABLE QUANTITIES OF THE PLANUM WIDTH, TRANSVERSAL TERRAIN GRADIENT AND CATEGORIES OF THE MATERIAL
IZRAČUN TROŠKOVA ZEMLJANIH RADOVA ŠPPC ZA PROMJENJIVE VELIČINE ŠIRINE PLANUMA, POPREČNOG NAGIBA TERENA I KATEGORIJE MATERIJALA

The transversal terrain gradient of 0° to 45° has been divided into categories of a 5° width. In this way the quantities 2.5°, 7.5°, 12.5°, 17.5°,...., 37.5° and 42.5° are obtained, which represent a particular category of the transversal terrain gra-

Table 11. The relation of the excavation costs in building a FFPR 1 000 m long, depending on the terrain gradient and the planum width for material of the III category
Tablica 11. Odnos troškova zemljanih radova pri izvedbi ŠPPC duljine 1 000 m, *ovisno o nagibu terena i širini planuma za materijal III. kategorije*

The terrain gradient ° *Nagib terena,* °	2.5	7.5	12.5	17.5	22.5	27.5	32.5	37.5	42.5
The planum width = 3.00 m *Širina planuma* = 3.00 m									
The excavation volume, m³ *Volumen iskopa,* m³	40	140	250	400	590	850	1,230	1,850	3,180
The excavation cost, kn *Cijena iskopa,* kn	149	521	930	1,488	2,195	3,162	4,576	6,882	11,830
The embankment volume, m³ *Volumen nasipa,* m³	40	140	250	400	590	850	1,230	1,850	3,180
The cost of embankment building, kn *Cijena izradbe nasipa,* kn	170	596	1,065	1,704	2,513	3,621	5,240	7,881	13,547
The earthwork cost, kn *Cijena zemljanih radova,* kn	3,409	4,207	5,085	6,282	7,798	9,873	12,906	17,853	28,467
The planum width = 3.50 m *Širina planuma* = 3.50 m									
The excavation volume, m³ *Volumen iskopa,* m³	60	190	350	550	810	1,160	1,680	2,520	4,330
The excavation cost, kn *Cijena iskopa,* kn	223	707	1,302	2,046	3,013	4,315	6,250	9,374	16,108
The embankment volume, m³ *Volumen nasipa,* m³	60	190	350	550	810	1,160	1,680	2,520	4,330
The cost of embankment building, kn *Cijena izradbe nasipa,* kn	256	809	1,491	2,343	3,451	4,942	7,157	10,735	18,446
The earthwork cost, kn *Cijena zemljanih radova,* kn	4,084	5,121	6,398	7,994	10,069	12,862	17,012	23,714	38,159
The planum width = 4.00 m *Širina planuma* = 4.00 m									
The excavation volume, m³ *Volumen iskopa,* m³	70	240	450	710	1,050	1,520	2,190	3,290	5,660
The excavation cost, kn *Cijena iskopa,* kn	260	893	1,674	2,641	3,906	5,654	8,147	12,239	21,055
The embankment volume, m³ *Volumen nasipa,* m³	70	240	450	710	1,050	1,520	2,190	3,290	5,660
The cost of embankment building, kn *Cijena izradbe nasipa,* kn	298	1,022	1,917	3,025	4,473	6,475	9,329	14,015	24,112
The earthwork cost, kn *Cijena zemljanih radova,* kn	4,678	6,035	7,711	9,786	12,499	16,249	21,596	30,374	49,287
The planum width = 4.50 m *Širina planuma* = 4.50 m									
The excavation volume, m³ *Volumen iskopa,* m³	90	310	570	900	1,330	1,920	2,770	4,160	7,160
The excavation cost, kn *Cijena iskopa,* kn	335	1,153	2,120	3,348	4,948	7,142	10,304	15,475	26,635
The embankment volume, m³ *Volumen nasipa,* m³	90	310	570	900	1,330	1,920	2,770	4,160	7,160
The cost of embankment building, kn *Cijena izradbe nasipa,* kn	383	1,321	2,428	3,834	5,666	8,179	11,800	17,722	30,502
The earthwork cost, kn *Cijena zemljanih radova,* kn	5,353	7,109	9,183	11,817	15,249	19,956	26,739	37,332	61,772
The planum width = 5.00 m *Širina planuma* = 5.00 m									
The excavation volume, m³ *Volumen iskopa,* m³	120	380	710	1,120	1,650	2,370	3,420	5,140	8,840
The excavation cost, kn *Cijena iskopa,* kn	446	1,414	2,641	4,166	6,138	8,816	12,722	19,121	32,885
The embankment volume, m³ *Volumen nasipa,* m³	120	380	710	1,120	1,650	2,370	3,420	5,140	8,840
The cost of embankment building, kn *Cijena izradbe nasipa,* kn	511	1,619	3,025	4,771	7,029	10,096	14,569	21,896	37,658
The earthwork cost, kn *Cijena zemljanih radova,* kn	6,107	8,183	10,816	14,087	18,317	24,062	32,441	46,167	75,693

dient. According to the previously derived mathematical expressions, the cost of the excavation, the total cost of the embankment construction and the total cost of the earthwork of forest fire-prevention roads 1 000 m long were calculated as final quantities, at various transversal terrain gradients, for the normal transversal profile of a forest fire-prevention road and according to the cost estimates of the works of the Public Enterprise "Croatian Forests".

The surface of the normal transversal profile of forest fire-prevention roads in which the grade line level under the terrain level for the value c in which the excavation surface is equal to the embankment surface was taken into consideration. The obtained surfaces were multiplied by 1 000 m to get the excavation and the embankment volumes. The excavation volume was multiplied by the cost of a particular type of work in the III category of the material, the prices were added and the total cost of earthwork was obtained.

The cost of earthwork for forest fire-prevention roads increases with the increase in planum width and with the increase in transversal terrain gradients. Also, the cost of earthwork increases with less acceptable terrain categories on which the work is executed. If we observe the cost movement for earthwork of a planum width of 4,00 m and if we compare it to the cost of earthwork for a terrain gradient of 42.5°, we will get interesting results shown in Table 12.

Table 12. A comparison of the quantity of FFPRs with a planum width of 4.00 m which can be executed with the same financial investment, but with different transversal terrain gradients

Tablica 12. Usporedba količine ŠPPC sa širinom planuma 4,00 m koje se mogu izvesti uz ista financijska ulaganja, ali pri različitim poprečnim nagibima terena

Transversal terrain gradient *Poprečni nagib terena*, °	The earthwork cost for 1,000 m of FFPR *Cijena zemljanih radova za 1 000* m ŠPPC kn	The length of FFPR which can be build for 49,287 kn *Duljina ŠPPC koje se mogu izvesti za 49 287* kn m
2.5	4,678	10,536
7.5	6,035	8,167
12.5	7,711	6,392
17.5	9,786	5,036
22.5	12,449	3,959
27.5	16,249	3,033
32.5	21,996	2,241
37.5	30,374	1,623
42.5	49,287	1,000

Table 13. A comparison of the length of FFPRs which can be built with the same financial investment in the same transversal terrain gradient and with materials of different categories

Tablica 13. Usporedba duljine ŠPPC koje se mogu izgraditi uz jednaka financijska ulaganja pri jednakim poprečnim nagibima terena i materijalu različitih kategorija

	Material of III cat. *Materijal III. kat.*		Material of IV. cat. *Materijal IV. kat.*		Material of V. cat *Materijal V. kat.*
A transversal terrain gradient *Popr. nagib terena*	The cost of earthwork for 1000 m of FFPR *Cijena zemljanih radova za 1000* m *ŠPPC*	The length of FFPR that can be made for the cost of earthwork of material of V category *Duljina ŠPPC koja se može izvesti za cijenu zemljanih radova materijala V. kat.*	The cost of earthwork for 1000 m of FFPR *Cijena zemljanih radova za 1000* m *ŠPPC*	The length of FFPR that can be made for the cost of earthwork of material of V category *Duljina ŠPPC koja se može izvesti za cijenu zemljanih radova materijala V. kat.*	The cost of earthwork for 1000 m of FFPR *Cijena zemljanih radova za 1000* m *ŠPPC*
°	kn	m	kn	m	kn
2.5	4,678	1,763	6,421	1,284	8,245
7.5	6,035	3,026	12,011	1,521	18,263
12.5	7,711	3,973	18,916	1,620	30,639
17.5	9,786	4,697	27,465	1,673	45,961
22.5	12,449	5,301	38,664	1,707	65,997
27.5	16,249	5,766	54,097	1,732	93,693
32.5	21,996	6,055	76,127	1,749	133,176
37.5	30,374	6,519	112,295	1,763	197,999
42.5	49,287	6,851	190,221	1,775	337,664

Therefore, whenever it is possible, those terrains whose transversal gradient is lower should be chosen as a route for forest fire-prevention roads, as then there are smaller surfaces of excavation and embankments on the normal transversal profile. Consequently, the lower the volumes of excavation and embankments for each segment of the forest fire-prevention road, the lower the total costs of earthwork for the whole fire-prevention road.

Naturally, all other factors of a spatially well-laid network of forest fire-prevention roads should also be taken into consideration.

With an increase in the transversal terrain gradient, differences in the number of kilometres that can be built for the same construction costs also increases, starting from the III to IV and V category of materials with which the work is done. Also, there are bigger differences between the possible quantity of FFPRs in the II and the III categories than in the III and the IV categories of materials.

THE CALCULATION OF THE COSTS OF EARTHWORK OF THE VARIANTS OF FFPRs, SIMULATED BY THE GROUND CENTRE LINE AND USING THE PROGRAMME "COST" AS ONE OF THE CRITERIA FOR CHOOSING THE MOST ACCEPTABLE VARIANT
IZRAČUN TROŠKOVA ZEMLJANIH RADOVA INAČICA ŠPPC, SIMULIRANIH NULTOM LINIJOM I UPORABOM PROGRAMA "TROŠAK", KAO JEDAN OD KRITERIJA ODABIRA NAJPOVOLJNIJE INAČICE

According to the previously mentioned theoretical presumptions and derived mathematical expressions, a simple computer programme called COST was written in the programme language C++. The programme calculates the cost of earthwork for forest fire-prevention roads, i.e. costs which are under the direct influence of the transversal terrain gradient, i.e. the terrain configuration. By the entry of the basic components of the normal transversal profile of forest fire-prevention roads such as planum width, planned straight clearing gradient, and planned embankment gradient, and by the entry of the transversal terrain gradient in degrees and excavation costs, the costs of building the embankment and the costs of planum planning, it is possible to obtain the total cost of earthwork for each particular segment of the ground centre line in a very short time. At this stage of planning, a forest fire-prevention line is approximately presented by the ground centre line, and the data which are entered are average values for each segment of the ground centre line or values measured in the middle of the segment. Total costs for the whole FFPR are obtained by adding the costs for each segment.

By comparing the total costs of earthwork for more variants of forest fire-prevention roads, it is possible to obtain in a very short time data according to which we can choose the most acceptable variant, taking into consideration other factors.

FINAL CONSIDERATIONS
ZAKLJUČNA RAZMATRANJA

According to the research that was carried out and the obtained results, the following conclusions can be drawn:

Forest fire-prevention roads are a special category of forest roads.

Due to other criteria, further classification should be made within the category of forest fire-prevention roads.

In the management unit Senjska Draga a total length of forest fire-prevention roads of 31,363.70 m has been established. Of this, a total of 10,459.90 m (33.35 %) was laid with a bigger longitudinal gradient than allowed, while on 20,903.80 m (66.65 %) of forest fire-prevention roads, the longitudinal gradient was within the limits of that allowed (up to 8 %). The total surface under FFPRs is 130,308.76 m^2 (13.03 ha).

The average geometric distance of the centroid of the section determined by the centroid method is 244.79 m, while the average real distance of the centroid of the section is 287.15 m.

Due to the relative openness of the research area, which was determined by laying down so-called buffers around the existing network of forest roads, the research area is satisfactorily opened for the average optimum geometric distance of the approach to the surface of 250 m, i.e. for the average optimum real distance of the approach to the surface of 216.72 m, and for the average optimum geometric distance of the approach to the surface of 300 m, i.e. for the average optimum real distance of the approach to the surface of 260.04 m.

The planning of future forest fire-prevention roads which have to fit into the existing network can efficiently be done on DTM by laying down the buffer around the existing forest fire-prevention roads and by examining various variants of future FFPRs in order to choose the most acceptable one.

The factor of the vertical correction of the terrain, by which the average optimum geometric distance of the approach to the surface is corrected, to obtain the average optimum real distance of the approach to the surface, can be quickly and precisely determined on the DTM, as well as the average terrain gradient in each section.

The cost of the earthwork of forest fire-prevention roads is proportionally related to the transversal terrain gradient (the terrain gradient vertically on the FFPR), provided that all other elements of the normal transversal profile of a forest fire-prevention road are constant and that the cost of earthwork is the same for the whole route of the road.

At the presently valid regulated normal transversal profile of a FFPR, it is necessary, in order to minimalize the costs of building roads, to move the level of the grade line under the level of the terrain for the particular value c, where the surface of the road in a straight clearing is the same to the surface of the road on the embankment.

Whenever possible, so-called side compensation should be used in building forest fire-prevention roads, since in this way more roads can be built with the same financial investment.

The computer programme "COST" gives us the possibility of a fast calculation of total costs of earthwork for particular digitised ground centre lines, which present different variants of forest fire-prevention roads. In combination with the efficacity of each variant determined by laying down a buffer at a distance of the average real distance of the approach to the surface from forest fire-prevention roads, we gain an opportunity to choose the most acceptable variant of the future forest fire-prevention road, naturally taking into consideration other factors that influence that choice.

It has been determined that forest fire-prevention roads should be built at a minimum distance of 300 m to a maximum distance of 600 m apart, i.e. that the

average real distance of the approach to the surface should be from 150 m to 300 m, depending on the degree of danger of forest fire.

The buffer method can be successfully used in an analysis of the existing network of forest fire-prevention roads, its advantages and weaknesses, and in determining the relative openness of an area for the required average optimum distance of approach to the surface. In combination with the programme COST, this method is a useful tool to improve the network quality of forest fire-prevention roads, i.e. in planning future FFPRs and in choosing the most acceptable variant and establishing its efficacity.

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ŠUMSKE PROTUPOŽARNE CESTE KAO POSEBNA KATEGORIJA ŠUMSKIH CESTA I ČIMBENICI KOJI UTJEČU NA NJIHOV RAZMJEŠTAJ U PROSTORU

SAŽETAK

Šumske protupožarne ceste (ŠPPC) jesu posebna kategorija šumskih cesta koja je vezana uz mediteransko i submediteransko područje, odnosno uz krško područje Republike Hrvatske. S obzirom na specifičnosti područja u kojem se planiraju, projektiraju i izvode, a samim time i s obzirom na svoju primarnu zadaću, odnosno na tehnička obilježja, ŠPPC se značajno razlikuju od šumskih gospodarskih cesta (ŠGC).

Primarna je zadaća ŠPPC preventivna zaštita od šumskih požara, koji su kao ekološki destabilizator ekosustava u primorskim šumama najveća opasnost od svih abiotskih i biotskih štetnih čimbenika. Isto tako ova kategorija šumskih cesta mora u slučaju izbijanja požara pružiti najpovoljnije uvjete za njegovo suzbijanje. Iz navedenih razloga prišlo se istraživanju čimbenika koji utječu na prostorni raspored

mreže šumskih protupožarnih cesta s ciljem da se uz što manja financijska ulaganja izgradi što veća količina cesta uz zadovoljenje propisanih zahtjeva za kakvoćom.

Istraživanja su provedena na području UŠ Senj, Šumarije Senj, u gospodarskoj jedinici Senjska draga. Osim terenskih izmjera postojećih cesta na istraživanom području uporabljen je i postupak digitalizacije šumskogospodarskih karata, izrađen je i digitalni model terena (DTM). Na digitaliziranim i obrađenim podlogama razvijena je metoda tzv. "buffera"– omeđenih površina, predložena je tehnologija ekonomičnije izgradnje ŠPPC s obzirom na čimbenike koji imaju izravan utjecaj na troškove zemljanih radova, te je u tu svrhu dizajniran jednostavan kompjuterski program koji izabire troškovno najpovoljniju inačicu šumske ceste.

Iz podataka izmjerenih na terenu, a prema karti izmjerenih šumskih protupožarnih cesta (karta 4) redom su raščlanjeni uzdužni nagibi protupožarnih cesta. Slikovni prikaz jedne ŠPPC dan je na slici 1. Na apscisi je označena stacionaža točaka loma nivelete, u kojima je ujedno mjerena širina planuma, dok je na ordinati relativna nadmorska visina svake točke loma.

U tablicama 6 i 7 prikazani su sumarni podaci za sve ŠPPC na području GJ Senjska draga.

Željelo se vidjeti i kolika je otvorenost GJ Senjska draga utvrđena težišnom metodom. U tu je svrhu, primjenom osobnoga računala i odgovarajućih programa, pronađeno težište svakoga odsjeka i ucrtano u digitaliziranu kartu. Najkraća udaljenost od težišta svakoga odsjeka pa do najbliže ceste, koja se može rabiti kao protupožarna, izmjerena je i definirana kao srednja geometrijska daljina pristupa površini odsjeka. Te su linije srednje vatrogasne intervencije ucrtane u karte. Da bismo dobili srednje stvarne daljine pristupa površini odsjeka, trebalo je pronaći čimbenik vertikalne korekcije terena i čimbenik horizontalnoga zaobilaženja prepreka. Čimbenik vertikalne korekcije terena određen je tako da su srednje geometrijske daljine pristupa površini odsjeka položene preko DTM-a i očitane vrijednosti nagiba u četiri međusobno jednako udaljene točke. Zatim je pronađena srednja vrijednost u stupnjevima i određen kosinus (cos) toga srednjega nagiba. Srednja geometrijska daljina pristupa površini odsjeka podijeljena je kosinusom srednjega nagiba i pomnožena čimbenikom horizontalnoga zaobilaženja prepreka da bi se dobila njezina stvarna istoznačnica. Kao čimbenik horizontalnoga zaobilaženja prepreka, za područje cijele gospodarske jedinice, uzeta je vrijednost od 1,10. Srednja geometrijska i srednja stvarna daljina pristupa površini cijele gospodarske jedinice izračunate su kao aritmetičke sredine tih vrijednosti za svaki odsjek, a kao težine su poslužile vrijednosti površine odsjeka. Srednja geometrijska daljina pristupa za GJ Senjska draga je 244,79 m, a njezina stvarna istoznačnica – 287,15 m.

Danas ne postoje propisani teoretski razmaci između ŠPPC, nema preporučene ili optimalne otvorenosti ŠPPC, a nema ni okvirnih granica u kojima bi se trebala kretati srednja daljina pristupa površini. To je dovelo do potrebe definiranja i utvrđivanja određenih vrijednosti kojima bi trebalo težiti pri planiranju, projektiranju i izgradnji šumskih protupožarnih cesta. U konzultacijama sa zapovjednicima profesionalnih vatrogasnih postrojba u Rijeci i dobrovoljnih vatrogasnih postrojba na otoku Rabu, s obzirom na taktiku gašenja šumskih požara koja se na

tim prostorima godinama uspješno primjenjuje, a danas je i zakonom propisana za cijelu Republiku Hrvatsku, došlo se do spoznaja da je stvarna površina koja se pri gašenju šumskih požara u prvoj navali može "pokriti" interventnim vatrogasnim vozilima samo površina 50 metara udaljena od šumske protupožarne ceste, u svim smjerovima, dok je u drugoj navali ta površina maksimalno do 300 metara od šumske protupožarne ceste, u svim smjerovima.

S obzirom na to da su to optimalne vrijednosti s vatrogasnoga stajališta, primjenom računala, oko prethodno digitaliziranih postojećih cesta na istraživanomu području položene su primjenom računala površine, tzv. "bufferi", koji su svagdje na svojemu rubu bili udaljeni od ceste za određeni isti iznos, koji je predstavljao srednju optimalnu geometrijsku daljinu pristupa površini. Inačice toga parametra iznosile su 50, 100, 150, 200, 250 i 300 metara.

Dobivene su površine rasterizirane i prebačene na digitalni model terena na kojemu je, na osnovi izrađenoga histograma, određen prosječni nagib terena u svakoj inačici, koji je poslužio za pronalaženje čimbenika vertikalne korekcije terena. Tim je čimbenikom pomnožena svaka inačica srednje optimalne geometrijske daljine pristupa površini, a zatim podijeljena čimbenikom horizontalnoga zaobilaženja, koji je za čitavo istraživano područje iznosio 1,10. To je učinjeno da bi se dobila srednja optimalna stvarna daljina pristupa površini. Pri tome su upotrijebljene formule (2), (3), (4).

Određivanjem površine koja je otvorena s obzirom na odabir pojedine inačice srednje daljine pristupa površini i ukupne površine GJ (zajedno s privatnim enklavama unutar površina kojima gospodari JP "Hrvatske šume"), dobivena je relativna otvorenost za svaku inačicu prema formuli (5). Rezultati ocjene relativne otvorenosti za odabrane vrijednosti srednje daljine pristupa površini prikazani su u tablici 8.

Možemo zaključiti da otvorenost GJ Senjska draga pri srednjoj stvarnoj daljini pristupa površini od 300 metara zadovoljava, jer je s jedne protupožarne ceste moguće intervenirati na obje strane. Pri srednjoj stvarnoj daljini pristupa površini od 250 metara otvorenost istraživanoga područja slabo zadovoljava. Za inačice pristupa površini od 50, 100, 150 i 200 metara otvorenost je šumskoga područja nedovoljna.

Opisana metoda polaganja tzv. "buffera", koji su na svome rubu svugdje jednako udaljeni od ŠPPC, idealna je metoda kojom se vrlo zorno može predočiti otvorena površina određenoga šumskoga područja s odabranom optimalnom srednjom daljinom pristupa. Primjenom ove metode uočavaju se i neotvorena područja, o kojima posebice treba voditi računa pri daljnjem otvaranju šumskoga područja. Metoda je "buffera" također učinkovita pri planiranju i pri daljnjem grananju mreže ŠPPC: oko mogućih inačica trasa budućih ŠPPC, koje su predstavljene nultom linijom i kao takve digitalizirane, položi se "buffer" određene veličine. Inačica ŠPPC koja otvara najveći dio neotvorenoga šumskoga područja, a istodobno obuhvaća najmanju površinu tzv. mrtvih zona, odnosno područja koja su za odabranu srednju optimalnu daljinu pristupa površini otvorena s dvije ili više cesta, najučin-

kovitija je i nameće se kao najbolja. Metoda "buffera" za srednju geometrijsku daljinu pristupa površini od 250 m prikazana je na karti 5.

Postavlja se pitanje: kolika je otvorenost šumskoga područja iskazana u m/ha za navedene inačice srednje geometrijske daljine pristupa površini ? Da bi se dobio odgovor, uzet je model šumske površine dimenzija 1200 x 1000 m i taj je model otvoren paralelnim šumskim protupožarnim cestama na međusobno jednakoj udaljenosti l ($l = 2S_{PG}$). Pri izračunu su primijenjene matematičke formule(6), (7), (8), a rezultati su dani u tablici 9.

Prema kriteriju otvorenosti šumskoga područja i prema spoznajama o otvorenosti u vodećim svjetskim šumarskim zemljama može se zaključiti da otvorenost od 100,00 m/ha, koja je dobivena za srednju optimalnu stvarnu daljinu pristupa površini od 50 m, ne dolazi o obzir, barem što se tiče izgradnje šumskih protupožarnih cesta. Otvorenost od 50 m/ha, koja je dobivena kod inačice $S_{PG}=100$ m, također je vrlo visoka i u praksi jedva da može naći opravdanje. Dakle, šumskim protupožarnim cestama, prema kriteriju otvorenosti šumske površine, moguće je otvarati šumska područja ugrožena požarima od srednje optimalne geometrijske daljine pristupa od 150 metara pa naviše.

Jedan od kriterija za utvrđivanje najveće dopuštene količine prometnica u određenom ekosustavu, a da se njegova ravnoteža ne poremeti i da opasnosti od šteta uzrokovanih erozijom ne prijeđu dopuštene granice, jest i površina šumskoga područja pod šumskim prometnicama. Za šumske ceste, prema Pičmanu (1994), ta veličina iznosi 3 %. Za različite inačice srednje optimalne stvarne daljine pristupa izračunata je površina pod šumskim protupožarnim cestama na prije rabljenoj teoretskoj šumskoj površini dimenzija 1 200 x 1 000 m. Kao ulazi uzete su i različite širine planuma šumskih protupožarnih cesta, a izračunate vrijednosti su u tablici 10.

Prema čimbeniku postotnoga udjela površine pod šumskim cestama, u ukupnoj površini područja koje se otvara, dobiveni su rezultati u skladu s prijašnjim promišljanjima. Mreža šumskih protupožarnih cesta u kojoj je međusoban razmak cesta 100 m, čak i kod minimalne širine planuma od 3,00 m, doseže maksimalne vrijednosti od 3 % površine pod šumskim cestama. Kao takva, ova je mreža šumskih cesta, iako najoptimalnija sa stajališta vatrogasnih djelatnika, potpuno neprihvatljiva sa šumarskoga gledišta i neodrživa u šumskim ekosustavima. Vrijednosti površine pod šumskim cestama za razmak cesta od 200 m, u prihvatljivim su granicama, ali se približavaju gornjem dopuštenom maksimumu. Kako se radi o protupožarnim cestama u krškim područjima, gdje su opasnosti od erozije velike, a vegetacija kao osnovni čimbenik koji sprječava nastajanje erozije nije bogata i nije bujna, to je bolje planirati i projektirati mreže šumskih prometnica s većim razmakom, a samim time i površina pod ŠPPC bit će manja.

Pri izboru određene inačice šumske protupožarne ceste veliku ulogu ima konačna cijena izvedbe. Stoga je napravljena raščlamba normalnoga poprečnoga profila ŠPPC. Troškovi zemljanih radova predstavljaju glavni izvor troškova na koje se pri planiranju buduće trase protupožarne ceste može utjecati. Položaj protupožarnih cesta prikazan je nultim linijama različitoga nagiba, ovisno o nagibu te-

rena. Budući da je poznat normalni poprečni profil šumske protupožarne ceste i da je položena nulta linija koja aproksimira buduću situaciju na terenu, moguće je, u vrlo kratkom vremenu, odrediti i usporedne cijene više inačica budućih trasa šumskih protupožarnih cesta. Pretpostavka je da je nagib terena okomit na nultu liniju stalan za čitavu širinu planuma ŠPPC, koja iznosi 4,00 m.

Pri izvođenju matematičkih izraza za izračun površina iskopa i nasipa, koji su nam potrebni za dobivanje volumena zemljanih radova i, u konačnici, za dobivanje približnih troškova zemljanih radova, uporabit ćemo trokute površina P_I (površina iskopa) i P_N (površina nasipa). Krajnji rezultat matematičkih izvoda su formule (13) i (19).

Površine iskopa i površine nasipa za šumsku protupožarnu cestu stalne širine planuma povećavaju se proporcionalno povećanju poprečnoga nagiba terena. Iz slike 4 uočljivo je povećanje manjka zemlje za izradbu nasipa u odnosu na raspoloživu zemlju iskopanu pri izvedbi zasjeka s povećanjem poprečnoga nagiba terena i povećanjem širine planuma. To znači da bi manjak materijala za izradbu nasipa trebalo riješiti na najekonomičniji način. Ideja o tome kako riješiti ovaj problem bila je u primjeni tehnologije gradnje tzv. bočnom kompenzacijom zemljanih masa.

Na slici 5 prikazani su potrebni preduvjeti za primjenu predložene tehnologije gradnje.

Treba primijetiti dvije promjene što nastaju pri pomicanju kote nivelete ispod kote terena, a koje su važne za daljnji tijek rada: površina iskopa jednaka je površini nasipa i odnos širine planuma u zasjeku i u nasipu više nije 1:1. Zato je bilo nužno pronaći novi omjer širina planuma ŠPPC u iskopu i u nasipu. Površine iskopa i nasipa iskazane su u ovisnosti o b_I i B_N, te su u ovisnosti o poprečnome nagibu terena dane matematičkim izrazima (20) i (21) za planiranu kosinu iskopa m = 4:1, te za planiranu kosinu nasipa n = 1:1 izrazima (22) i (23). Budući da je riječ o bočnoj kompenzaciji, mora biti $P_I = P_N$ (24), i konačno rješavanjem dviju jednadžba s dvije nepoznanice (25) i (26) jednostavno ćemo izračunati širinu planuma u zasjeku i širinu planuma u nasipu. Razliku kote terena i kote nivelete (c) izračunat ćemo pomoću izraza (27).

Kad znamo površine iskopa i nasipa koje vrijede za svaki segment nulte linije, a određuju se na sredini segmenta, moguće je, budući da je svaki segment nulte linije jednake duljine, odrediti i volumen zemljanih radova iskopa i nasipa za svaki segment nulte linije (28) i (29), dok će se za čitavu protupožarnu cestu volumen potrebnih iskopa i nasipa izračunati prema formulama (30) i (31), a želimo li doći do ukupnoga troška izvedbe iskopa i nasipa na protupožarnoj cesti, uporabit ćemo formule (32) i (33).

Htjelo se ispitati ponašanje troškova zemljanih radova pri mijenjanju određenih utjecajnih čimbenika, prije svega širine planuma, poprečnoga nagiba terena i kategorije materijala u kojem se radovi izvode.

Poprečni nagib terena od 0° do 45° podijeljen je u kategorije širine 5°. Tako su dobivene vrijednosti 2,5°, 7,5°, 12,5°, 17,5°,....., 37,5° i 42,5°, koje predstavljaju pojedinu kategoriju poprečnoga nagiba terena. Prema prije izvedenim matema-

tičkim izrazima izračunate su kao konačne veličine ukupna cijena iskopa, ukupna cijena izradbe nasipa i cjelokupna cijena zemljanih radova ŠPPC duljine 1 000 m kod različitih poprečnih nagiba terena, za normalni poprečni profil šumske protupožarne ceste i prema troškovniku radova JP "Hrvatske šume" (tablica 11).

Cijena zemljanih radova kod ŠPPC raste s povećanjem širine planuma i s povećanjem poprečnih nagiba terena. Isto tako, cijena je zemljanih radova viša što je nepovoljnija kategorija zemljišta u kojoj se radovi izvode. Promotrimo li kretanje cijene zemljanih radova za širinu planuma od 4,00 m, te ako cijenu zemljanih radova za poprečni nagib terena od 42,5° uzmemo za usporedbu, dobit ćemo zanimljive rezultate prikazane u tablici 12.

Kad god smo, dakle, u mogućnosti, za trasu ŠPPC treba birati one terene kod kojih je poprečni nagib što manji, jer nas tada čekaju manje površine iskopa i nasipa na normalnom poprečnom profilu, manji će biti volumeni iskopa i nasipa za svaki segment ŠPPC, a, analogno tomu, manji će biti i ukupni troškovi zemljanih radova za cijelu protupožarnu cestu. Razumije se da u obzir treba uzeti i ostale čimbenike prostorno dobro položene mreže ŠPPC.

Broj kilometara koje je moguće izvesti uz jednake troškove gradnje, opada idući od III. preko IV. do V. kategorije materijala u kojem se radovi izvode. Također su veće razlike između moguće količine ŠPPC u II. i III. nego u III. i IV. kategoriji materijala (tablica 13).

Na temelju prije navedenih teoretskih postavki i izvedenih matematičkih izraza napisan je jednostavan računalni program nazvan TROŠAK u programskom jeziku C++. Program izračunava troškove zemljanih radova ŠPPC, dakle troškove koji su pod izravnim utjecajem poprečnoga nagiba terena odnosno konfiguracije terena. Unosom osnovnih sastavnica normalnoga poprečnoga profila ŠPPC, kao što su širina planuma, planirani nagib kosine zasjeka, planirani nagib kosine nasipa, te unosom poprečnoga nagiba terena u stupnjevima i troškova iskopa, troškova izradbe nasipa i troškova planiranja planuma, moguće je u kratkome vremenu dobiti ukupnu cijenu zemljanih radova za svaki pojedini segment nulte linije. ŠPPC je u ovoj fazi planiranja približno predstavljena nultom linijom, a podaci koji se unose jesu srednje vrijednosti za svaki segment nulte linije ili vrijednosti izmjerene na sredini segmenta. Ukupni se troškovi za čitavu ŠPPC dobiju zbrajanjem troškova za svaki segment.

Usporedbom ukupnoga troška zemljanih radova više inačica ŠPPC vrlo se brzo mogu dobiti podaci na osnovi kojih, dakako, uz uvažavanje ostalih čimbenika, možemo odabrati najpovoljniju inačicu.

Ključne riječi: šumske protupožarne ceste, šumski požari, krško područje, digitalni model terena, relativna otvorenost, troškovi zemljanih radova

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RODENTS AND THEIR HARMFUL EFFECTS ON TUROPOLJSKI LUG (TUROPOLJE GROVE) AND ON CROATIAN FORESTS

MIŠOLIKI GLODAVCI I NJIHOVA ŠTETNOST U TUROPOLJSKOM LUGU I U DRUGIM HRVATSKIM ŠUMAMA

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The natural and artificial regeneration of a stand, as well as the production of plant material in forest nurseries, is directly influenced by numerous biotic and abiotic factors. Several species of murids (family Muridae, Rodentia) which belong to two subfamilies, mice (subfamily Murinae) and voles (subfamily Arvicolinae), can be distinguished among biotic factors as pests of forest seeds, shoots and young plants. In the lowland forests of Croatia three species of mice are present (the yellow necked field mouse – *Apodemus flavicollis*, the common field mouse – *Apodemus sylvaticus* and the striped field mouse – *Apodemus agrarius*), and six species of voles (the bank vole – *Clethrionomys glareolus*, the common vole – *Microtus arvalis*, the field vole – *Microtus agrestis*, the water vole – *Arvicola terrestris*, the European pine vole – *Microtus subterraneus* and the Alpine pine vole – *Microtus multiplex*. The population density of these rodents changes during a year, but also in a period of several years. In years when there is a high density of population, the damage to forestry can be catastrophic. Research on the population dynamics of rodents, which is important for the measures and methods of contemporary forest protection to be carried out successfully, was done during 1995 and 1996 in Turopoljski Lug (Forest Office of Zagreb). Modified methods of a minimum square with snap traps, "Y" methods and methods of linear transect were used. Computer data processing was done by a statistical method of linear regression, by a method of calculating the population density of animals over a surface unit by the total catch of animals and by a method of calculating the relative population density. This paper deals with the harmful effects of rodents in Croatian forests in

the period from 1980–1995 and the amount of harm caused to the seeds of pedunculate oak and to forest sprouts by small rodents during periods of different population dynamic densities.

Key words: lowlands forests, rodents, population density, forest seeds, forest sapling, forest regeneration

INTRODUCTION
UVOD

The decay of some trees and groups of forest trees and whole stands has been known throughout the history of forestry. In some areas of the Republic of Croatia (Gorski Kotar, around Zagreb, central Posavina), the drying of stands has reached high proportions.

Forests of pedunculate oak with broom *(Genisto elatae-Quercetum roboris* Ht. 1938) (Prpić et al. 1988) are among the most damaged forest communities. The main reason for the drying of lowland stands is seen by Prpić (1977) in the decrease of the level of underground water caused by extensive hydromelioration. Natural and artificial regeneration of stands, as well as the production of plant material in forest nurseries, is directly influenced by numerous biotic and abiotic factors (Spaić & Glavaš 1988). Rodents can be distinguished among biotic factors as pests of forest seeds, seedlings and young plants. They constantly cause minor damage in forests. In years of high population density, the damage can significantly increase and inflict high losses to the forest economy (Vajda 1974). It is known that rodents can do damage in all kinds of forests (mountain, seaside, highland and lowlands). In Croatia, the greatest damage was noted in lowland forests of pedunculate oak (the report – Diagnostic Prognostic Services of the Institute of Forestry of Jastrebarsko for the period 1980–1994). Rodents frequently have a decisive role in the production of germinable seed of pedunculate oak. In some cases, the whole crop of acorn in a pedunculate oak stand can be completely destroyed by rodents, particularly in years of high population density (Spaić & Glavaš 1988). Their harmful effect in forest communities of pedunculate oak is particularly significant in years of a decrease in the acorn crop (Crnković 1982).

The negative effect of rodents is even more emphasised if they cause damage to seeds and plant material which are used in the regeneration of forests where there is an intensive process of drying. Several economic factors should be considered when dealing with damage in artificial regeneration (costs of collecting forest seeds, costs of plant production in forest nurseries, costs of afforestation, costs of protection of young growths). The material means that forest operative units invest in the regeneration of a stand could be lost in a short time if there is a high population density of rodents on the region that has to be regenerated. Freshly cultivated plants and forest seeds of high quality become an important source of food

for these animals. The problem of rodents in forest protection has not been sufficiently studied. Detailed research on this group of pests in the forestry of Croatia has not been done.

Successful control of increased population densities of rodents is impossible without good knowledge of their morphological and physiological features, their food habits, reproduction, as well as the ecological factors that influence members of the community. Unprofessional procedures in this domain can have unpredictable negative consequences for the forest ecosystem and the animal species which live in it and which are not to be controlled. Monitoring the population dynamics of these pests is of considerable importance for measures and methods of contemporary forest protection to be successfully carried out. Using direct or indirect methods, forest science can considerably decrease the damage caused by rodents. The main aim is to create high-quality prerequisites for the successful regeneration of the forest stand, either natural regeneration or artificial acorn introduction, i.e. forest plants. Numerous methods to reduce the high population densities of pests have recently been used in order to complete this task (preventive, mechanical, chemical and biological methods). In order to consider the problems of rodents in pedunculate oak forests more efficiently, it was necessary to examine in detail the community structure according to species, to determine their population density, the intensity of the damage done to forest seeds and young plants, and to recommend protective measures.

In order to examine the quantity of the damage done by rodents to forest seeds (the acorn of pedunculate oak) it was necessary to find a stand which was richly fruitful. To determine the damage done by small rodents on young growths, the aim was to find a stand where artificial regeneration was made by plant material and on which research on the quality and the quantity of the mentioned pests was planned. These conditions were fulfilled in the forests of the Management Unit Turopoljski Lug. Turopoljski Lug is situated 30 km SE of Zagreb. The Management Unit is 4333.6 ha, and forms the west part of the Panonian lowland. The altitude of the Management Unit Turopoljski Lug is between 97 and 109 m. According to Köppen's classification, this area belongs to the "mediate warm and rainy 'cfwbx' type of climate" (Prpić et al. 1994). The precentagés of the main tree species are: 77 % *Quercus robur*, 8 % *Alnus glutinosa*, 8 % *Carpinus betulus*, 4 % *Fraxinus excelsior*, 1 % *Fagus sylvatica* and 2 % others. The whole unit is considered as a forest-management area of regular forests. Field research was done in the central part of the Management Unit in subcompartments 58a, 59a, 62a, 75a, 90a, 98a.

RODENTS (RODENTIA)
GLODAVCI (RODENTIA)

Discussing this group of mammals, some authors (Vajda 1974, Delany 1974, Kowalski 1976, Spaić & Glavaš 1988, Kovačić 1988, Trilar 1991, Matić & Sken-

derović 1993, Baltić 1995, Glavaš et al. 1996) use various names for them like: "forest rodents", "rodents", "tiny rodents" and "small rodents".

The expression "small mammals" (Micromammalia) is mostly used in literature for species of Mammalia in which the weight of adult members is greater than 2 g and less than 120 g (Delany 1974). This group of mammals includes: moles, soricids, squirrels, voles, mice etc.

BIOLOGICAL FETURES OF RODENTS
BIOLOŠKE OSOBINE MIŠOLIKIH GLODAVACA

Rodents are mammals with characteristic front (upper) incisors. Their body is cylindrical (Kowalski 1976). They are very nimble, cautious and react quickly. Their paws usually have five toes with claws. The tail is usually well developed and covered with horny scales or hairs. *A. flavicollis* and *Myoxus glis* have the longest tail among the rodents (Kowalski 1976). Their jaw is strong in its rear part, so food is mixed with circular movements. There is one pair of incisors in the upper and the lower jaw (incisiva) and three pairs of molars (molara). Some of them have premolars (premolare). Their incisors are very sharp, as they are coated with enamel only from the front. The incisors are used for gnawing food and other materials. In order to keep them adequately long, they are forced to use them daily as they constantly grow, and in that way they are worn away. These animals do not have canines. Most of these mammals are active by night, in contrast to those species who live in cold areas and mostly take their food during the day. Some of them collect food for colder days by making stocks in special stores. Digging activity is well developed in many species. Small rodents have a relatively short life span. Most of them do not live longer than 2.5 – 3 years. The mass of crystalline lens and the length of the skull are proportional to the age of the animal (Gurnell & Knee 1984). The most precise data on the age of the individual is obtained by measuring these parameters.

Reproduction
Razmnožavanje

The reproduction of rodents and the growth and development of offspring depend on the influence of several factors, among which the characteristics of the climate, particularly the outer temperature, are very important. The potential for reproduction is very high. Females can have a litter several times a year. In moderate and cold climatic areas, reproduction stops during the winter. The average number of young in each litter is 2 to 8. The gestation period of a female lasts over 20 days. The time from their birth to complete sexual maturity is 2–4 months. Young voles mature sexually very early, much sooner than they reach their full growth (Kowalski 1976). The young are born with closed eyelids, closed auditory

canals and without fur. After 7–12 days the fur completely covers the body, while the eyelids and auditory canals open between the age of 10 and 12 days. The young suckle and depend on their mother until approximately 20–25 days of age. In most mammals, a female is not ready for new fecundation until breast-feeding stops, while in rodents a female can mate and become pregnant the same or the next day after giving birth.

One of the important activities of the adults, particularly females, is building a nest. It is a place for rest, a shelter from natural enemies and the place where the young are raised. A nest can serve as a store of gathered food. Males take little care of the offspring. The strongest males mate with females (Thor & Carr 1979). In taking care of the offspring, a female becomes very aggressive in cases where there is danger for the young or she skilfully and quickly hides them in a safe place (Meehan 1984).

The growth of the young depends a great deal on the kind and quantity of food accessible to mothers during the gestation period and lactation. Wehmer & Jen (1978) proved that a reduction of 25 % of food during the gestation period causes a decrease in lactation and also a decrease in weight of the litter. The light also influences the reproduction, development and growth of certain species of rodents. The young born at the end of spring or at the beginning of summer mature sexually more quickly than those born during the autumn and winter.

THE ROLE OF SENSE ORGANS
ULOGA OSJETILA

The sense of smell has an important role in the reproduction of rodents, in the raising of offspring, in finding food, in their relationship with animals of the same or different species and so on. According to Bowers & Alexander (1967) these mammals can sense the smell of other animals and can unmistakably distinguish members of the population. With their sense of smell, female small rodents can distinguish their offspring from the offspring of other females (Moor 1981). Male mice attack other males of an unfamiliar smell which come to their colony for mating.

The smell of other animal species can also influence the behaviour of rodents. Some species of mice suffer a genuine shock when they sense the smell of the urine of a cat or some other predator. The attraction to or repulsion from the smell of other animals of the same or different species can be used as one of the possibilities of controlling the population density of rodents. Research directed at finding and producing attracting and repelling devices has been very intensive during recent years.

One of the most important senses of these animals is mechanoreception. Sense hairs are distributed on the back and sides of the body and the snout. The safe movement of this animal in the dark is possible following its tactile introduction to the objects in the environment. By removing sense hairs, sensibility to touch is con-

siderably decreased and the animal loses its ability to orientate itself in space (Taylor & White 1978).

The sense of sight has a relatively small role in most small rodents. Some of these animals can see well at night. Most species from the genera *Apodemus, Mus* and *Rattus* can clearly identify objects up to a distance of 15 m (Sloane et al. 1978).

Their hearing is well developed. They can register sound above the limit of man's hearing ability (20 kHz). Apart from registering ultrasound waves, rodents can also produce them (Watts 1980), and they use them in their mutual communication. Ultrasound has a significant role in their sexual behaviour. Newborns also produce ultrasound waves in order to attract their mother's attention (Smith 1979).

The sense of taste in small rodents has mostly been researched in the genus *Rattus*, and it has been established that rats register four tastes, like man: sweet, salty, sour and bitter (Brouwer & Hellcant 1973).

FOOD HABITS
PREHRANA

Most rodents are polyphagous animals. The quality of food is very important for their normal growth and development. The lack of certain nutritious components can cause various kinds of avitaminosis, rachitis etc. Baits used to catch these animals, which consist of food tasty to man, are not always necessarily attractive to rodents. A combination which could be used as a universal nutritious base for making poisonous baits has not been found. Plant food or a thick cloth with grease in which bacon and onion were fried is particularly attractive to members of the genus *Apodemus* and some species of voles and, due to its efficacity, it is frequently used in baiting them. Water is an important factor in the nutrition of rodents. While researching the nutrition of rodents, Knote (1982) noticed that if mice eat food with a constituency of only 12 % moisture and no water, they die after 3–4 days. Members of the genera *Apodemus, Microtus* and to some extent *Mus* drink relatively small quantities of water. If the outside temperature drops, their need for food increases.

FACTORS IN THE INCREASE OF POPULATION DENSITY
ČIMBENICI POVEĆANJA GUSTOĆE POPULACIJE

Population density is the number or the biomass of the members of a species on a surface unit in a given time (Androić 1970). Many factors contribute to an increase in the population of rodents. These factors can be grouped in four basic groups (Androić et al. 1981):

1. The population density and physiological condition of the population

The possible increase in number depends on the population age structure, behaviour and physiology of its members, on the relation of sexes in the population, social relations within the population, competition within the species, genetic predisposition and on the birth-rate and the death-rate.

2. Climatic conditions

Favourable climatic conditions are an important factor in the increase of the population density. These are determined by temperature, humidity, precipitation and the distribution of these factors during the year.

3. Habitat and food sources

Rich ground vegetation, particularly in neglected and weedy habitats, is an important food source. The presence of herbaceous and granular food sources is a condition for the nutrition of the population. The establishment of natural cycles in the fructification of ligneous plants is successfully used to estimate the possible increase in the size of the rodent population in forest stands.

4. Natural enemies and diseases

Numerous predators (fox, marten, polecat, wild cat, buzzard, hawk, owls, crows, etc.) and epidemics of infectious diseases are important factors in regulating the rodent population. Epidemics usually appear when the density of populations is high and cause their sudden decrease.

RODENTS AS POTENTIAL VECTORS OF ZOONOSES
MIŠOLIKI GLODAVCI KAO POTENCIJALNI PRIJENOSNICI ZOONOZA

Rodents are a constant "reservoir" of various zoonoses and when their number increases, they can transmit them to men and domestic and wild animals (Fališevac 1976). These diseases are divided into several groups according to the agents:

1. diseases caused by bacteria (tularaemia, leptospirosis, plague, salmonellosis, tuberculosis, etc.);
2. diseases caused by viruses and rickettsiae (rabies, haemorrhagic fever, lymphatic choriomeningitis, etc.);
3. diseases caused by mycoses (various forms of dermatomycosis and trichophytosis, e.g. flavus, sporotrichosis, etc.);
4. diseases caused by protozoa (sarcocystis, amebiasis etc.);
5. diseases cause by parasites (coccidiosis, leishmaniosis etc.).

Turopolje is a natural focus of tularaemia, leptospirosis and rabies (Borčić et al. 1976, 1986, 1987).

SPECIES OF POTENTIALLY HARMFUL RODENTS IN THE MANAGEMENT UNIT TUROPOLJSKI LUG
VRSTE POTENCIJALNO ŠTETNIH MIŠOLIKIH GLODAVACA U GOSPODARSKOJ JEDINICI TUROPOLJSKI LUG

In the forest stand of Turopoljski Lug there are several species of rodents (family Muridae) (Meštrov 1986), which in years of high population density cause great damage to forest seeds and young plants. They belong to two subfamilies: mice (Murinae) and voles (Arvicolinae).

The subfamily Murinae includes 122 genera and 529 species (Wilson & Reeder 1992). Three species which belong to the genus *Apodemus* are distinguished in this subfamily as pests of forest seeds in the oak lowlands forests of Turopoljski Lug (Meštrov 1986). These species are:

1. *Apodemus flavicollis* (Melchior 1834);
2. *Apodemus sylvaticus* (Linneus 1758);
3. *Apodemus agrarius* (Pallas 1771).

The subfamily Arvicolinae includes 26 genera and 143 species (Wilson & Reeder 1992). According to the research of Meštrov (1986), the following species of voles (subfamily Arvicolinae) live in the forests of Turopoljski Lug:

1. *Clethrionomys glareolus* (Schreber 1780);
2. *Microtus arvalis* (Pallas 1778);
3. *Microtus agrestis* (Linnaeus 1761);
4. *Microtus subterraneus* (de Selys-Langchamps 1836);
5. *Microtus multiplex* (Fatio 1905);
6. *Arvicola terrestris* (Linnaeus 1758).

RODENTS IN FOREST ECOSYSTEMS
MIŠOLIKI GLODAVCI U ŠUMSKIM EKOSUSTAVIMA

In already damaged forest stands, which include our pedunculate oak forests in northern Croatia (Prpić et al. 1988), rodents become significant pests and are controlled preventively to save the regeneration of forests. However, we must not forget that they are a natural part of forest ecosystems. Their natural role in forests is complex and important for forests to keep their biological diversity and balance. Turček (1968) already noticed this and he systematised their influence on the forest ecosystem:

- on the microclimate of windfall leaves and uppermost layers of soil;
- on the nature of soil, its aeration and humification;
- on the flow of inorganic and organic matters;
- on the decay of organic matters;

- on the structure of the stand, both of ground growth and of trees;
- on spreading plants by the spreading of seeds;
- on the population density of some harmful insects;
- on the preservation of the population of various forest predators whose main food are rodents;
- on the succession on clearings.

RODENTS AND THEIR HARMFUL EFFECTS ON CROATIAN FORESTS IN THE PERIOD FROM 1980-1995
MIŠOLIKI GLODAVCI I NJIHOVA ŠTETNOST U HRVATSKIM ŠUMAMA OD 1980. DO 1995. GODINE

Mice and voles cause damage to forests by eating forest seeds, gnawing barks and roots. Mice (subfamily Murinae) can be particularly distinguished as pests of forest seeds and can completely destroy seedings in forest nurseries or disable the natural regeneration of forest areas. This form of damage in lowland forests is mostly done by the species *Apodemus flavicollis* and *Apodemus sylvaticus* (Androić et al. 1981). Rodents dig long corridors underground by which they frequently undermine young plants in forest nurseries and forest stands, and they gnaw young plants and the roots of forest trees. Some of them can climb, so they gnaw the bark of fully grown trees. Most frequently they gnaw the bark of young plants 2–15 years old. They completely gnaw through young plants and ring the older ones or gnaw them on the sides. When they multiply, they cause real waste in cultures and forest nurseries. Forest areas offer abundant food to rodents, good conditions for reproduction and hibernation, as well as protection from natural enemies. Forest areas rich in ground (grassy) vegetation are particularly suitable for these mammals. They are particularly abundant in forests which are bordered by fields and meadows. In autumn mice migrate to border forests. These mammals rarely gnaw roots. Such damage is mostly caused by *Arvicola terrestris*. According to the report of the Croatian Board for Aspens (1995), in 1988 this pest destroyed about 150 ha of willow and aspen culture, gnawing in the winter months the bark of the offshoots of trees underground or immediately above the ground. This occurred in the localities of Erdutski Rit and Bjelobrdski Rit. Efforts to establish the number and to control this species were not successful.

In the period from 1980–1994, the biggest damage from rodents was noted in 1994 over an area of 3,947.51 ha, while considerable damage was registered in 1989 (2,905 ha), in 1990 (2,596.10 ha) and in 1993 (2,293.87 ha). In the period from 1980-1988 damage was very small. For the years 1991 and 1992, the Diagnostic Prognostic Service of the Institute of Forestry of Jastrebarsko does not have precise data on damaged areas due to the war in the Republic of Croatia. Control of these pests on the field in the period from 1980-1994 was most frequently done by chemical methods using various rodenticides.

The extent of damage for 1995 was examined by carrying out a survey in all forest offices of the public enterprise "Croatian forests". The aim of the survey was to obtain high-quality data on the harmful effects of rodents in forest stands of Croatia in 1995 (areas of damaged forest stand, the season when the damage appeared, the species of the pest, the population density of the pests, methods of control, etc.).

According to the data from all forest offices of the public enterprise "Croatian forests", damage on forest areas caused by rodents in 1995 was registered on 3,795 ha.

Most of the damaged forest areas in 1995 were registered in the area of the Forest Office of Vinkovci, while on the areas of the Forest Office of Buzet, the Forest Office of Gospić and the Forest Office of Senj, damage was not registered.

Damage caused by rodents during 1995 was mostly done in autumn, winter and early spring. Damage was mostly done on forest seeds (acorn), young growth and young plants in the communities of pedunculate oak. In the beech stand, damage on forest seed was registered in the Forest Office of Ogulin (Forestry Josipdol) and the Forest Office of Nova Gradiška (Forestry Slavonski Brod). In the stand of the sessile oak, damage on the forest seed was registered only in the area of the Forest Office of Našice, while damage by small rodents on the seeds of the bay oak was registered in the Forest Office of Split (Forestry of Sinj).

The age of damaged forest stands varies and ranges from one to 130 years, depending on whether damage was done on young plants (plants at an age from one to ten years) or on forest seeds (where the age of the stand is most frequently over 70 years). According to the results of the survey, damage to the bark of young plants is mostly done by voles (subfamily Arvicolinae), while damage to forest seeds was done by mice (subfamily Murinae).

Establishment of the population density of rodents in 1995, according to the results of the survey, was done in several Forest Offices: the Forest Office of Vinkovci, the Forest Office of Bjelovar, the Forest Office of Požega, the Forest Office of Sisak and in the Forestry of Đurđevac (the Forest Office of Koprivnica).

In the forestry of Croatia in 1995, the most frequent method of controlling rodents in increased numbers was a chemical method, and among rodenticides, the most frequently used were "Faciron" and "Brodilon", while "Ratox", "Antikolin" and "Arex" were rarely used.

The control of rodents (deratization) includes various preparations and preliminary work which has to be done before carrying out the control in practice. An elaboration of the plan of control, informing people, as well as testing the efficacy of the deratization are some of the tasks which require the presence of professional staff on these occasions. Most of the Forest Offices in which high numbers of rodents were established asked for the help of professional staff in carrying out deratizational measures (veterinaries or scientists whose subject of research is small mammals). High-quality processes of deratization resulted in the decrease of damage in almost all localities. On the area of the Forest Office of Sisak, after the

control of pests was carried out, damage decreased by 80 %, while on the areas of the Forestry of Križevci and Slavonski Brod, deratization was not as successful as expected, which can be the result of low-quality control. From the account of the problems of rodents, it is obvious that further research into these areas is necessary in lowland forests, and this is described further in the paper.

METHODS
METODE RADA

In research so far, already-known and elaborated methods of biological study have been used. Most of them are described in the scientific papers of the authors who examined species of the family Muridae in a similar way (Zejda & Holišova 1971, Kovačić 1988, Kirkland et al. 1990, Trilar 1991, Zukal & Gaisler 1992, Kirkland & Sheppard 1994). In this study, the intensity of damage on young plants and forest seeds was established by individual methods.

During the research, the used methods were divided into three groups:

a) The field methods of establishing the population density and sampling of rodents
   1. Modified Standard Minimum Method with snap traps (Zejda & Holišova 1971, Pelikan 1971);
   2. "Y Method" (Kirkland et al. 1990, Zukal & Gaisler 1992, Kirkland & Sheppard 1994);
   3. Linear transect (Androić et al. 1981, Crnković 1982).

b) Field methods of establishing the intensity of damage
   1. Collecting of fallen acorns;
   2. An analysis of the damage of forest plants.

c) Laboratory methods
   1. Determination and treating of morphometric features of the caught animals (Niethammer & Krapp 1978, 1982);
   2. Examination and analysis of collected acorn;

d) Mathematical methods of determining the population density
   1. Multiple Regression Method (Poole 1974);
   2. The method of calculating population density on the surface unit (Zukal & Gaisler 1992);
   3. Relative population density determined by the method of linear transect (Androić et al. 1981, Crnković 1982);
   4. Comparison of population density of rodents calculated by different methods (t-test, Pranjić 1986).

ESTABLISHING THE POPULATION DENSITY AND SAMPLING OF ANIMALS
TERENSKE METODE ZA UTVRĐIVANJE BROJNOSTI I UZORKOVANJE ŽIVOTINJA

Taking measures for timely rodent control in order to decrease the intensity of damage to young plants and forest seeds is only possible with a periodical analysis of the population density of these animals. For that purpose, several methods are used, which, according to Tapper (1976), can be divided into three main groups. They are primary, secondary and tertiary methods. By primary methods, animals are sampled in an area of a precisely determined size ("Capture–recapture method", "Y Method", "Standard Minimum Method"), while by secondary methods the animals from an incompletely defined area are sampled (linear transect). All methods which do not sample animals are tertiary methods and the density of population is determined indirectly through signs of the animals' activities, like counting traces or droppings (Bider 1968, Lord et al. 1970, Lidicker 1973). The advantages of tertiary methods are that they do not influence the population, require very little equipment and sometimes only one coming to the field is enough. Their main disadvantage is obtaining exact relations with the actual density of the population, achieving only relative values. In this study, three methods were used by which the population density of small rodents in the forests of Turopoljski Lug was determined.

Standard Minimum Method consists of establishing the number of the population collected in the catching places of a particular area. This method was suggested by Grodzinski et al. (1966), involving the catching of animals over a period of five nights in an area of 5.76 ha. Traps are placed within a staked out "square" on precisely defined catching places. According to the suggestion of Grodzinski et al. (1966), the square consists of 16 x 16 catching places at a mutual distance of 15 m. Two snap traps are placed in each catching place (a total of 512 traps). According to Zejda & Holišov (1971) and Pelikan (1971), the 16 x 16 square in catching places is too big, as the same results are achieved with a smaller square of 8 x 8 in catching places on an area of 1.44 ha. For success in this method, it is important that the conditions of catching are the same, i.e. that all members of the population have the same chance of being caught, that at the time of catching, deviations of mortality are slight, that there are no immigrations and emigrations of animals in the period of catching and that the weather conditions are approximately the same.

The population density of rodents is calculated by a method of linear regression. Results of the use of the minimum square method have shown that the first day's catch was the biggest and that it decreases during other days (Grodzinski et al. 1966). In the field research, snap traps with a wooden base, a "Museum Special" type, and snap traps with a metal base were used. The "Museum Special" trap proved to be of better quality in the field than metal ones, for three reasons:

1. a wooden base is more resistant to atmospheric influences (particularly humidity) in comparison to traps with a metal base which tend to corrode;
2. when killed, the animal's skull is not damaged, as the length of the spring enables it to catch the animal behind the head. The whole skull is used to determine the species of the caught animal;
3. the preparation of the bait for this type of snap trap is faster and simpler.

For the "Museum Special", a mixture of oat cereals and canned sardines was used as bait. For the metal snap traps, a thick cloth (about 1 cm^2) dipped into oil in which onion and bacon were fried was used as bait. Such baits are efficient without having to be replaced (they keep their smell to catch rodents for several months). They are frequently used in practice, thanks to their efficiency. The catch of animals on the study area lasted five nights. The date of the catch, the name of the trial surface and the symbol of the catching place on which the catch was registered were noted. Further treatment of animals (determination, measuring of length and weight) was done in the laboratory of the Croatian Natural History Museum in Zagreb. In the period from April 1995 to November 1996, a study area was activated four times (April 1995, and May, June and October 1996).

The "Y Method" is the latest method of determining the population density of rodents. Kirkland and Sheppard (1994) used it in their research of the population dynamics of terrestrial mammals in the forests of North America.

The aims of using this method in Turopoljski Lug, were to examine its efficiency in determining the population density of rodents in lowland pedunculate oak forests and to compare the obtained results with the results of the population density of rodents obtained by other methods. The "Y" method is based on catching small terrestrial mammals in pitfalls filled with water. The catch is done on a surface area of 0.735 ha (Zukal & Gaisler 1992, Kirkland & Sheppard 1994). The "Y" method is included in a group of primary methods of determining the population density of small mammals. Kirkland & Sheppard (1994) caught small mammals with the "Y" method in a period of 10 hunting nights. Zukal & Gaisler (1992) established that to calculate the density of populations, only the results of the first five nights of catching can be taken into consideration, due to the edge effect and the immigration of animals from the surrounding area.

Due to the great influence of weather changes on the activity of animals (Bider 1968) and also on the catch of animals by the "Y" method and the minimum square method, in the period of research (April 1995 and May 1996), the air temperature was measured daily, and rain, snow and clouds were registered (Table 9). Temperature was measured by a digital thermometer at 7.30. The "Y" method showed very good results in the years of a high population of animals (Zukal & Gaisler 1992). Apart from the population density of rodents, it can also determine the population density of other animals that live on the ground surface (insects from the family Carabidae, frogs, insectivorous species, salamanders, etc.). The disadvantages of the "Y" method are:

1. a lot of time spent on preparing a plot on the field;
2. frequent damage to partitions by big game, wind, snow, etc.

The "Y" method was applied in April 1995 and in May and October 1996 in a forest community *Carpino betuli-Quercetum roboris*, subcompartment 98a. Consideration was given to the choice of its microlocation. Two study areas were placed on the field with a richly developed layer of shrubbery. According to Vraneš (1972), rodents more frequently stay on such a habitat than on fields with a poorly developed layer of ground growth and shrubbery. The surfaces were placed at a distance greater than 100 m which prevents the catch of animals from a neighbouring surface. The study area for the "Y" method was placed in the same section and with the same plant community as the described study area with snap traps, in order to compare the results of the animal catch by these two methods.

Ten pitfalls were placed from the central point in three directions at an angle of 120° (the shape of the letter "Y", according to which the method was named). The three containers in each direction were completely buried so that their upper edge was level with the soil at a distance of 5 m. The length of one line of the "Y" was 15 m.

Metal containers were used with a diameter of 12 cm and 20 cm deep. To prevent the filling of containers with water above the recommended level during rain, they were pierced on the side, at a depth of 10 cm. 25–30 cm high partitions were put between the catching containers, which were buried 3–5 cm in the ground, to prevent animals passing under them and serving to direct animals towards the vessels. PVC bands were used which were tightened by wooden sticks one metre high. The containers were filled with water to prevent the escape of the animals and in order to kill them by drowning. The surfaces were visited for five days (Zukal & Gaisler 1992) early in the morning.

The method of linear transect is included in the group of secondary methods of determining the population density of small mammals. The absolute population density cannot be determined by this method, but only relative relations. Its advantage is that within a short time the population density of animals over a larger area can be researched. The traps and the bait as described in the standard minimum method were used. Snap traps were placed in a straight line, at a distance of five metres. The traps were inspected in the morning. 50 or 100 traps were placed in the chosen direction. The population density of rodents was determined by this method 10 times: in spring (1x) and in autumn (4x) 1995 and in spring (1x), in summer (1x) and in autumn (3x) 1996. A hunting transect was activated in subcompartments 58a, 59a, 62a, 75a and 90a. The obtained results were compared with the results of the population density of rodents obtained by other methods.

The population density of small mammals was expressed by the percentage of the catch of animals in relation to the total number of placed traps. If the catch is 1–2 % - the density of population is low; if the catch is up to 10 % - the population density is moderate; the values of 30–60 % are obtained with an increased popula-

tion density; a catch bigger than 80 % means that there is heavy infestation (Androić et al. 1981). If the number of animals on the area is increased, the animals should be controlled.

MATHEMATICAL METHODS
MATEMATIČKE METODE

Relative and absolute methods of determining the population density were used. Results of a higher quality (Delany 1974) are obtained in their combined use.

Multiple Regression Method
Statistička metoda linearne regresije

To process the sample obtained by the method of the minimum square, the Multiple Regression Method of the programme Statistica (Stat Soft; 1994) was used. The Multiple Regression Method is based on the presumptions that:

1. Values of the independent variable are fixed and measured without mistakes;
2. Values of the dependent variable are on the ordinate;
3. For the values of the independent variable, the values of the dependent variable are independently and normally distributed;
4. The distribution of points around the regression line is equal on both sides (Pool 1974).

The purpose of the method is to determine the dependence of one variable (X) on the other variable (Y), in which the value "Y" corresponds to each value "X" . If there is a dependence between them, then the points with co-ordinates "X" and "Y" are on the regression line. Its existence can be shown by the expression: Y = a + bX, where: X = an independent variable (a cumulative catch of animals during previous days); Y = a dependent variable (a catch of animals per day); a = segment on the ordinate; b = the line gradient.

The segment on the ordinate ("a") represents the value of the function b=0 and is calculated by the expression: a = Y – bX, where: Y is the arithmetic mean of the number of animals per number of days, X is the arithmetic mean of the cumulative catches per number of days.

The line gradient (the regression coefficient, "b") represents the relation between variables "X" and "Y" and is calculated:

$$b = \frac{\Sigma xy}{x^2} \qquad \Sigma xy = \Sigma XiYi - \frac{(\Sigma X_i)\cdot(\Sigma Y_i)}{n}, \; i = 1,2 \ldots n$$

$$\Sigma x^2 = \Sigma X^2 - \frac{(\Sigma Xi)^2}{n}, \quad i = 1,2 \ldots n$$

n = number of catching days

The Multiple Regression Method for the estimation of the population size is used in such a way as to calculate the parameters of the regression line "a" and "b" according to the daily catch (values on the ordinate) and cumulative catches of the previous days (values on the abscissa). The degree of dependence of values "X" and "Y" is expressed by the correlation coefficient, and is calculated:

$$r = \frac{N \cdot (\Sigma XY) - (\Sigma X) \cdot (\Sigma Y)}{\sqrt{[N \cdot (\Sigma X^2) - (\Sigma X)^2] \cdot [N(\Sigma Y^2) - (\Sigma Y)^2]}}$$

Variables X and Y are in linear correlation for $-1 < r < 1$. If the correlation coefficient ("r") is closer to the absolute unit, the correlation is higher. The number of animals on the plot is represented by a point in which the regression line intersects the abscissa axis (Y = 0). An adequate approach for research of the population density of rodents requires a regular catch of animals in the field (Delany 1974).

The method of calculating on a surface unit
Metoda preračunavanja na jedinicu površine

In order to compare the results of the minimum square method (the area of 1.44 ha) and the "Y" method, the catch of animals from both "Y" plots was regarded as a single plot catch (the area of 1.47 ha because they were added). In that case, the areas of catch by the study area method and by the "Y" method were almost identical.

The results of the catch obtained by the "Y" method on five hunting nights were regarded as the total animal catch. The number of caught animals on the surface was the real number of animals on that surface (Zukal & Gaisler 1992). The number of animals from the surface was converted into the number of animals on one hectare according to the expression:

$$N/ha = \frac{10.000 \cdot N/p}{P}$$

where:
N/h = the number of animals on one hectare;
N/p = the number of animals on a trial surface (two "Y");
P = the surface in m^2 (14,700 m^2).

t-test

To compare the calculated values of the number of rodents on one hectare according to the "Y" method and the multiple regression method (Table 8), a t-test was used. It was used with small samples ($n_1<30$ and $n_2<20$) to examine the difference between the arithmetic means which follow t-distribution (Pranjić 1986). The aim was to establish if there was a significant difference in the obtained results between these two methods. As a zero-hypothesis, it was assumed that there was no difference between N/haY and N/haKV, i.e. Ho; N/haY = N/haKV. In that case, the following expression was used:

$$t = \frac{\bar{x}_1 - \bar{x}_2}{s\sqrt{\frac{n_1+n_2}{n_1 \cdot n_2}}}$$

where:

$\bar{x}_1$ = arithmetic mean of the elements from samples "1" (the number of animals per one hectare in the seasons of catch calculated by the multiple regression method);

$\bar{x}_2$ = arithmetic mean of the elements from samples "2" (the number of animals per one hectare in the seasons of catch calculated by the "Y" method);

n_1 = number of elements in sample "1";

n_2 = number of elements in sample "2";

s = standard deviation.

To calculate standard deviation, the following expression was used (Pranjić 1986):

$$s = \sqrt{\frac{\Sigma(xi-\bar{x}_1)^2+\Sigma(x_j-\bar{x}_2)^2}{n_1+n_2-2}}$$

xi = the elements of sample "1";

x_j = the elements of sample "2".

FIELD METHODS OF DETERMINING THE INTENSITY OF DAMAGE
TERENSKE METODE UTVRĐIVANJA INTENZITETA OŠTEĆENJA

Determination of the intensity of damage is one of the parameters in the estimate of the population density of rodents in a forest stand. The damage they cause is present in the form of gnawing on seeds and on young plants in the form of two parallel shallow grooves 1–2 mm wide (personal measuring on the field). If the co-

lour of the gnawed place is light, it is new damage. Vajda (1974) emphasises that mice are mostly the pests of forest seeds, while voles mostly do damage to young plants (saplings and seedlings).

Collecting the fallen acorn
Skupljanje otpaloga žira

Fallen acorn was collected every 14 days to establish the intensity and dynamics of damage to forest seeds from small rodents. Collected acorns from 5 study areas which were of the size 3 x 3 m each served as a sample. The choice of location for collecting was mostly under the crown of the trees which had the richest fruit. Also of interest was if the catch of rodents influenced the quantity of damage and if seeds were collected outside the study area on the part of the stand 100 m away from its edge, where there was no catch. The date of the taking of the sample, the number of the section and the name of the trial surface on which the seeds were collected were noted.

An analysis of the damage of forest plants
Analiza oštećenosti šumskih sadnica

The intensity of damage to young plants in subcompartment 58a was determined. Damage was noticed on young plants in the form of gnaws on a large number of plants in the lower part of stems. According to the bite marks, it was obvious that they were done by rodents. A darker colour of the gnawed place meant that damage was older than a year. The size of damage proved that at the time of its appearance, the population density of the animals on the field was increased. On this site, linear transects were placed to continue following the population density of rodents and to observe the dynamics of the appearance of new damage on young plants. Plants were examined on seven surfaces 5 x 5 m in size in order to follow the intensity of new gnaws on them. The intention was to include as large a number of plants as possible in the research. The height of a stem and the height of the damage on all the plants within the surfaces were noted (a total of 430 pieces). The measurements were written in the field form. The percentage of the damage for each plant was calculated:

$$\text{the dama ge of the plant} = \frac{\text{the height of the damage}}{\text{the height of the plant}} \times 100$$

Due to various intensities of damage, the results were arranged in five groups:
0 – undamaged plant;
1 – partially damaged plant (individual, shallow gnaws);
2 – a plant damaged from 0–5 %;
3 – a plant damaged from 5–10 %;
4 – a plant damaged more than 10 %.

Plants on the marked surfaces were examined in the period May–November 1996, six times all together.

LABORATORY METHODS
LABORATORIJSKE METODE

Determination and treatment of morphometric features of the caught animals
Determinacija i obrada morfometrijskih osobina ulovljenih životinja

The caught animals were sorted according to the experimental plots and the dates of catch and were placed in containers with 75 % alcohol. The animals were determined using the books Niethammer & Krapp (1978, 1982). The following parameters of the animals were measured: the body weight, the length of the body and tail, the length of the tail, the length of the hind foot without claws and the length of the ear. The body weight was measured using the scale "Pesola" to an accuracy of 0.5 g, and the length with a ruler to an accuracy of 0.5 mm. The sex and the approximate age of the caught animals were determined. The treated animals were labelled. All the samples were deposited in the collection of mammals of the Croatian National History Museum in Zagreb.

Examination and analysis of the collected acorn
Pregled i analiza skupljenoga žira

The treatment of the samples of pedunculate oak was done immediately after they had been brought from the field. This consisted of counting seeds in the sample and in determining the number of seeds damaged by rodents and other biotic factors (insects and fungi). By examining the acorns in October and November 1996, the dynamics and the intensity of damage to forest seeds caused by small rodents was followed. An acorn on which the described damage was visible was separated and further analysed. Its length and width was measured using a slide calliper and an eyepiece estimate of the damage was made. The name of the damaged part of the acorn was noted (basal, top or a central part). The separated fruit was further analysed in order to establish if there was some other visible damage from other pests, apart from gnaws (*Cydia* spp., *Balaninus* spp., fungi, etc.). In this way, it was possible to answer the question: "Do rodents more frequently damage healthy seeds or do they damage seeds "attacked" by other pests?"

RESULTS
REZULTATI

THE DAMAGED CONDITION OF FOREST SEEDS
OŠTEĆENOST ŠUMSKOGA SJEMENA

The size of the damage by rodents on forest seeds was determined by a detailed examination of the collected acorn of pedunculate oak from the study area. Damage was easily noticeable and was in the form of characteristic shallow bite marks of various intensities.

Seeds were also damaged by various kinds of fungi and insects from the genus *Balaninus* and the genus *Cydia*. The biology of the mentioned insects is closely connected with the oak seed. Larvae emerge from the seeds by biting with strong mandibles through the exit hole from the interior of the acorn. For species of the genus *Balaninus* (ordo Coleoptera), the exit hole is round, while for leaf roller moths (ordo Lepidoptera) (Hrašovec 1993) it is oval.

Seeds attacked by fungi were also separated from the samples. The damaged acorn had a dense net of hyphae which covered its cupule and wall. The results of the analysis of the damage of seeds are shown in Table 1. In the research on the size of damage on seeds, a total of 4,817 pieces of pedunculate oak acorn were examined. Analysis determined that 82.90 % of the seeds in the sample were healthy, while the rest were damaged by the following agents: rodents 2.35 %, acorn weevil *(Balaninus* spp.) 6.70 %, leaf roller moths *(Cydia* spp.) 6.29 % and fungi 1.76 %. Figure 1. shows the dynamics of damage on pedunculate oak acorns by rodents.

Figure 1. The dynamics of damage by rodents according to the surfaces on the samples of the pedunculate oak seed (October–November 1996)
Slika 1. Dinamika štete od mišolikih glodavaca po plohama na uzorcima sjemena hrasta lužnjaka (listopad–studeni 1996)

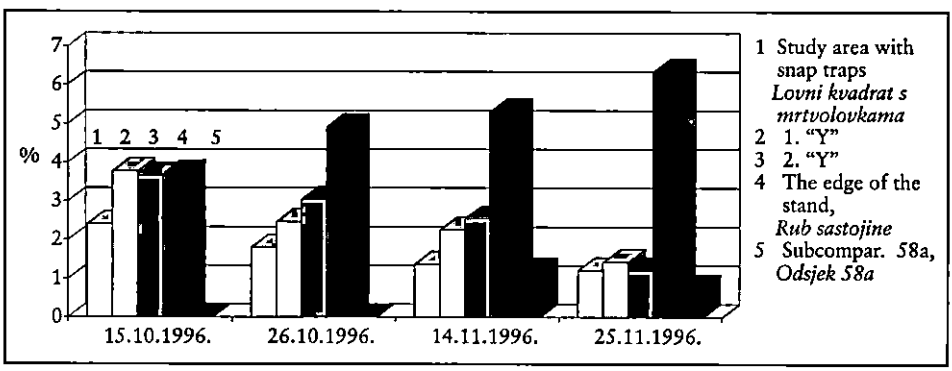


Table 1. The damaged condition of the pedunculate oak acorn by biotic factors
Tablica 1. Oštećenost žira hrasta lužnjaka od biotskih čimbenika

A trial surface *Pokusna ploha*	The quality of the seed *Kakvoća sjemena*	The sample collected on *Uzorak skupljen dana* 15.10.1996.		The sample collected on *Uzorak skupljen dana* 26.10.1996.		The sample collected on *Uzorak skupljen dana* 14.11.1996.		The sample collected on *Uzorak skupljen dana* 25.11.1996.	
		pieces. *kom.*	%	pieces *kom.*	%	pieces *kom.*	%	pieces *kom.*	%
Study area with snap traps (subcomp. 98a) *Lovni kvadrat s mrtvo-lovkama (odjel 98a)*	healthy *zdravo*	197	79.12	178	80.18	186	84.55	211	85.08
	damaged by rodents *oštećeno (glod.)*	6	2.41	4	1.80	3	1.36	3	1.21
	damaged by *oštećeno* (*Balaninus* spp.)	18	7.23	15	6.76	13	5.91	11	4.44
	damaged by *oštećeno* (*Cydia* spp.)	21	8.43	19	8.56	18	8.18	14	5.64
	damaged by funghi *oštećeno (gljive)*	7	2.81	6	2.70	-	-	9	3.63
	Total *Ukupno*	249	100.00	222	100.00	220	100.00	248	100.00
The first "Y" (subcomp. 98a) *Prvi "Y" (odjel 98a)*	healthy *zdravo*	187	78.24	168	82.76	158	88.76	175	82.94
	damaged by rodents *oštećeno (glod.)*	9	3.77	5	2.46	4	2.25	3	1.42
	damaged by *oštećeno* (*Balaninus* spp.)	22	9.21	14	6.90	8	4.49	19	9.00
	damaged by *oštećeno* (*Cydia* spp.)	16	6.69	10	4.93	6	3.37	14	6.64
	damaged by funghi oštećeno (gljive)	5	2.09	6	2.95	2	1.13	-	-
	Total *Ukupno*	239	100.00	203	100.00	178	100.00	211	100.00
The second "Y" (subcomp. 98a) *Drugi "Y" (odjel 98a)*	healthy *zdravo*	203	82.52	169	85.79	172	87.31	216	87.10
	damaged by rodents *oštećeno (glod.)*	9	3.66	6	3.04	5	2.54	3	1.21

	damaged by *oštećeno* (*Balaninus* spp.)	19	7.72	12	6.09	11	5.58	15	6.04
	damaged by *oštećeno* (*Cydia* spp.)	14	5.69	10	5.08	7	3.55	11	4.44
	damaged by funghi *oštećeno (gljive)*	1	0.41	-	-	2	1.02	3	1.21
	Total *Ukupno*	246	100.00	197	100.00	197	100.00	248	100.00
The edge of the stand (subcomp. 98a) *Rub sastojine (odjel 98a)*	healthy *zdravo*	248	83.50	226	79.30	176	85.02	163	86.24
	damaged by rodents *oštećeno (glod.)*	11	3.71	14	4.91	11	5.31	12	6.35
	damaged by *oštećeno* (*Balaninus* spp.)	14	4.71	17	5.96	7	3.38	8	4.23
	damaged by *oštećeno* (*Cydia* spp.)	16	5.39	21	7.37	11	5.31	6	3.18
	damaged by funghi *oštećeno (gljive)*	8	2.69	7	2.46	2	0.98	-	-
	Total *Ukupno*	297	100.00	285	100.00	207	100.00	189	100.00
Subcomp. 58a *odjel 58a*	heathy *zdravo*	241	79.80	288	78.90	207	82.47	224	85.17
	damaged by rodents *oštećeno (glod.)*	-	-	-	-	3	1.20	2	0.77
	damaged by *oštećeno* (*Balaninus* spp.)	29	9.60	37	10.14	16	6.37	18	6.84
	damaged by *oštećeno* (*Cydia* spp.)	23	7.62	29	7.95	21	8.37	16	6.08
	damaged by funghi *oštećeno (gljive)*	9	2.98	11	3.01	4	1.59	3	1.14
	Total *Ukupno*	302	100.00	365	100.00	251	100.00	263	100.00

In the first collection of seeds (15.10. 1996), the condition of acorns damaged by rodents was almost equal and ranged from 2.41% to 3.77 % (Figure 1). In a forest stand under normal management, such a size of damage is considered as accep-

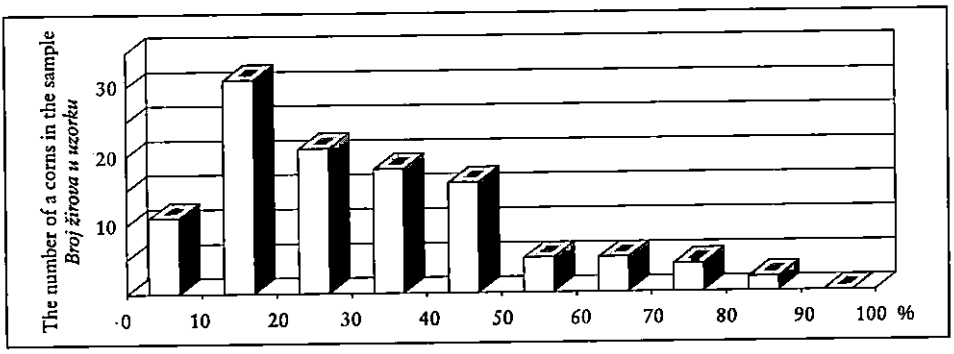
table. In the sample collected from the trial surface in subcompartment 58a, not a single damaged sample of acorn was found, which was repeated in the next collection two weeks later and which is an indirect indicator that the number of rodents in the subcompartment 58a was small.

On analysing the seeds from the surfaces of both "Y" and the study area (subcompartment 98a) collected approximately two weeks after first coming to the field (26.10. 1996), a noticeable decrease in seeds damaged by rodents was found in the samples. The decrease in the quantity of damaged seeds continued until the end of November 1996.

The results of the analysis of the collected material from the edge of the stand on which there was no catch of animals were different. Checking samples from that surface, an increase in damaged seeds from 3.77 % to 6.35 % was noticed.

A damaged part was estimated on each separated acorn and visible bites by rodents (a sample of 113 pieces) were viewed with an eye-piece. The damage was expressed as a percentage in relation to the size of the seed (Figure 2).

Figure 2. The percentage of the damaged condition of the seed in a sample
Slika 2. Postotna oštećenost žira u uzorku



In the examined sample there were 31.21 % of acorns with an estimated damage of 10-20 % of the total area, while 14.17 % of the seeds had an estimated damage higher than 50 % of the total size. In the same sample, an examination was made on which part of the acorn (base, middle or the top part) was mostly attacked by rodents (Figure 3). The examination showed that 59.77 % of seeds were damaged on the basal part, 28.32 % on the top part, while 11.91 % were damaged in the middle part. When analysing the sample of seed damaged by rodents, it was also examined if there was damage by other pests *(Balaninus* spp., *Cydia* spp. fungi, etc.) apart from that by rodents. The aim of this research was to determine whether rodents more frequently attack healthy, undamaged acorn, or if they prefer damaged seeds already attacked by other pests. The results of the analysis of the samples are shown in Figure 4.

It was established that 73.45 % of the sample was damaged only by rodents. Damage by other biotic factors on this portion of the samples was not noticeable.

Figure 3. The damaged condition of parts of the acorn
Slika 3. Udio oštećenosti dijelova žira

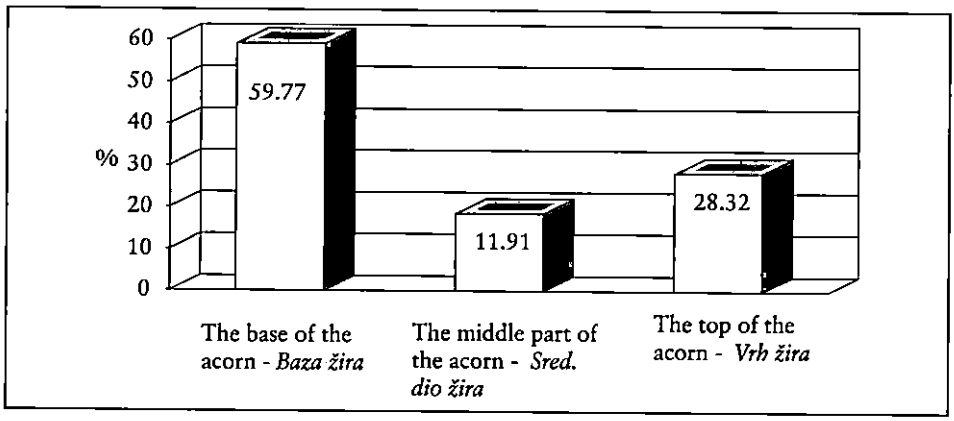
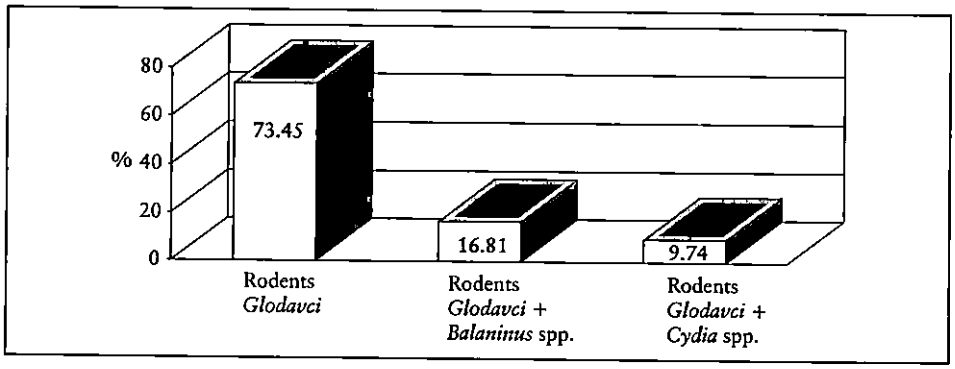


Figure 4. The damaged condition of the acorn by biotic factors
Slika 4. Oštećenost žira od biotskih čimbenika



On 16.81 % of the samples, apart from gnaws by rodents, exit holes of insects from the genus *Balaninus* were visible, while on 9.74 % of the acorn sample, apart from gnaws by rodents, exit holes by insects from the genus *Cydia* were visible. Rodents most frequently damaged acorn which had not been attacked by acorn weevil and leaf roller moths. It was not noticed that rodents had damaged any acorn which had previously been infected by fungi.

THE DAMAGED CONDITION OF FOREST PLANTS
OŠTEĆENOST ŠUMSKIH SADNICA

In subcompartment 58a, in a forest community of *Genisto elatae-Quercetum roboris*, the intensity of damage by small rodents on new growth was studied. Re-

search began in spring 1996 (in May) on seven surfaces. In order to examine precisely the dynamics of damage, with the aim of defining the period of its most frequent appearance, five field measurements were taken, during which a total of 2,580 forest plants (a total of 430 plants x 6 examinations) were treated. In the first examination of plants (May 1996) all noted damage by rodents was older than a year (autumn 1994 and winter 1994/95). On that occasion no new damage was noticed. Either no gnaws or gnaws of various intensities (plants without damage, partially damaged plants and completely damaged plants) were observed. Figure 5 shows the percentage of damaged plants in the sample on the surfaces. On all surfaces, more than 50 % of damaged material was recorded. The smallest percentage of damaged plants after the first examination was registered on surface 1, amounting to 58.42 %, while the most damaged plants in the sample were registered on surface 2 (97.38 %). On other surfaces, the damage of plants was between 80 % and 95 %.

Table 2 shows the analysis of damage of plants after the first examination in spring 1996 and according to the described categories of damage (see "Methods" section). Plants with a percentage of damage between 5 % and 10 % (degree of damage 3) (Table 2) were the most frequent. The second examination of plants on the study area (July 1996) did not show any new damage.

During the examination of young plants in the middle of October 1996, new gnaws by small rodents on surface 4 (one piece of damage), surface 6 (two pieces of damage) and surface 7 (two pieces of damage) were noticed. All were noted on plants which were already damaged. Rodents gnawed undamaged parts of bark up to a height of 10 cm from the soil surface. During the fourth examination of samples (26.10. 1996), no gnaws were noticed on any plant. In the middle of November 1996, new damage was noticed only on two plants on surface 7. The amount

Figure 5. The damaged condition of plants on surfaces 1–7
Slika 5. Oštećenost biljaka na plohama 1– 7

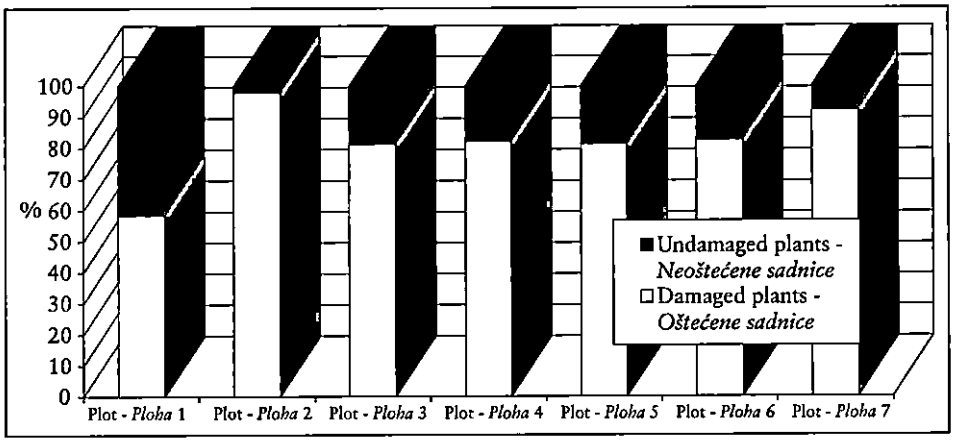


Table 2. The population density of plants on plots according to the degrees of damage
Tablica 2. Brojnost biljaka na pokusnim plohama po stupnjevima oštećenosti

N° of the plot *Broj plohe*	The degree of damage *Stupanj oštećenosti* 0		The degree of damage *Stupanj oštećenosti* 1		The degree of damage *Stupanj oštećenosti* 2		The degree of damage *Stupanj oštećenosti* 3		The degree of damage *Stupanj oštećenosti* 4		Total *Ukupno*	
	N° *kom.*	%	N° *kom.*	%	N° *kom.*	%	N° *kom.*	%	N° *kom.*	%	N° *kom.*	%
1.	42	41.58	32	31.69	3	2.97	8	7.92	16	15.84	101	100.00
2.	1	2.13	8	17.02	5	10.64	21	44.68	12	25.53	47	100.00
3.	6	18.75	8	25.00	3	9.38	9	28.12	6	18.75	32	100.00
4.	10	17.86	16	28.57	4	7.14	18	32.14	8	14.29	56	100.00
5.	6	18.75	3	9.38	5	15.63	15	46.88	3	9.36	32	100.00
6.	8	17.39	10	21.74	7	15.22	14	30.43	7	15.22	46	100.00
7.	9	7.76	7	6.03	38	32.76	50	43.10	12	10.35	116	100.00
Σ	82	19.07	84	19.54	65	15.12	135	31.39	64	14.88	430	100.00

of newly damaged plants in this examination was 0.47 %. With the examination of samples at the end of November 1996, new damage was noticed only on one plant of common ash on surface 1. The measured gnaw was partial, 7.4 cm long.

In the period from July to November 1996 (not taking into consideration the first examination in May 1996), among 2,150 examined plants, new damage by rodents was noticed on eight plants. The estimate of damage on plants, as an indirect method of determining the number of rodents on this site, indicated a low population of mentioned animals.

THE POPULATION DENSITY OF RODENTS
BROJNOST POPULACIJE MIŠOLIKIH GLODAVACA

In the forests of Turopolje, the following species of rodents were determined: *Apodemus flavicollis, A. sylvaticus, A. agrarius, Clethrionomys glareolus, Microtus arvalis* and *M. agrestis.*

THE POPULATION DENSITY OF RODENTS CALCULATED BY MULTIPLE REGRESSION METHOD
BROJNOST MIŠOLIKIH GLODAVACA IZRAČUNATA METODOM LINEARNE REGRESIJE

Four species of rodents were caught, with a total of 39 animals (Table 3).

Table 3. The catch of rodents by the minimum square method according to species and dates of the catch

Tablica 3. Ulov mišolikih glodavaca metodom minimalnoga kvadrata po vrstama i datumima ulova

The date of the catch *Datum ulova*	The catching day *Lovni dan*	*Clethrionomys glareolus*	*Apodemus flavicollis*	*Apodemus sylvaticus*	*Microtus arvalis*	ΣΣ
20.04.1995.	1	1	7	–	–	8
21.04.1995.	2	–	1	–	–	1
22.04.1995.	3	–	4	–	–	4
23.04.1995.	4	–	–	–	–	–
24.04.1995	5	1	2	–	–	3
Σ		2	14	–	–	16
03.05.1996.	1	–	2	–	–	2
04.05.1996.	2	–	–	–	–	–
05.05.1996.	3	–	–	–	–	–
06.05.1996.	4	–	–	–	1	1
07.05.1996.	5	–	–	–	–	–
Σ		–	2	–	1	3
11.07.1996.	1	–	3	–	–	3
12.07.1996.	2	–	2	–	–	2
13.07.1996.	3	–	1	–	–	1
14.07.1996.	4	–	–	–	–	–
15.07.1996.	5	–	–	–	–	–
Σ		–	6	–	–	6
23.10.1996.	1	–	5	–	–	5
24.10.1996.	2	–	4	–	–	4
25.10.1996.	3	–	2	–	–	2
26.10.1996.	4	–	–	–	–	–
27.10.1996	5	–	2	1	–	3
Σ	–	–	13	1	–	14
ΣΣ	–	2	35	1	1	39

The dominant species was *A. flavicollis* (89.75 % of the catch). 5.13 % of the caught animals belonged to the genus *C. glareolus*, while the *A. sylvaticus* and *M. arvalis* amounted to 2.56 % of the total sample. Table 4 shows the results of the daily and the cumulative catch of animals per season of catches. The population density of rodents per surface (1.44 ha) for each season of catch was calculated by the method of linear regression. Converting the obtained results to a surface of one

hectare, the population density of animals per hectare was calculated. These results are shown in Table 5.

Table 4. The account of daily (X) and cumulative catches (Y)
Tablica 4. Prikaz dnevnih (X) i kumulativnih (Y) ulova po sezonama izlova

The season of the catch *Sezona izlovljavanja*	April *Travanj* 1995	April *Travanj* 1995	May *Svibanj* 1996	May *Svibanj* 1996	July *Srpanj* 1996	July *Srpanj* 1996	October *Listopad* 1996	October *Listopad* 1996
x - daily catch *x - dnevni ulov* y - cumulative catch *y - kumulativni ulov*	X1	Y1	X2	Y2	X3	Y3	X4	Y4
Day *Dan* 1	8	0	2	0	3	0	5	0
Day *Dan* 2	1	8	0	2	2	3	4	5
Day *Dan* 3	4	9	0	2	1	5	2	9
Day *Dan* 4	0	13	1	2	0	6	0	11
Day *Dan* 5	3	13	0	3	0	6	3	11

Table 5. The population density of rodents on the plot (N/p) and on one hectare of the surface (N/ha) calculated by the multiple regression method
Tablica 5. Brojnost mišolikih glodavaca na pokusnoj plohi (N/p) i na jednom hektaru površine (N/ha) izračunata metodom linearne regresije

The season of the catch *Sezona izlovljavanja*	N / p	N / ha
April *Travanj* 1995	15.24	10.58
May *Svibanj* 1996	2.65	1.84
July *Srpanj* 1996	6.40	4.44
October *Listopad* 1996	15.54	10.79

THE POPULATION DENSITY OF RODENTS CALCULATED BY THE "Y" METHOD
BROJNOST POPULACIJE MIŠOLIKIH GLODAVACA IZRAČUNATA "Y" METODOM

The population density of the rodent population was investigated using the "Y" method in spring 1995 and in spring and autumn 1996. On both "Ys" five species of rodents were caught in a total of 34 animals (Table 6). *A. flavicollis* (67.65 %) was dominant. *C. glareolus* and *A. sylvaticus* were each present in 5.88 % of the

sample while 11.76 % of the caught animals belonged to the species *M. arvalis*. *M. agrestis* was present in the sample at a rate of 8.87 %. Using the "Y" method, the number of animals were caught on 2 plots of a total area of 1.47 ha (N/p) per each catch season. Converting the obtained results to the surface of one hectare, the population density of rodents per hectare was determined (N/ha) (Table 7).

Table 6. The catch of rodents by the "Y" method according to species and dates of the catch
Tablica 6. Ulov mišolikih glodavaca "Y" metodom po vrstama i datumima ulova

The date of the catch *Datum ulova*	The catching day *Lovni dan*	*Clethrionomys glareolus*	*Apodemus flavicollis*	*Apodemus sylvaticus*	*Microtus arvalis*	*Microtus agrestis*	ΣΣ
13.04.1995.	1	1	1	–	–	–	2
14.04.1995.	2	–	1	–	–	–	1
15.04.1995.	3	1	1	–	1	–	3
16.04.1995.	4	–	5	–	1	–	6
17.04.1995	5	–	1	–	1	–	2
Σ		2	9	–	3	–	14
03.05.1996.	1	–	–	–	–	–	–
04.05.1996.	2	–	–	–	–	–	–
05.05.1996.	3	–	–	–	–	–	–
06.05.1996.	4	–	–	–	–	2	2
07.05.1996.	5	–	–	–	–	–	–
Σ		–	–	–	–	2	2
23.10.1996.	1	–	9	2	1	1	13
24.10.1996.	2	–	4	–	–	–	4
25.10.1996.	3	–	–	–	–	–	–
26.10.1996.	4	–	–	–	–	–	–
27.10.1996	5	–	1	–	–	–	1
Σ	–	–	14	2	1	1	18
ΣΣ	–	2	23	2	4	3	34

Table 7. The population density of rodents on a plot (N/p) and on one hectare (N/ha) calculated by the "Y" method
Tablica 7. Brojnost mišolikih glodavaca na pokusnoj plohi (N/p) i na jednom hektaru (N/ha) izračunata "Y" metodom

The season of the catch *Sezona izlova*	N / p	N / ha
April *Travanj* 1995	14	9.52
May *Svibanj* 1996	2	1.36
October *Listopad* 1996	18	12.24

The arithmetic means of the population density of rodents per hectare by t-test (Table 8) determined by the multiple regression method and the "Y" method was compared.

Table 8. The population density of rodents on one hectare according to seasons of the catch calculated by the "Y" method (N/haY) and the multiple regression method (N/haKV). "x" denotes the arithmetic mean N/ha Y and N/haKV
Tablica 8. Brojnost mišolikih glodavaca na jednom hektaru po sezonama izlova izračunata "Y" metodom (N/haY) i metodom linearne regresije (N/haKV); "x"označava aritmetičku sredinu N/haY i N/haKV

The season of the catch *Sezona izlova*	N/haKV	N/haY
April *Travanj* 1995	10.58	9.52
May *Svibanj* 1996	1.84	1.36
October *Listopad* 1996	10.79	12.24
$\bar{x}$	7.74	7.71

The calculated "t" (t_{izr} = 0.007) was compared with the "t" tabular (t_{tab}= 4.303) for the reliability limit of 0.05 and the number of the degree of freedom n = 2. As $t_{izr} < t_{tab}$, it could be concluded that the zero-hypothesis was acceptable, i.e. the population densities of rodents calculated by the multiple regression method and the "Y" method were statistically significantly different from each other (Ho; N/haY = N/haKV). The results of the measurement of the weather conditions are shown in Table 9.

Table 9. Weather conditions in the forest community of the pedunculate oak and hornbeam (subcompartment 98a) according to the sampling days
Tablica 9. Vremenske prilike u šumskoj zajednici hrasta lužnjaka i običnoga graba (odjel 98a) po danima uzorkovanja

The date of the sampling *Datum uzorkovanja*	Cloudiness *Oblačnost*	Precipitation *Oborine*	The air temperature *Temperatura zraka* °C	The soil temperature *Temperatura tla* °C
13.04.1995.	cloudy *oblačno*	rain *kiša*	9.2	8.7
14.04.1995.	cloudy *oblačno*	rain, snow at night *kiša, noću snijeg*	6.4	6.2
15.04.1995.	cloudy *oblačno*	rain at night *noću kiša*	4.9	6.6
16.04.1995.	cloudy *oblačno*	rain *kiša*	8.4	6.9
17.04.1995.	fair *vedro*		7.7	7.7
20.04.1995.	partly cloudy *poluoblačno*	rain at night *noću kiša*	9.0	9.7
21.04.1995.	cloudy *oblačno*		12.0	11.1
22.04.1995.	fair *vedro*		9.1	10.7
23.04.1995.	fair *vedro*		9.9	10.7
24.04.1995.	cloudy *oblačno*	rain *kiša*	8.6	9.8
03.05.1996.	cloudy *oblačno*	rain at night *noću kiša*	8.2	9.1
04.05.1996.	fair *vedro*		7.6	9.4
05.05.1996.	fair *vedro*		11.5	9.2
06.05.1996.	cloudy *oblačno*	rain at night *noću kiša*	12.7	11.3
07.05.1996.	fair *vedro*		9.6	10.3

In Figures 6, 7 and 8 measured air temperatures, registered precipitation and the catch of animals per sampling day are shown. The dates of the catch were placed on the abscissa and the number of caught animals and air temperature on the ordinate. The biggest number of rodents was caught on plots (study area and two "Ys") in the period when it was raining or immediately before rain.

DETERMINING THE RELATIVE POPULATION DENSITY OF RODENTS BY THE LINEAR TRANSECT METHOD
ODREĐIVANJE RELATIVNE BROJNOSTI MIŠOLIKIH GLODAVACA METODOM LINEARNOGA TRANSEKTA

The population density of rodents by the linear transect method was checked in forest communities *Genisto elatae-Quercetum roboris* Ht. 1938 (subcompartments 58a and 62a) and *Carpino betuli-Quercetum roboris* Rauš 1969 (subcompartments 59a, 75a and 90a). The transects were in the same forest communities in which the squares were placed and where the "Ys" were done. The catch of animals lasted one night. Research of the population density of animals by the linear

transect method was started in spring 1995 by placing 100 snap traps (transect I) next to the edge of subcompartment 90a (pedunculate oak and a hornbeam forest). On checking the transect the next morning, it was found that animals were caught in eleven traps. Among the caught animals the dominant species was *C. glareolus* (seven animals). The result is logical, as the red-backed vole most frequently lives on habitats with little water and rich grassy vegetation (Androić et al. 1981) and a

Figure 6. The account of the catch of rodents, the air temperature, rain and snow according to the sampling days by the "Y" method in April, 1995
Slika 6. Prikaz ulova glodavaca, temperature zraka, kiše i snijega po danima uzorkovanja "Y" metodom u travnju 1995. godine

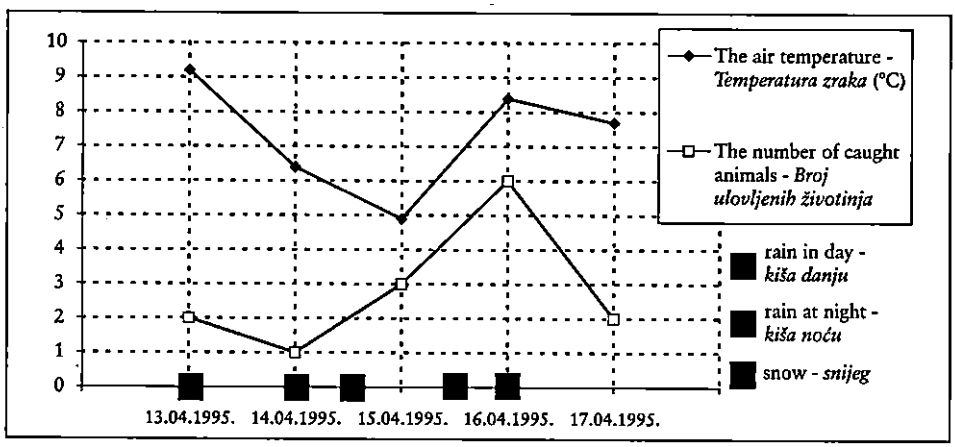


Figure 7. The account of the catch of rodents, the air temperature and rain according to the sampling days by the minimum square method in April, 1995
Slika 7. Prikaz ulova glodavaca, temperature zraka, kiše i snijega po danima uzorkovanja metodom minimalnoga kvadrata u travnju 1995. godine

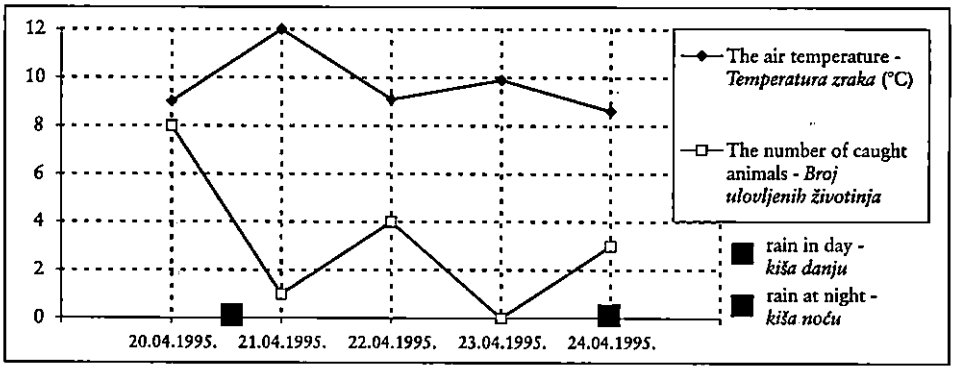
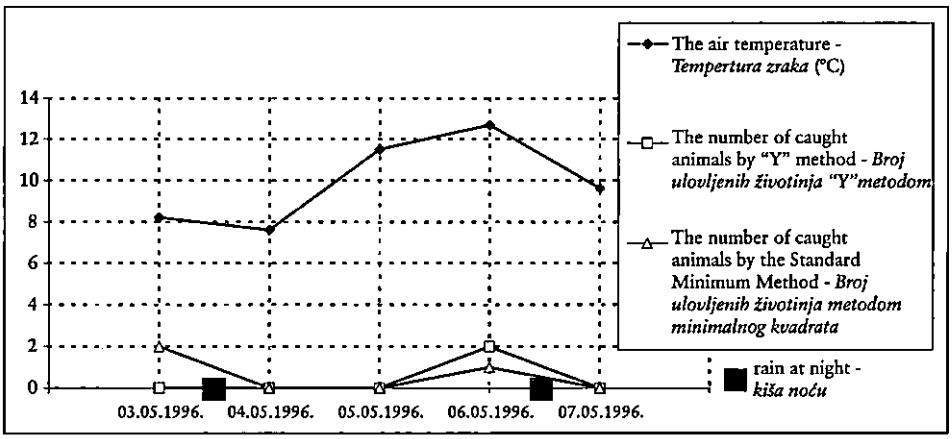


Figure 8. The account of the catch of rodents, the air temperature and rain according to the sampling days by the minimum square and the "Y" method in May, 1996
Slika 8. Prikaz ulova glodavaca, temperature zraka, kiše i snijega po danima uzorkovanja metodom minimalnoga kvadrata i "Y" metodom u svibnju 1996. godine



transect was placed on such a field. *A. flavicollis* (two animals) and *A. sylvaticus* (two animals) were also caught in transect I.

The next time the population density of rodents was checked was in autumn 1995, when two parallel transects were placed about 200 m from each other, in subcompartments 75a (transects II and III) and 62a (transects IV and V) in which various plant communities are prevalent (pedunculate oak and hornbeam forest in subcompartment 75a and pedunculate oak and broom forest in subcompartment 62a). To avoid the edge effect on rodents, transects were placed 50 m from the edge of the stand. Four species of rodents (17 specimens) were caught. An analysis of the catch area showed that each species lived on a particular microhabitat. In the transects placed in a community of pedunculate oak and hornbeam, the dominant animals were *A. flavicollis* (88 % of the catch), while the rest were *C. glareolus.*

Eight animals were caught in two other transects (transects IV and V) placed in the forest community of pedunculate oak and broom (section 62a). In each transect 50 traps were placed. All the animals were caught in transect V.

The percentage of caught rodents in transect V was 16 %. The dominant animal was *A. agrarius* (62.5 %), while the rest of the sample included *M. agrestis* (37.5 %). The result of the catch shows the presence of various species of rodents in certain forest communities. In the community *Carpino betuli-Quercetum roboris*, two species were noticed: *A. flavicollis* and *C. glareolus*, while in the forest *Genisto elatae-Quercetum roboris* Ht. 1938, *A. agrarius* and *M. agrestis* were caught.

The third determination of the population density of rodents was done by the linear transect method in May 1996 by placing 100 snap traps in the catching line in subcompartment 58a (forest community *Genisto elatae–Quercetum roboris*). No animal was caught. Two months later, a catching transect was put on the same

place (transect VII). Only one *A. flavicollis* and one *M. arvalis* were caught. In autumn 1996, three new catching transects (VIII, IX and X) were activated, and at the same time the population density of the mentioned pests was investigated by the "Y" method and the minimum square method. Animals were not caught by catching transects VIII, IX, X.

DISCUSSION
RASPRAVA

According to the data of the Diagnostic Prognostic Service of the Institute of Forestry of Jastrebarsko and the author's personal survey over several years, in all Forest Offices of the public enterprise "Croatian Forests", damage has been noticed on the forests seeds and young plants in Croatian forests over an area of several thousand hectares. The relation of the number of animals in the countryside and the amount of damage they can cause is proportional (Vajda 1974). The greatest intensity of damage was registered in lowland pedunculate oak forests. In order to prevent this in time, it is necessary to regularly check the population densities of the causes of the damage in the field. Three different methods were used to examine the population density of rodents in the forests of the Management Unit Turopoljski Lug during two subsequent years. Absolute and relative population densities of rodents were calculated in the forest communities *Genisto elatae-Quercetum roboris* and *Carpino betuli-Quercetum roboris*. In May 1996 the lowest absolute population density was registered in the community of pedunculate oak and hornbeam using the "Y" method (N/ha = 1.36), and the highest in October of the same year (N/ha = 12.24). The dominant species was *A. flavicollis*, as the habitat on which the study area for this method was placed completely suited this species (a great quantity of windfall leaves and poorly developed shrubbery) (Vraneš 1972).

Very similar results were obtained for the population density of rodents in the same region by the multiple regression method. The lowest absolute population density of rodents was also determined in May 1996 (N/ha = 1.84). The result corresponds to Vajda (1974) and Androić et al. (1981) who emphasise that the population density of rodents in spring is smaller than in autumn. During the winter months the mortality of animals increases due to the effects of low temperatures and a lack of food (Delany 1974). In July 1996, a lower increase in the population density of animals (N/ha = 4.44) was noticed. Three months later the population density reached its highest value (N/ha = 10.79). Comparing by a t-test the results of the population density determined by the "Y" method and the minimum square method, it can be concluded that there is no significant difference between them, with a degree of reliability of 95 %. If the catch is analysed according to species, differences can be noticed. In spring 1995, two animals of the species *C. glareolus*

were caught by both methods. In comparison with Kovačić (1988), this number is minimal considering the usual population density of that species in this area. The population density of the *C. glareolus* in the forests of this management unit was 26 animals per hectare in April 1984 (Kovačić 1988). The highest density of population of this species was noticed in November 1983 (N/ha = 138) (Kovačić 1988).

In the period of almost two years, no *M. agrestis* were caught on the study area, while in catching containers placed in a "Y" in the same period, three animals of that species were caught. Similar results were obtained with *M. arvalis* and *A. sylvaticus*. On the study area one animal of each type was determined, while in both "Ys" *A. sylvaticus* were caught and four *M. arvalis* (Table 3 and Table 6). *A. flavicollis* was the most numerous species on the plots. The catch dynamics of the *A. flavicollis* shows that the most numerous catches were in spring 1995 and autumn 1996. The greatest catch was always registered on the first three nights.

Kovačić (1988) registered the maximum population density of the species *A. flavicollis* in the Turopolje forests in December 1983 (N/ha = 88), and the minimum in April 1984 (N/ha = 6). Analysing the population density of all rodents together put the maximum number in November 1983 (N/ha = 209), and the minimum in February 1984 (N/ha = 20) (Kovačić 1988). The population density of the rodent community follows the population dynamics of the dominant species *C. glareolus* and *A. flavicollis*. This fact was also confirmed by the results of this study in which the population density of the community follows the population dynamics of *A. flavicollis*. Having compared the calculated maximum population density of that community with Kovačić (1988), it was concluded that the population density of animals during the present research was very small. It was 10-15 times smaller than in the period from July 1983 to June 1984 (Kovačić 1988). The same conclusion was reached on the small population density of rodents on the mentioned area by the linear transect method. An analysis of the relation of the number of caught animals and determined species in comparison with other used methods showed that the catch of animals in one night by this method was insufficient to learn completely about the composition of the community of small mammals. In the transect three species of rodents were determined. The highest relative value of the population was determined in transect IV in the community of *Genisto elatae-Quercetum roboris* (subcompartment 62a) in November 1995 when a catch was registered in 16 % of the snap traps. The most abundant was *A. agrarius*. The result of the catch at linear transects IV and V is at first sight illogical. Both catching lines were placed on the same habitat, so it was expected that the catch in them would be approximately the same. However, the outcome was the result of the different placing of the traps. In transect V, snap traps were placed in protected places (in baréd litter, under tree-stumps, in microdepressions, etc.), while the snap traps in transect IV were placed in unprotected places on the surface of windfall leaves. A decision on control is made according to the number of caught animals in the transect. Control is not necessary if the percentage of caught rodents is under 20 % (Crnković 1982). If the catch is between 20 % and 30 %, the control

can, but need not, be done, depending on whether there is artificial or natural afforestation, which depends on whether there are young plants and forest seeds on the field which have to be protected. When animals are caught in 30 % of the snap traps, the pests must be controlled. According to Androić et al. (1981), the relative number of animals from 30 % to 60 % is a sign of an increased number of animals, while Delany (1974) considers the situation in which animals are caught in 80 % of the traps as a true indicator of a high population density of rodents in the forest.

Factors which influence the choice of microhabitat of certain species of small mammals are the quantity of light in lower layers of a stand, the presence of ground vegetation, the level of underground water and the length of periods of flood (Price 1978, Dueser & Hallet 1980). According to Vraneš (1972), *A. flavicollis* mostly lives on drier areas with poorly developed shrubbery and a great quantity of windfall leaves. However, *C. glareolus*, apart from on the edges of the stand, lives on forest areas rich in shrubbery. The results in the catching transects during spring 1995 and summer 1996 in the forest community *Carpino betuli-Quercetum roboris* completely correspond in number and species of caught rodents to the results of the "Y" method and the minimum square method. There are no differences in the community *Genisto elatae-Quercetum roboris* linear transect method done in May and July 1996. By comparing the catch of animals by various methods in subcompartments 90a and 98a (the community *Carpino betuli-Quercetum roboris*) in autumn 1995, the differences in results are significant. At that time, the highest population density of animals was registered by the minimum square method and the "Y" method. In the simultaneously placed transects IX and X in subcompartment 90a, no animals were caught. The cause might be a heterogeneous microdistribution of populations in the forest or the possible unfavourable climatic influence on the percentage of the catch. Tracing the population densities of rodents is possible only by catching animals over several days (Kovačić 1988, Trilar 1991, Zukal & Gaisler 1992). Comparing the catch in the transects with the values at which Crnković (1982) defines control in the field to be necessary, it was concluded that it was not necessary to control the rodents during last two years in the Management Unit "Turopoljski Lug". Even the highest percentage of caught animals in linear transects (16 % - in the section 62a in autumn 1995) was under 20 % of the catch, at which point Crnković (1982) recommends that rodents be controlled.

The dynamics of the catch of animals depends on the influence of temperature and precipitation. Following the effects of these parameters, it was established that most rodents were caught in the rainy period or immediately before it, when the activity of rodents is increased (Figures 10, 11, 12). According to the research of Bider (1968), at this time the activity of animals increases. Analysing the damaged condition of the seed of the pedunculate oak, it was determined that the highest percentage of the damaged acorn was 6.35 % per sample on the edge of vegetation. The increase in damage occurred because the acorn became an important source of food for rodents after the end of vegetation, and their population density

on this surface was not reduced by the catch. A small increase in damage on forest seed on the edge of the stand is not disturbing. In the years of the low population density of rodents, damage caused by them to the crop of acorn is negligible. Rodents mostly damage the healthy acorn not attacked by other pests (insects). Most gnaws by rodents were noticed in the basal part of the acorn. The high percentage of damage to the base part has a logical explanation, since it is known that an acorn is thinnest at that part (Hrašovec 1993). The greatest damage to the pedunculate oak seed was done by *A. flavicollis*, as these species were the most abundant among the caught animals.

An important task is to regenerate devastated forest stands. Numerous authors have written about determining the most suitable kinds of trees and methods of regenerating areas devastated by the drying of pedunculate oak (*Quercus robur* L.) in Croatia (Dekanić 1977, Matić 1989, 1993, 1994, Prpić et al. 1994, Matić et al. 1994, Oršanić et al. 1996). Examining the new growth of autochtonous kinds of trees that appear on surfaces devastated by the drying of pedunculate oak communities and knowing the biological features, ecological demands and economic features of trees, Matić (1989) concludes that pedunculate oak, common ash and alder are three basic kinds which should be used in the regeneration of these forests.

Due to the great mosaicism of the decay of pedunculate oak which takes place in Turopoljski Lug at a higher or smaller intensity on almost the whole surface (Prpić et al. 1994), the regeneration of the forest by a natural or an artificial method should take place in numerous compartments (9, 13, 20, 32, 38, 58, 59, 60, 61, 62, 74). The choice of the method of regeneration, as well as the choice of the kinds of trees, was made according to the estimate of the future biotope and the future structure of the stand, which would guarantee its stability. On a specific plate-like field on which dryings of great quantity were noticed, artificial regeneration was done by planting pioneer species of trees (alder, common ash) which have the common task of creating conditions in the soil and on the soil for the pedunculate oak which belongs here. Plant material used in the regeneration of the stand is frequently exposed to the attack of numerous pests. Intensities of damage by small rodents on the plants are distinguished in 3 categories: plants without damage, partially damaged plants, and completely damaged plants. Partial damage means a shallow, discontinued gnawed surface on the bark several centimetres long. Such damage does not represent a great danger for the physiology of a plant, as gnaws heal up in a short time. The consequences of partial gnaws are indirect, as a gnawed place serves as the entrance for numerous fungi to the host plant, causing its disease (Glavaš 1984, 1984a, 1989, Glavaš & Halambek 1992). Complete damage was defined as a continuous, deeply gnawed region of various length in the lower part of a stem.

When damage was done (it is assumed that it was in winter 1994/95), the population of rodents was very high. At that time, the control of rodents ought to have been done by one of the methods of contemporary forest protection, in order to avoid the consequences which we witness today.

In May 1996 old gnaws of various intensity were determined in the lower parts of the plants on all seven study areas. According to the colour of the gnawed places, it was concluded that voles caused the damage in late autumn 1994 and during winter 1994/1995. The damage was probably done by *M. agrestis* or *M. arvalis*, while the habitat and the way of damaging the plants completely correspond to these species. In linear transects (transects VI and VII) *A. flavicollis* and one *M. arvalis* were caught. The smallest percentage of old damaged material (58.42 %) was registered on surface 1, while the majority of plants (97.87 %) were damaged on surface 2. According to the quantity of damage and the time of its appearance, the population density of the rodents was very high. From July to November 1996, new damage was noticed on only 1.86 % of forest plants, which is negligible. The absence of new damage in July 1996 was expected, as during vegetation rodents use other food sources (herbaceous plants, insects, earthworms, forest fruit, etc.). If the obtained result is compared with the low population density of rodents which was established at that time on that site by a linear transect method, then this is logical. One of the indirect methods of defining the population density of small mammals in the field is by following the intensity of damage on seeds and young plants (Vajda 1974). From the result of the damaged conditions of plants, it could be noticed that the population density of rodents was very small and that it was not necessary to control them.

Control measures to reduce the population density of rodents are taken because of the epidemiological danger and damage that these rodents can do during periods of high population densities. Knowing the characteristics of the majority of the species of these pests (high reproduction potential, the possibility to adapt to various conditions of life and types of habitat, euryvalence in relation to numerous factors of the environment, etc.), the problem of controlling their population density with the use of preventive or direct measures is a very complex task. Preventive measures are particularly significant in the control of rodents and are taken with the aim of decreasing the quality of the habitat on which the rodents live. For that purpose, various methods of tillage (plowing, earthing up), the management of forest order, weed control, etc. are taken. The unprofessional management of forest order creates conditions for high population densities of animals. The use of repellents is also included in preventive measures in the control of rodents. The potential repellent must have an irritating effect through the sense of smell and not through the sense of taste. According to this personal survey and the data of the Diagnostic Prognostic Service of the Institute of Forestry of Jastrebarsko, repellents were not used in Croatian forestry in the period from 1981–1995 as preventive measures against rodents.

Various mechanical methods are also frequently used in the control of small rodents. They include catching animals by placing hunting containers and using various traps (snap traps and livetraps). These measures are very expensive, since a great deal of time, material means and labour force are necessary for their use on large areas. They are therefore not economically justified.

By organising the prognostic service in all Forest Offices of the public enterprise "Croatian Forests" and by regularly monitoring the dynamics of the population density of rodents, the expenses of forest cultivation would be rationalised, and at the same time, the damaging effects on the rest of forest fauna would decrease.

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MIŠOLIKI GLODAVCI I NJIHOVA ŠTETNOST U TUROPOLJSKOM LUGU I U DRUGIM HRVATSKIM ŠUMAMA

SAŽETAK

Mišoliki (sitni) glodavci pripadaju grupi biotskih čimbenika koji utječu na kakvoću prirodne i umjetne obnove šumskih sastojina, te na proizvodnju mladih biljaka u rasadnicima. Redovito žive u šumama gdje stalno čine sitnu štetu na šumskom sjemenu i mladim biljkama. U godinama kada se prenamnože, šteta može znatno porasti i nanijeti šumskom gospodarstvu velike gubitke. Mišoliki glodavci čine štetu u svim tipovima šuma. U Hrvatskoj je najveća šteta od njih zabilježena u nizinskim šumama hrasta lužnjaka. Ovi sisavci često imaju odlučujuću ulogu u produkciji klijavo sposobnoga sjemena hrasta lužnjaka. Štetno djelovanje osobito im je naglašeno u godinama smanjena uroda žira. Negativni učinak još im je izraženiji ako su štetu počinili na sjemenu i sadnicama kojima su obnovljene šume zahvaćene sušenjem. U nekoliko mjeseci mogu biti izgubljena znatna materijalna sredstva koja je šumarska operativa uložila u obnovu posušenih sastojina (troškovi skupljanja šumskoga sjemena, troškovi proizvodnje sadnica u rasadnicima, troškovi pošumlja-

vanja i zaštite mladih biljaka) ako se na tim terenima glodavci prenamnože. Šumarska je znanost u mogućnosti umanjiti štetu od njih primjenom različitih posrednih ili neposrednih metoda (uzgojni radovi, te mehaničke, kemijske i biološke metode suzbijanja) namijenjenih redukciji njihovih prenamnoženih populacija. Cilj je stvoriti bolje preduvjete za prirodnu ili umjetnu obnovu šumskih sastojina. Uspješno suzbijanje povećane populacije mišolikih glodavaca nemoguće je bez dobroga poznavanja njihovih morfoloških i fizioloških osobina, kao i ekoloških čimbenika koji u manjem ili većem stupnju utječu na dinamiku njihove populacije. Nestručno izvedena deratizacija može izazvati negativne posljedice za šumski ekosustav i životinjske vrste koje obitavaju u njemu, a nisu cilj suzbijanja. Praćenje dinamike populacije mišolikih glodavaca veoma je važno za uspješno provođenje mjera i metoda suvremene zaštite šuma. Detaljna istraživanja ovih sisavaca u hrvatskom šumarstvu dosada nisu rađena.

Utvrđivanje brojnosti mišolikih glodavaca i intenziteta štete koju uzrokuju na šumskom sjemenu i mladim biljkama obavljeno je u šumama GJ Turopoljski lug kojom gospodari JP "Hrvatske šume" (Uprava šuma Zagreb, Šumarija Velika Gorica). Gospodarska se jedinica ubraja u šumskogospodarsko područje jednodobnih šuma, a nalazi se 30-ak kilometara jugoistočno od Zagreba. Površina gospodarske jedinice je 4333,6 ha. Na ovom području prevladava nizinski reljef. Hidrološke prilike koje vladaju u GJ Turopoljski lug vrlo su važne za uspijevanje hidrofita, ponajprije hrasta lužnjaka (*Quercus robur*), poljskoga jasena (*Fraxinus angustifolia*), crne johe (*Alnus glutinosa*), domaćih topola (*Populus* spp.) i vrba (*Salix* spp.). Fitocenološka istraživanja šumske vegetacije Turopoljskoga luga pokazala su da u normalnim prilikama ove sastojine imaju svojstva, sastav i strukturu tipičnih nizinskih šumskih ekosustava Pokuplja i Posavine. Glavne su šumske zajednice: šuma hrasta lužnjaka i običnoga graba (*Carpino betuli-Quercetum roboris* /Anić 1959/ emend. Rauš 1969), šuma hrasta lužnjaka i velike žutilovke (*Genisto elatae-Quercetum roboris* Ht. 1938) i šuma poljskoga jasena s kasnim drijemovcem (*Leucoio-Fraxinetum parvifoliae* Glav. 1959), dok šumska zajednica crne johe s trušljikom (*Frangulo-Alnetum glutinosae* Rauš 1968) zauzima tek nekoliko hektara.

U sklopu istraživanja gustoće populacije mišolikih glodavaca u radu su iznesени opći podaci o njihovim biološkim osobinama (razmnožavanje, uloga osjetila i prehrana). Na povećanje brojnosti ovih sisavaca utječe veći broj čimbenika koji su podijeljeni u četiri osnovne grupe:

1. brojnost i fiziološko stanje populacije (dob populacije, odnos spolova u populaciji, stupanj nataliteta i mortaliteta i sl.)
2. obilježja podneblja (temperatura i vlažnost zraka, vjetar, količina i raspored oborina)
3. stanište i izvori hrane (zakorovljenost staništa, količina i vrsta hrane)
4. prirodni neprijatelji i bolesti (brojnost i vrsta predatora, prisutnost zaraznih bolesti kao čimbenici reguliranja populacije mišolikih glodavaca).

Mišoliki glodavci stalan su izvor različitih zoonoza (tularemija, leptospiroza, kuga, bjesnoća, hemoragična groznica i dr.), a pri povećanoj brojnosti mogu ih pre-

nijeti na čovjeka, te domaće i divlje životinje. Praćenje brojnosti populacije mišolikih glodavaca, te suzbijanje povećane im brojnosti važna je mjera u zaštiti ljudskoga zdravlja i suzbijanju bolesti drugih životinja.

Šume GJ Turopoljski lug nastanjuje više vrsta mišolikih glodavaca (porodica Muridae) koje pripadaju dvjema potporodicama: miševima (Murinae) i voluharicama (Arvicolinae). Iz potporodice Murinae prisutne su tri vrste:

1. *Apodemus flavicollis* (Melchior 1834) – žutogrli šumski miš
2. *Apodemus sylvaticus* (Linneus 1758) – šumski miš
3. *Apodemus agrarius* (Pallas 1771) – poljski miš.

Iz potporodice Arvicolinae prisutne su ove vrste:

1. *Clethrionomys glareolus* (Schreber 1780) – šumska voluharica
2. *Arvicola terrestris* (Linnaeus 1758) – vodeni voluhar
3. *Microtus arvalis* (Pallas 1779) – poljska voluharica
4. *Microtus agrestis* (Linnaeus 1761) – livadna voluharica
5. *Microtus subterraneus* (de Selys-Longchamps 1836) – podzemni voluharić
6. *Microtus multiplex* (Fatio 1905) – alpski voluharić.

Šumske površine pružaju mišolikim glodavcima obilan izvor hrane, povoljne uvjete za razmnožavanje i prezimljavanje, te zaštitu od prirodnih neprijatelja. Osobito im pogoduju šumski tereni bogati prizemnom vegetacijom, te šume koje graniče s poljima i livadama s kojih glodavci u jesen migriraju u granične sastojine. Miševi i voluharice čine štetu u šumi hraneći se šumskim sjemenom, te glodanjem kore i korijenja mladih biljaka. Kao štetnici šumskoga sjemena osobito se ističu miševi (potporodica Murinae) koji mogu potpuno uništiti sjetvu u rasadnicima, ili onemogućiti prirodno pomlađivanje šumskih površina. Prema podacima Dijagnozno-prognozne službe Šumarskoga instituta u Jastrebarskome u razdoblju 1980–1994. godine najveća šteta od mišolikih glodavaca zabilježena je 1994. godine na 3947,51 ha, dok je znatna šteta zabilježena i 1989. godine (2905 ha), 1990. godine (2596,1 ha) i 1993. godine (2293,87 ha). Veličinu štete u hrvatskim šumama u 1995. godini osobno sam istražio provođenjem anketnoga ispitivanja u svim upravama šuma JP "Hrvatske šume". Iz rezultata istraživanja izlazi da je šteta od mišolikih glodavaca u 1995. godini zabilježena na 3794,8 ha. Najveća je šteta bila na području Uprave šuma Vinkovci (1359 ha). Šteta je većinom počinjena u jesen, zimi, te u rano proljeće. Dob oštećenih sastojina je različita i kreće se od jedne do 130 godina, ovisno o tome jesu li oštećenja zabilježena na mladim biljkama (dob do deset godina), ili na šumskom sjemenu (dob je sastojine najčešće iznad 70 godina). Tijekom 1995. godine brojnost mišolikih glodavaca bila je određena samo u UŠ Vinkovci, UŠ Bjelovar, UŠ Požega, UŠ Sisak, te dijelom u UŠ Koprivnica (Šumarija Đurđevac). Te godine u šumama u Hrvatskoj njihovo je suzbijanje najčešće obavljeno kemijskom metodom primjenom preparata "Faciron" i "Brodilon". Provedena deratizacija u većini uprava šuma rezultirala je smanjenjem štete u šumama, npr. u UŠ Sisak, gdje je nakon provedenoga suzbijanja glodavaca šteta od njih smanjena 80 %.

Primijenjene metode tijekom istraživanja podijeljene su u pet grupa:

a) terenske metode utvrđivanja brojnosti i uzorkovanja glodavaca

1. modificirana metoda minimalnoga kvadrata s mrtvolovkama (Zejda & Holišova 1971, Pelikan 1971)

2. "Y" metoda (Kirkland et al. 1990, Kirkland & Sheppard 1994, Zukal & Gaisler 1992)

3. linearni transekt (Androić et al. 1981)

b) terenske metode utvrđivanja intenziteta oštećenja

1. skupljanje otpaloga žira

2. analiza oštećenosti šumskih sadnica

c) laboratorijske metode

1. determinacija i obrada morfometrijskih osobina ulovljenih životinja

2. analiza skupljenoga žira

d) matematičke metode izračunavanja brojnosti mišolikih glodavaca

1. statistička metoda linearne regresije (Poole 1974)

2. metoda preračunavanja na jedinicu površine totalnim izlovom (Zukal & Gaisler 1992)

3. relativna brojnost

e) usporedba rezultata brojnosti mišolikih glodavaca izračunatih različitim metodama

1. t - test (Pranjić 1986).

Standardna metoda minimalnoga kvadrata sastoji se u utvrđivanju broja jedinki populacije skupljanih na definiranim lovnim mjestima površine od 1,44 ha. Izlov životinja pomoću mrtvolovki traje pet noći. Za uspješnost metode važno je da su uvjeti lova isti, tj. da sve jadinke u populaciji imaju jednake izglede da budu ulovljene, da su u vrijeme izlova odstupanja mortaliteta neznatna, da nema imigracija i emigracija jedinki u razdoblju lova, te da su vremenski uvjeti tijekom izlova približno isti. U razdoblju istraživanja od travnja 1995. godine do studenoga 1996. godine lovni je kvadrat aktiviran četiri puta (u travnju 1995. godine, te u svibnju, srpnju i listopadu 1996. godine) u šumskoj zajednici hrasta lužnjaka i običnoga graba (*Carpino betuli-Quercetum roboris*).

"Y" metoda temelji se na izlovljavanju sitnih terestričkih sisavaca pomoću lovnih posuda. Životinje se usmrćuju padom u lovnu posudu napunjenu vodom. Izlov se obavlja na plohi površine 0,735 ha postavljanjem deset lovnih posuda raspoređenih od središnje točke u tri smjera pod međusobnim kutom od 120° (oblik slova "Y") na međusobnom razmaku od 5 m (Zukal & Gaisler 1992, Kirkland & Sheppard 1994). Između lovnih posuda postavlja se pregrada (najčešće traka od PVC visine 25–30 cm). Za ovu metodu postavljene su na terenu dvije pokusne plohe u šumskoj zajednici *Carpino betuli-Quercetum roboris* na međusobnoj udaljenosti većoj od 100 m kako bi se izbjegao ulov životinja s različitih ploha. Izlov životinja trajao je pet noći. Gustoća populacije mišolikih glodavaca "Y" metodom utvrđivana je tijekom istraživanja tri puta (u travnju 1995. godine, te u svibnju i listopadu 1996. godine).

Metodom linearnoga transekta moguće je u kratkom vremenu odrediti približnu (relativnu) brojnost glodavaca na većem području. Na odabranom pravcu postavljaju se mrtvolovke na međusobnom razmaku od 5 m. Lov životinja traje jednu noć. Brojnost mišolikih glodavaca izražava se postotkom ulovljenih životinja u odnosu na ukupan broj postavljenih klopki. Ako ulov iznosi 1–2 %, brojnost populacije je niska; ako je ulov do 10 %, brojnost glodavaca je umjerena; kod ulova od 30 do 60 % brojnost je životinja povećana, dok ulov veći od 80 % znači da je nastupila masovna pojava (Androić i dr. 1981). Suzbijanje je potrebno ako je brojnost životinja na terenu povećana.

Među ulovljenim životinjama determinirane su ove vrste mišolikih glodavaca: *Apodemus flavicollis*, *Apodemus sylvaticus*, *Apodemus agrarius*, *Clethrionomys glareolus*, *Microtus arvalis* i *Microtus agrestis*. Dinamika ulova životinja ovisi o utjecaju temperature i oborina. Prativši međusobni utjecaj tih parametara, utvrđeno je da je većina glodavaca ulovljena u kišnom razdoblju ili neposredno prije njega kada je aktivnost jedinki pojačana (slike 6–8). Metodom linearne regresije izračunata je brojnost glodavaca na lovnom kvadratu za svaku sezonu izlova. Najmanja brojnost glodavaca ovom metodom utvrđena je u svibnju 1996. godine, a najveća u listopadu iste godine (tablica 5). Slični rezultati dobiveni su i "Y" metodom (tablica 7). Usporedivši t-testom rezultate brojnosti glodavaca dobivenih "Y" metodom i metodom linearne regresije (tablica 8), zaključeno je, uz granicu pouzdanosti od 95 %, da među njima ne postoji signifikantna razlika. Dominantna vrsta na lovnom kvadratu i na oba "Y"-a bio je žutogrli šumski miš (*Apodemus flavicollis*). Metodom linearnoga transekta utvrđena je niska do umjerena relativna brojnost mišolikih glodavaca, te je zaključeno da ih u razdoblju istraživanja nije bilo potrebno suzbijati. Analiza odnosa broja ulovljenih životinja i determiniranih vrsta, u usporedbi s ostalim primijenjenim metodama, pokazuje da je kod ove metode ulov jedinki u jednoj noći nedostatan za potpuno upoznavanje sastava zajednice mišolikih glodavaca koje obitavaju na istraživanom terenu.

Utvrđivanje intenziteta oštećenja na sjemenu i mladim biljkama jedna je od posrednih metoda definiranja brojnosti populacije mišolikih glodavaca. Analizirajući oštećenost žira hrasta lužnjaka od ovih sisavaca, zaključeno je da oni najčešće oštećuju zdravi, neoštećeni žir (slika 4). Većina oštećenja zabilježena je u bazalnom dijelu sjemena (slika 3). Pri prvom pregledu oštećenosti mladih biljaka od mišolikih glodavaca u svibnju 1996. godine utvrđene su u donjim dijelovima biljaka grizotine starijega datuma i različita intenziteta. Prema boji oglodanoga mjesta zaključeno je da je šteta nastala u jesen 1994. godine i tijekom zime 1994/95. godine. Velika je šteta (slika 5) pokazatelj da je brojnost populacije glodavaca u to vrijeme bila velika, te ih je tada bilo potrebno suzbijati. Daljnjim praćenjem dinamike nastanka štete (do studenoga 1996. godine) nova su oštećenja zabilježena samo na 1,86 % biljaka. Iz tih rezultata izlazi da je u razdoblju istraživanja brojnost glodavaca u Turopoljskom lugu bila vrlo mala.

Ekonomski je opravdano samo ono suzbijanje mišolikih glodavaca koje se provodi prije početka njihova masovnoga razmnožavanja. Suzbijanje poduzeto u vrije-

me kada populacija dostigne svoj maksimum ili prije sloma kalamiteta redovito će promašiti svoj cilj (Vajda 1974). Financijska su sredstva koja se izdvajaju za kemijsko suzbijanje mišolikih glodavaca u hrvatskim šumama velika, a ima primjera da se često troše i u situacijama kad to nije potrebno. Redovitim praćenjem brojnosti mišolikih glodavaca u svim upravama šuma JP "Hrvatske šume" racionalizirali bi se troškovi uzgajanja šuma, a ujedno bi se time smanjili i štetni utjecaji na ostalu šumsku faunu.

Ključne riječi: nizinske šume, mišoliki glodavci, brojnost populacije, šumsko sjeme, šumske sadnice, obnova šuma

A. Meštrović: The Growth of Bosnian Pine (*Pinus heldreichii* Christ) in Herzegovina.
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Izvorni znanstveni članak

THE GROWTH OF BOSNIAN PINE (*Pinus heldreichii* Christ) IN HERZEGOVINA

USPIJEVANJE MUNIKE (*Pinus heldreichii* Christ) U HERCEGOVINI

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Stands of Bosnian pine on the mountain Čvrsnica in Herzegovina are pure natural stands with distinctive protective, social, pioneering and productive functions. Bosnian pine is an endemic tree species and a relict from the Tertiary period, preserved in the Balkans and in the southern part of the Apennine peninsula from the glaciation period. It grows naturally over a small, broken, and limited area, to which very few artificial additions have been made. Past research on these stands has mostly been concerned with their floral and geographical aspects, the study of soil, and the survey of plant communities featuring the Bosnian pine, while research on structural and taxative elements in the stands of Bosnian pine has been almost negligible. The current production capacity, forest soil potential, age and increment were assessed on the basis of recorded management elements and descriptions in the existing stands of Bosnian pine. The processes of natural regeneration in these stands should be adapted to the actual conditions in the stands, as well as to the condition of the soil, natural regeneration and rotation period. Bosnian pine on Čvrsnica in Herzegovina grows on a terrain characterised by harsh conditions and the poor productive capacity of the soil. In such conditions, it plays a multiple role: not only is it a pioneering species, but it also protects the soil, creates suitable conditions for the arrival of other tree species, and gives an attractive appearance to the landscape. Productive capabilities on Mount Čvrsnica are lower than those in other parts where this tree occurs, but are still satisfactory in the light of the given conditions.

Key words: *Pinus heldreichii* Christ, tertiary relict, endemic species, biological properties, site class, young growth, tree growth and increment, stand growth and increment, production.

INTRODUCTION
UVOD

Bosnian pine is a Tertiary relict preserved in the Balkan Peninsula during the glaciation period. This endemic tree species of a limited, broken and small natural distribution occurs in central and western parts of the Balkan Peninsula, and in the southern part of the Apennine peninsula. Forest stands of Bosnian pine occur fragmentarily in high mountains of Herzegovina, Montenegro, Kosovo, Macedonia, Albania, Bulgaria and Greece, while in southern Italy the species appears in separate groups. This leads to the conclusion that Bosnian pine is distributed over a sub-Mediterranean region, where its forest associations occur mostly at high altitudes (between 1,000 and 1,900, and sometimes over 2,200 m above sea level), and cover steep, arid slopes on a lime substrate. In this way, they often form the upper border of forest vegetation. The growth rate of Bosnian pine in stands is very slow. It occurs predominantly on limestone and dolomite, and less frequently in the zone where lime and dolomite substrates meet with serpentine or acid silicate substrates. In the former case, it covers extreme sites characterised by narrow ridges, steep slopes, prominent cliffs and ground slides, and sometimes it even occurs in flatter calcareous areas. On such shallow, stony soils of a mostly humus type, stands of Bosnian pine represent a permanent stage of vegetation. As it is not threatened by other forest tree species, it is practically the only species to be used in reforesting such arid, water-less areas. The stands often have inconsistent, broken and open canopies. More comprehensive complexes are only found in relatively more favourable site conditions (Stefanović 1977). In spite of their very limited distribution range, Bosnian pine forests are very important for many reasons: for example, they represent a rarity in the forest vegetation, and have a very important role in preventing erosion. The excellent technical properties of Bosnian pinewood make these forests economically valuable, too. Bosnian pine is also known to be a distinctly pioneering tree species. For this reason, it plays a very important role in the dynamics of vegetation, particularly in progressive succession (Fukarek 1966). As a tree species, it contributes significantly to the rich dendroflora of Herzegovina. There have been a number of papers and studies about the Bosnian pine, but most have treated it only partially. Therefore, in order to study this tree in full detail, future research should adopt a more comprehensive approach.

The goal of this research is to provide further insights into some productive characteristics of pure Bosnian pine stands in Herzegovina. The following steps have been taken: Bosnian pine stands in Herzegovina have been located, their ecological conditions studied, the biological properties of Bosnian pine examined, the development and increment of the tree and stands studied, and Bosnian pine productive capacity assessed in given ecological conditions. The study of some taxative elements, believed to be good indicators of the productive capacity of Bosnian pine forests, has been carried out. The research was carried out on the mountain of

Čvrsnica, where one of the largest complexes of pure stands of Bosnian pine in Herzegovina occurs.

RESEARCH SO FAR
DOSADAŠNJA ISTRAŽIVANJA

In the middle of the 19th century, Theodor Heldreich, a Greek botanist, found a new species of pine while studying the flora on the mountain Olympus in Greece. The new species seemed to him to resemble the species *Pinus maritima* Ait., and so he sent a twig under this name to Edmond Boisser, a botanist in Geneva. The twig remained in a herbarium until it came into the hands of a Swiss botanist Herman Christ, who was at that time preparing a monograph on European pines. On the basis of this twig, H. Christ described a new, previously unknown pine species, which he called *Pinus heldreichii* Christ 1863.

At that same time, a well-known collector Franjo Maly found a large number of related pine species on the mountain Orjen (the border of Austrian Dalmatia and Turkish Bosnia of the time), and took ample material to Vienna. He gave the collected material to the botanist Antoine Franjo, who was also preparing a monograph on European pines. After studying this rich material, F. Antoine concluded that it was a specific pine, so he made a comprehensive and detailed description illustrated with a number of original photographs, and called the species *Pinus leucodermis* Antoine 1864 & Fukarek 1979. After some time, the botanist Christ 1867 realised that the "new" species *Pinus leucodermis* Antoine was in fact the species from the mountain Olympus, and suggested that it might be its "young form". He changed its name into *Pinus laricio* var. *leucodermis* (Ant.). This should be pointed out, because by doing so, Christ himself renounced his earlier described "species", which he, on the basis of some morphological similarities with the black pine, added to the varieties of the species *P. laricio* Poiret Fukarek 1979. After that, whenever new sites of white-bark pine were found, they were named *Pinus leucodermis* Antoine by most botanists. *Pinus heldreichii* Christ was considered a special species, or its name was attributed as a synonym to the species *P. leucodermis* Antoine. A detailed description of the species *P. leucodermis* Ant. appears in the first edition of a classic handbook on conifers by Beissner in 1891, but a separate description of the species *P. heldreichii* Christ also appears in a footnote. Among the first to point out the identity of *P. heldreichii* and *P. leucodermis* was the botanist Boissier in 1884, later joined by the botanists Adamović 1905 & Halacsi 1904, whose authority at the time was unquestionable. This belief was held until recently, when a connection between these two pine species was re-established, but depicted in a new manner. Particular merit goes to the botanist Hayek 1926, who, observing the rules of botanical nomenclature, used the name *P. heldreichii* Christ as the correct one. Since then, white-bark pine has been referred to as *P. heldreichii* Christ in most dendrological-botanical discussions. Had it been possible to unquestionably establish the identity between the species discovered by Heldreich and described by Christ, and the species discovered by

Maly and described by Antoine, there would have been no problems in their nomenclature. The name *P. heldreichii* Christ, as the older, would have been the only correct one. However, such complete identity between white-bark pine from the mountain Olympus and that from the mountain Orjent was again questioned by the botanist Markgraf 1931. Gaussen 1960 gave a new interpretation of white-bark pine as two independent species. As we see, there have been different opinions on the problems of variability and taxonomic affiliation of white-bark pine. The whole problem was well presented by Fukarek 1979. He suggested that Bosnian pine was the basic species, and that white-bark pine of hybrid character came into being by crossing *P. leucodermis* x *P. nigra*. With regard to the fact that white-bark pine is similar or identical to Bosnian pine, and that hybrids with black pine occur where their distribution areas overlap, the belief of Fukarek 1979 should be adopted, provided, as he himself says, that its validity is confirmed by further research. This tree species displays individual and group variability, which is manifested by its morphological and phenological characteristics, growth and the anatomical structure of needles (Stilinović & Tucović 1972, Tucović & Stilinović 1975, 1977, Popnikola 1975, 1978). Known varieties of Bosnian pine are: var. *leucodermis* (Ant.) Markgraf, var. *longiseminis* Papaioannou (1975b), var. *pančići* Fukarek (1951), var. *typica* Markgraf (1931) and spontaneous hybrids between *P. nigra* x *P. leucodermis* (Fukarek & Vidović 1965) occurring on the mountain Prenj, in the Rujište locality in Herzegovina. From the above, it follows that Bosnian pine has two taxons: var. *heldreichii* Christ (Syn. var. *typica* Markgr.) and var. *leucodermis* (Ant.) Markgr.

The majority of research on the Bosnian pine so far has dealt with plant-geographical research, the study of soil in its forests, the survey of plant communities in which it occurs, and similar studies. Little, or hardly any, attention at all has been paid to the structural and productive characteristics of Bosnian pine forests.

NATURAL DISTRIBUTION
PRIRODNA RASPROSTRANJENOST

Bosnian pine usually forms pure stands, but sometimes it is mixed with other conifers (Macedonian pine, black pine, fir) and deciduous trees (beech) in Mediterranean and sub-Mediterranean mountains of the Balkan Peninsula and south Italy. Beautiful small stands are found in the Bosnian mountains of Hranisava, Bjelašnica and Visočica, and in Herzegovina on the northern slopes of Čvrsnica, Čabulje, Prenj, Velež and Orijen-Štirovnik. In Montenegro and Kosovo, it occurs on Bijela Gora, Lovćen, Durmitor, Sinjajevina, Bjelasica, Maganik, Kamenik, Komovi, Koritnik, Žlijeb and on the slopes of the Prokletije range. In Macedonia, it is found on Galičica, Korab, Rudoka and a range of Šar-Planina. In Bulgaria, it occurs on Pirin and Slavjanka (Ali-Batuša). In Albania, it has the widest distribution from the north to the south of the country. In Greece, it occurs in the north, in Epirus, Macedonia and Tesalia on the mountains of Gramos, Tymphi, Pinda, Vermion, Olympus, and lower Olympus (Kato-Olympus). In south Italy, it is found in

Calabria and Brasilicata. On Bjelašnica near Hranisava, south-west of Sarajevo, at a distance of about 24 km as the crow flies and about 43° 44' 30" latitude and 18° 08' longitude east of Greenwich, there is the northernmost site of this pine on the Balkan Peninsula. Longo studied the occurrence of Bosnian pine (Markgraf 1931) in Italy; in 1905 he found the pine on Montes Fina near Lauria in Brasilicata and on Monte Pollino, and in 1906 on the line from Orso Marso all the way to Monte Mantea in Calabria. This is the southernmost point of its geographical distribution in Italy, located at an eastern latitude of about 39° 42' and a longitude of 15° 55'. According to Hoffman, Bosnian pine is present in the Apennines of Campagnia east of Naples. Its northernmost site in Italy is located at a latitude of 40° 43' to 40° 44', and a longitude of 2° 43' east of Monte Mario. In 1921, Stojanov announced the occurrence of Bosnian pine on South Orvil (Ali-Batuš) in Bulgaria in the eastern part of the Balkan Peninsula. A year later, Stefanov found it slightly more northward, on the northern-east slopes of the highest peak of Orvil (Pirin) at 41° 46' to 41° 50' latitude on Muller's map. In 1957, Papaioannou found the southernmost site of Bosnian pine distribution in Greece, at 41° 20' 30" latitude and 0° 06' 20" longitude east of Athens. Earlier, the distribution borders of Bosnian pine extended from the north to the south and from the east to the west. A disjunct distribution of Bosnian pine within the above-mentioned borders was established in more detail by numerous local studies. In the vertical distribution, it usually takes up a belt 1,000 – 1,900 m above sea level, but also occurs at lower altitudes (720 m) in Greece, and higher ones (2,500 m) on Olympus, also in Greece.

ARTIFICIAL DISTRIBUTION
UMJETNA RASPROSTRANJENOST

In order to extend the area of Bosnian pine distribution artificially, a careful study of its ecology, adaptive capacity to new sites, resistance, and other factors should be made. As Bosnian pine is a very important sub-Mediterranean tree species, it would be useful to present data on how this tree behaves outside its natural area, that is, in specific sites where it has been grown for shorter or longer periods in the form of larger or smaller forest cultures. The bio-ecology of Bosnian pine has been dealt with in detail by a number of scientists (Blečić 1959, Janković 1960, 1967, Blečić-Tatić 1960, Fukarek 1966). Bosnian pine is adapted to a short vegetation period, a dry and mountainous summer climate, and harsh winter conditions in high mountains. Knowledge gained by practical and scientific research so far has prompted foresters to use this species to reforest xerothermal sites, and sometimes even mesophyllic ones. About four to six decades ago the first smaller Bosnian pine cultures were established, which speaks of the interest at that time to introduce this tree species into areas outside its natural distribution range. These and similar undertakings enable us to follow the success of introducing the Bosnian pine into more or less unfavourable specific sites in the Balkan Peninsula. In the sites where Bosnian pine was artificially raised, a significantly slower growth rate of this spe-

cies was noted compared to that of black pine, which confirms the assumption that this species is characterised by slow growth at its young stage. Individual variability in artificial populations confirms the observations of other authors about the individual and group variability of this tree species in its natural populations. The presence of extreme changes in Bosnian pine cultures (dwarf growth, viviparity, and others) requires more detailed, comprehensive and experimental research on this species in its natural and artificial populations. The existence of 10 to 20 per cent better phenotypes in Bosnian pine populations analysed so far justifies their selection (mostly through multiple selection procedure) for further growth in lower sites. Therefore, it is reasonable to expect that this tree species will achieve much better results in the sites outside its natural distribution. This fact is very important for forestry, especially with regard to afforesting inhabited areas. Ample fructification of Bosnian pine in its lowest natural sites points to prospective benefits from raising vegetative and generative seed plantations in warmer sites outside its natural distribution range. In order to do so, detailed bio-ecological, genetic and other experimental research should be carried out. Bosnian pine is ideal for afforesting bare, stony, calcareous, water-less and karstic mountain regions in which black pine does not occur and where only Bosnian pine can form beautiful, well-developed trees. Bosnian pine is a tree species with the fewest requirements in Europe. Its wide ecological range enables it to grow at high altitudes in a belt of dwarf pine, where it reaches the border of forest vegetation. For this reason, Bosnian pine should be used to afforest high, bare mountainous regions in which other commonly used afforesting species are out of the question.

BOSNIAN PINE IN HERZEGOVINA
MUNIKA U HERCEGOVINI

GENERAL
OPĆENITO

Bosnian pine is distributed in the form of pure natural stands over high mountain ranges in Herzegovina. However, it often forms mixed stands with black and dwarf pine, and may also individually occur in mixed stands of beech and fir. The wide ecological amplitude of this tree species enables it to occur in a number of forest types, that is, to form a special alliance of *Pinion heldreichii* forests (Horvat 1946). This alliance represents a wide complex of phytocoenoses, of which Herzegovinian phytocoenoses is one of the basic groups. Several types of Bosnian pine forests from the group of Herzegovinian phytocoenoses growing naturally on the above mentioned mountains have been studied so far. Herzegovinian forests of Bosnian pine (*Pinetum heldreichii hercegovinicum* Horv. 1963) most commonly occur in the form of fragmented stands, where either individual trees or groups of trees are found within several phytocoenoses in high-mountainous swards or in associations of sub-Alpine beech and dwarf-pine pine forests. According to Fukarek

(1966), Bosnian pine forms the following phytocoenoses in this natural part of its distribution area:

a) *Amphoricarpo-Pinetum heldreichii* Fukarek 1966 inhabits narrow, exposed and extremely steep dolomite crests between 1,300 and 1,800 m above sea level. It is characterised by a number of endemic species, among which *Amphoricarpus neumameri*, *Thesium auricilatum* and *Hieracium villosum*, typical of xerophyllic and rocky phytocoenoses, are prominent.
b) *Senetio-Pinetum heldreichii* Fukarek 1966 occupies relatively more favourable sites. This association is also characterised by some endemic species, such as *Senetio vissianianus* and *Sesleria coerulans*.
c) *Pinetum-nigre-heldreichii* Fukarek 1966 covers border regions of black pine and Bosnian pine, where the natural hybridisation of these two species takes place. This is reflected in the morphological characteristics of both species in the phytocoenoses of black pine and Bosnian pine.
d) *Mugo-Pinetum-heldreichii* Fukarek 1966 inhabits higher altitudes of the sub-Alpine border area with dwarf pine, where a sub-Alpine form of Bosnian pine is represented in the phytocoenoses of dwarf and Bosnian pine.

In terms of geographical position, Bosnian pine in Herzegovina is naturally distributed between 43° 23' 00" northern latitude, or between 17° and 19° longitude east of Greenwich. Above a 4-square-kilometre-large glacial lake of Blidinje at an altitude of 1.183 m, there are pure natural stands of Bosnian pine extending in a north-east - south-west direction on the mountain of Čvrsnica, whose highest peak Pločno is situated 2,226 m above sea level. In this part of the natural range of Bosnian pine distribution, which is located at the edges of forests with neglected and abandoned mountain pastures and swards, this species expands by natural regeneration. There, young stands of Bosnian pine display a clear tendency to expand further into the areas previously covered by pastures. The basic reason for this phenomenon lies in the diminution of the number of cattle in the area, the movement of the local people into the foothills of Čvrsnica, and a general abandonment of nomadic-style cattle-breeding in Herzegovina.

SITES
NALAZIŠTA

More important complexes of pure Bosnian pine stands in Herzegovina are found on the mountains of Prenj (863 ha), Čvrsnica and Čabulja (472 ha), Velež and Nevesinje Crna Gora (105 ha), and Orjen-Štirovnik (76 ha). The stands of Bosnian pine in the westernmost and northernmost border of its natural distribution on Mountain Čvrsnica are excluded from forest management. This area of 340 ha within the management unit of Čvrsnica belongs to the karst commune of Posušje. Some pure stands of Bosnian pine in Herzegovina are located in the region of "Central Neretva", as well as in that of "Upper Neretva".

An important feature of these forests is a high percentage (over 50%) of the parent substrate (limestone), which significantly lessens the productive capacity of this tree species and these forests. According to the data from the forest-management basis, the total area under Bosnian pine in Bosnia and Herzegovina is 5,865 ha, which is only about 0.5% of the total surface area under high forests. Of this, 1,528 ha are taken by pure stands of Bosnian pine. Pure stands are those in which Bosnian pine is represented by 90 or more per cent in terms of wood volume. A more significant artificial distribution of forest cultures of Bosnian pine has not been recorded over larger areas in Herzegovina, except the sporadic planting of several dozen individual seedlings.

CLIMATE
KLIMA

The climate of a country depends to a great extent on its geographical position, the distance from the sea and orographic conditions. The area of natural distribution of the Bosnian pine falls within the sub-Mediterranean region, where this species mostly occupies the highest positions (between 1,000 and 1,900 m). The river valleys of the Neretva, with its tributaries the Drežnjanka, the Doljanka, the Rama and others, open this region to a warmer and more humid climate than that of the continental parts. Above this belt, the influence of a mountainous climate is felt as high as 1,500 m above sea level. The regions of a sub-Alpine belt with spruce and dwarf pine forests above this altitude have a typical harsh climate, which is characterised by very long winters and abundant snowfall. The features of the climate with a pronounced mountainous influence are reflected in sudden transitions from one season to another. Winters are usually long and rich with precipitation, especially snow, and summers are short and cool. There are early autumn and late spring frosts. Bosnian pine is naturally distributed on the border of the Mediterranean and continental climate, where air currents differ both in their strength and duration. It can, therefore, be concluded that the climatic conditions in the area of natural Bosnian pine distribution in Herzegovina are very heterogeneous, and that a continental-mountainous climate and a sub-Mediterranean climate of a cooler belt can be distinguished. As there are no meteorological stations in the stands of Bosnian pine, the data from the four closest stations were taken: Mostar, Konjic, Posušje and Tomislavgrad. A ten-year average from the period 1981 – 1990 was taken for the meteorological station of Mostar, and ten-year averages for the periods 1971 – 1980 were taken for those of Konjic, Posušje and Tomislavgrad.

AIR TEMPERATURE
TEMPERATURA ZRAKA

The mean annual air temperatures are between 9.1°C and 14.4°C However, if mean annual air temperatures are calculated with a thermal gradient for the belt at altitudes between 1,000 and 1,900 m, (in which adult natural Bosnian pine stands

grow), the mean annual air temperature is between -0.9°C and 5.4°C. From this, it can be concluded that natural stands of Bosnian pine in Herzegovina appear at annual air temperatures averaging between -0.9°C and 5.4°C. The lowest mean monthly temperature of -0.9°C occurs in January, while the highest of 24.6°C occurs in July. The mean monthly maximums and minimums are as follows: the mean monthly maximum in the warmest month (M) is between 23.7°C and 31.7°C, the mean monthly minimum in the coldest month (m) is between -3.3°C and 1.9°C, and the temperature deviation (M-m) is from 29.8°C to 26.4°C. The absolute annual temperature minimum varies greatly and ranges from -18.8°C to -8.8°C. The absolute annual temperature maximum differs less dramatically and ranges from 35.0°C to 41.2°C. Bosnian pine is greatly affected by the number of icy days with temperatures below -10°C. If several such days occur in a row, this tree species will die. These data allow us to conclude that Bosnian pine is a very plastic pine species as regards air temperature.

PRECIPITATION
OBORINE

According to data, the mean annual precipitation quantity in the stands of natural Bosnian pine distribution in Herzegovina is between 1,279 mm and 1,553 mm. The lowest mean monthly precipitation of 10 mm was recorded in August, while the highest of 352 mm was recorded in November. The most important factor for the growth of Bosnian pine is the pattern of precipitation over seasons. According to the available data, the seasonal arrangement of precipitation is unfavourable, which has a damaging effect on the development of the species, particularly in the summer period (July - August). The least rainfall, between 46 mm and 49 mm, occurs in the summer season, which is 15.3 mm, or 16.3 mm on average per month. According to the data for the meteorological station which has the highest annual precipitation quantity (1,553mm), spring accounts for 23.5%, summer for 8.9%, autumn for 38.1% and winter for 29.5% of the total precipitation quantity. The whole growing season receives only 36.7% of rainfall. With temperatures over 5°C, or 10°C, the season lasts 305 or 205 days a year. The data for the meteorological station which has the smallest precipitation quantity a year (1,279mm) show that precipitation is distributed as follows: 29.4% occurs in the spring, 11.4% in the summer, 28.6% in the autumn, and 30.6% in the winter. The vegetation period, lasting for 324, or 223 days in a year, and having average temperatures of 5°C or 10°C, receives slightly more rainfall (40.3%). The number of rainy days ranges between 107 and 122. The number of snowy days, which is between 12 and 29, is much more important. The height of snow on the ground ranges from 2 cm to 110 cm. Heavy, wet snow is especially harmful for the tops of Bosnian pines. It can be concluded from the above that natural stands of Bosnian pine grow well in those areas where an abundant quantity of humidity from air and precipitation is available.

WINDS
VJETROVI

The region in Herzegovina where Bosnian pine grows naturally is rather windy. Strong winds mostly occur outside the growing season. These include northerly, north-westerly, north-easterly and south-westerly winds. Northerly winds blow mostly in winter and spring, while southerly ones occur in summer and autumn. The region is dominated by a north-easterly wind (buran), typical for the karst area in general. Dominant and important winds of a northerly direction blow with an incidence of 43%, while winds of a southerly direction blow with an incidence intensity of 20%. The studied area is characterised by the fact that the total number of windless days in a year is 25%, and the total number of windy days is 75%. The impact of the buran is of decisive importance for the growth of forests in this region. This impact is mainly reflected in its detrimental mechanical action involving the drying of the atmosphere and the soil.

SOIL
TLO

The diversity of soil types is closely connected with the kind of geological substrate. The sites in which the complexes of pure natural stands of Bosnian pine occur are geologically built of younger lime and dolomite rocks of the Cretaceous period and in higher regions of lime and dolomite rocks with distinct karst landforms of the Triassic and Jurassic period. The soil complexes on limestone and dolomite are most frequently represented on the parent substrate of these rocks. Black soil (humus) occurs most frequently on steep slopes, brown calcareous soil on milder slopes and inclinations, while illimerised soil is found at the foothills and in funnel-shaped holes. The most represented soils are as follows: a class of immature soils (A)-C, profile-type lithosol (rock material), a class of humus-accumulative soils A-C, profile-type calco-melanosol (calcareous-dolomite humus and rendzina), a class of cambic soils A-(B)-C, profile-type calco-cambisol (brown soil on limestone and dolomite), and a class of eluvial-illuvial soils A-E-B-C, profile-type luvisol (illimerised soil). The soils in the chosen experimental plots are developed on two basic geological substrates - limestone and dolomite - and have different typological properties. Apart from the differences resulting from the role of the parent substrate in the soil formation, the soils developed on the limestone have more typological characteristics due to a more pronounced karst phenomenon. An evolutionary soil series has been recorded on limestone, ranging from shallow black soil, to medium-deep brown soil, to deep illimirised soil. With the last, the geological substrate is deep and outside a physiologically active profile (funnel-shaped-holes). Rendzina, with its series of shallow, less skeletal soils in the profile and no stone blocks on the soil surface, (a particular characteristic of a karst region), has developed on the dolomite substrate.

SOIL TYPE CHARACTERISATION
KARAKTERIZACIJA TIPOVA TALA

Rendzinas on dolomite are found in Plot 3 (Orlov Kuk) and are represented by the profile Orlov Kuk 3. These are predominantly shallow soils. By their mechanical structure, they are sandy clays, that is, skeletal sandy clayey loams. In these soils the skeletal part is calcareous. The quantity of free carbon is over 50%, and the soil reaction is alkaline. The surface horizon has a very high humus content, and the transitional horizon still contains enough humus. The participation of nitrogen in the soils is almost analogous with the humus content, and the C:N ratio is favourable. In terms of physiologically active nutrients, these soils have a poor to medium supply of K_2O, and a poor supply of physiologically active P_2O_5. Therefore, the nutritive values of these soils on dolomite (rendzina) are lower than those of black soils (humus) on limestone. Humus on limestone occurs in Plot 2 (Kraljeva Kleka) and is represented by the profile Kraljeva Kleka 2. These are shallow and distinctly skeletal soils. On the profile of the soil, a 5cm - thick subhorizon A is clearly visible, made up of pine needles in various degrees of decomposition. The soil profile is airy and porous due to high amounts of the skeletal factor. However, the soil residue is porous and well drained due to a stable crumbly-granular structure, although by its structure it is clay. The soil reaction is neutral. Apart from this, black soils on limestone contain a high percentage of free carbons due to large amounts of tiny skeletal particles. The mentioned soils are well supplied with K_20, but poorly supplied with P_2O_5, They have a medium to high humus factor. Brown soils on limestone are found in Plot 1 (Šestiver) and are represented by the profile Šestiver 1. The surface horizons of these soils are similar to the shallow soils in the respective plots described above, but with less humus, apart from the specially excluded subhorizon A_0A_1 in the profile Šestiver 2. The deeper horizons of the mentioned soils are light clays with a well-defined granular-crumbly structure. The soil reaction is slightly acidic, there are no free carbons, and the C:N ratio is favourable, as is the case with most such soils. Like rendzinas and humus, these soils are also well supplied with physiologically active potassium, and poorly supplied with phosphorus.

BIOLOGICAL PROPERTIES
BIOLOŠKA SVOJSTVA

Bosnian pine is a monoecius, anemophilous, heliophytic, calcific tree species. However, it can also develop on the silicate substrate in secondary sites in areas where the calcareous and silicate parent substrates meet. It blossoms in May and June, depending on the altitude, propagates with seeds, and commonly inhabits the steep, stony and rocky terrain of the sub-Alpine belt, where it has no competition. It forms pure or mixed stands with other coniferous and deciduous trees. In terms of general distribution, Bosnian pine is an endemic species of the central and western part of the Balkan Peninsula and the southern part of the Apennine peninsula.

REPRODUCTION
POMLAĐIVANJE

Bosnian pine reproduces naturally only with seeds. Artificial methods of reproduction, apart from sowing seeds, are not known. Several attempts at vegetative propagation have not been successful, although this method of propagating this species would be very important in general, as it would greatly ease the selection of individuals with higher yields, a faster increment, larger dimensions, and other factors. Vegetative propagation in Herzegovina and other areas has not yet been put into practice. Bosnian pine growing in stands begins bearing seed after the age of 40, and that growing in isolated spots much earlier. Crop years occur every 2 to 3 years.

ADAPTABILITY
ADAPTIVNOST

An extremely important property of every tree is its ability to adapt to various living and growing conditions. Bosnian pine in Herzegovina occurs naturally in isolated areas as a Tertiary relict and as an endemic tree species. So far, it has not been introduced into cultures on a large scale. In the ecological conditions reigning in the sub-Mediterranean region and the region of high mountains, Bosnian pine has found its place on steep stony or rocky terrain of the sub-Alpine belt, where it has no competition. It has adapted well to the soils developed both on limestone and dolomite (primary sites), and to a drier climate (with less air humidity and precipitation). Bosnian pine also occurs on a serpentine and silicate substrate, where the climate is slightly more favourable (secondary sites), and at meeting points of limestone and dolomite substrates. In relation to temperature, Bosnian pine has wide amplitude, because it tolerates both winter lows and summer highs. It has very modest requirements in terms of soil and soil humidity. It succeeds naturally on sun-exposed sites, where the soil is usually immature, the parent rock comes to surface, and the growing period is marked by arid conditions. The primary site of Bosnian pine is in the sub-Alpine region, most commonly on a carbonate substrate. Due to its modest humidity requirements, this pine is capable of forming stable stands despite adverse conditions. As a distinctly calcific species, it can also grow in sites with a silicate substrate, in a meeting zone with calcareous or dolomite parent substrate, provided that there is no competition from other, faster-growing tree species, since Bosnian pine grows very slowly, especially at the early age. Such conditions usually occur when the primary forest vegetation growing at lower altitudes or on sun-exposed slopes is suppressed by a fire or clearcutting. Bosnian pine appears there as a pioneering tree species. Its forests are then in the secondary site and represent the first stage of progressive succession. They are more productive, but their survival depends on adequate management procedures, which should be adapted to the bio-ecology of this tree species. In its primary site, Bosnian pine grows well and regenerates naturally. In all stands in Herzegovina, there is natural young growth whose quality is conditioned by the space and light in the parent

stand, and by the size of the mountain clearings immediately adjacent to the parent stands of Bosnian pine.

WORKING METHODS
METODA RADA

To study the growth and productive capacity of Bosnian pine forests in Herzegovina, a control method was used for assessing increment and production. A method of tree analysis was used for monitoring tree growth and production. The control method requires a longer measuring period if reliable results are needed.

The volume and volume increment of Bosnian pine stands is expressed in m^3 of the total timber mass (with small branches). Böhmerle's tables for black pine were used to calculate the volume (Grunder - Schwappach 1952). Böhmerle's tables show the timber mass in so-called large timber (over 7 cm at the thinner end) including branch material. By using this percentage, the timber mass of large trees was converted into the so-called total timber mass and then equalised. The results were then compared with the volume tables for total timber mass according to Drinić & Prolić 1979. The data from these tables provide mean values of site quality classes for Bosnian pine in Herzegovina. These tables proved to be very reliable.

In order to evaluate the possible extent of cutting in experimental plots, trial tree marking was conducted. The trees were marked according to the silvicultural principles of productive continuity. The trees were classified using the silvicultural-technical criteria of classifying common and black pine (Matić 1971). To ensure successful natural regeneration in Bosnian pine stands, a system of shelterwood cutting in very small groups and with a long regeneration period is recommended. This recommendation is realistic and justified in view of the fact that the site conditions of Bosnian pine are very poor. This tree is a distinctly heliophytic species whose stands have typical multi-layered, and even step-like canopies.

To determine the degree of canopy cover, the length of the line covered by the tree crowns above the taxative limits in experimental plot diagonals was measured. The relation between the length of the covered lines and the total length of diagonals in an experimental plot represents the degree of canopy cover in a corresponding experimental plot.

The number of seedlings (young trees below the taxative limit) was studied in randomly arranged experimental circles with a diameter of 17.84 m (area 250 m^2). The number of young trees was classified according to tree species, and within the species according to growth classes.

CHOICE OF EXPERIMENTAL PLOTS
IZBOR POKUSNIH PLOHA

Since Bosnian pine is distributed naturally on the mountains of Herzegovina, the initial decision was to focus on the mountains of Prenj, Čabulja and Čvrsnica.

However, the initial decision had to be abandoned owing to a multitude of mines left over from the war, or due to the inaccessibility of some areas. This made the choice of experimental plots more difficult, and so they were set up in the following localities of Bosnian pine on the northern slopes of Čvrsnica which gravitate towards Blidinje Lake:

1. Šestiver (Čvrsnica), compartment 23a - experimental plot No.1.
2. Kraljeve Kleke (Čvrsnica), compartment 22 - experimental plot No. 2.
3. Orlov Kuk (Čvrsnica), compartment 18a - experimental plot No. 3.

Experimental plots were set up in the area of the Management Unit Čvrsnica (one part). All plots were rectangular and 1 ha in size, placed over sloping terrain, with a longer side parallel to isohypsometric line. All experimental plots in the field were marked with a red horizontal line on the border trees at a breast height of 1.30 m. One experimental plot was placed in a stand of black pine on the mountain of Čvrsnica, the aim being to compare the results for Bosnian pine with those for black pine (*Pinus nigra* var. *ilirica* Vidaković). The basic characteristics of the studied stands are shown in Table 1. acteristics of the studied stands are shown in Table 1.

Table 1. The location and size of studied stands
Tablica 1. Položaj i veličina pokusnih ploha

Compartment *Odjel*	Size *Površina* (ha)	Size of exp. plot *Površina pok. plohe* (ha)	Altitude *Nadm. visina* (m)	Exposition *Izloženost*	Inclination *Nagib* (°)
23a	91.0	1.0	1,460-1,500	N-NW	35°
22b	24.0	1.0	1,360-1,400	NW	40°
18a	30.0	1.0	1,270-1,300	N	20°
26a	39.0	1.0	1,280-1,310	W-NW	25°

TREE MENSURATION
IZMJERA STABALA

The trees in every experimental plot were measured at breast height (1.30 m above the ground) with a calliper of 1cm accuracy and a taxation limit of 5 cm, which means that all the trees in the plots with a breast diameter of 5 or more cm were measured. In order to measure the diameter increment, samples (increment cores) were taken in each of the experimental plots with a Pressler increment borer. Increment cores were always taken from the right side of a measured breast diameter. The length of the core (annual ring width) has been measured for the last 10 years to an accuracy of 0.5 mm. The double value of the core length represents the current periodic (ten-year) diameter increment. The heights of several trees were also measured in order to construct a height curve for each experimental plot. The height of trees was measured with the Blume-Leiss hypsometer with an

accuracy of 0.5 m. A sample of the tree best representing the mean stand tree in terms of diameter and height was taken for each of the plots for tree analysis.

DATA ANALYSIS
OBRADA PODATAKA

TIMBER MASS CALCULATION
IZRAČUN VOLUMENA

Timber mass was calculated in the following manner: curves were constructed using the measured tree heights in order to obtain the mean heights for certain tree diameters. With the obtained mean heights, and the use of tables for the black pine (Bohmerle 1893), a tariff was constructed for each experimental plot. The tariffs were equalised with a line. The timber mass in experimental plots was obtained by multiplying the tariffs with the number of trees. For easier presentation and tabling, the calculation based on diameter degrees of 5 cm with a taxative limit of 5 cm was shown. Indicators on the number of trees, basal area and timber mass for all experimental plots are shown in Tables 2 and 3.

CALCULATING INCREMENT AND PRODUCTION
IZRAČUN PRIRASTA I PRODUKCIJE

Increment and production for the stands in experimental plots were calculated using the control method on the basis of two measurements conducted in all existing experimental plots over 15 years. The results of increment and production in experimental plots are shown in Table 4.

Table 4. Increment and production per hectare
Tablica 4. Prirast i proizvodnja po hektaru

No of plot *Broj plohe*	Age from - to *Dob od - do*	Increment *Prirast* (m^3)			Prinova (m^3)			Production *Proizvodnja* (m^3)		
		Bos. pine *Munika*	Other *Ostalo*	Total *Ukupno*	Bos. pine *Munika*	Other *Ostalo*	Total *Ukupno*	Bos. pine *Munika*	Other *Ostalo*	Total *Ukupno*
1	43 - 58	84.46	-	84.46	1.86	-	1.86	86.31	-	86.31
2	47 - 62	31.36	2.78	34.14	0.95	0.07	1.02	32.31	2.85	35.16
3	23 - 38	41.93	2.65	44.58	0.25	0.05	0.30	42.18	2.70	44.88

TREE ANALYSIS
ANALIZA STABALA

According to the accepted practice, the trees in the experimental plots were analysed in the manner presented in the book "Growth and increment of forest

Table 2. Number of trees and basal area per hectare
Tablica 2.Broj stabala i temeljnica po hektaru

No. of plot *Broj pok. plohe*	Name of area *Naziv predjela*		Age *Dob* (Year-*Godina*)	Number of trees *Broj stabala*			Basal area *Temeljnica* (m^2)			Mean tree for principal stand *Srednje stablo za glavnu sastojinu*	
				Bos. pine *Munika*	Other *Ostalo*	Total *Ukupno*	Bos. pine *Munika*	Other *Ostalo*	Total *Ukupno*	DBH $D_{1.30}$ (cm)	Vol. (m^3)
1	Šestiver	I	43	1,032	3	1,035	19.30	-	19.30	16.6	0.12
		II	58	1,287	11	1,298	24.07	0.24	24.31	18.7	0.17
2	Kraljeva kleka	I	47	732	20	752	13.07	1.34	14.41	16.2	0.12
		II	62	785	102	887	14.02	1.68	15.70	17.9	0.15
3	Orlov kuk	I	23	1,804	8	1,812	22.60	0.08	22.68	10.9	0.04
		II	38	2,060	62	2,122	25.80	0.67	26.47	12.5	0.06

I - Data from the first inventory - *Podaci prve inventarizacije*
II - Data from the second inventory - *Podaci druge inventarizacije*

Table 3. Timber mass per hectare
Tablica 3. Volumen po jednom hektaru

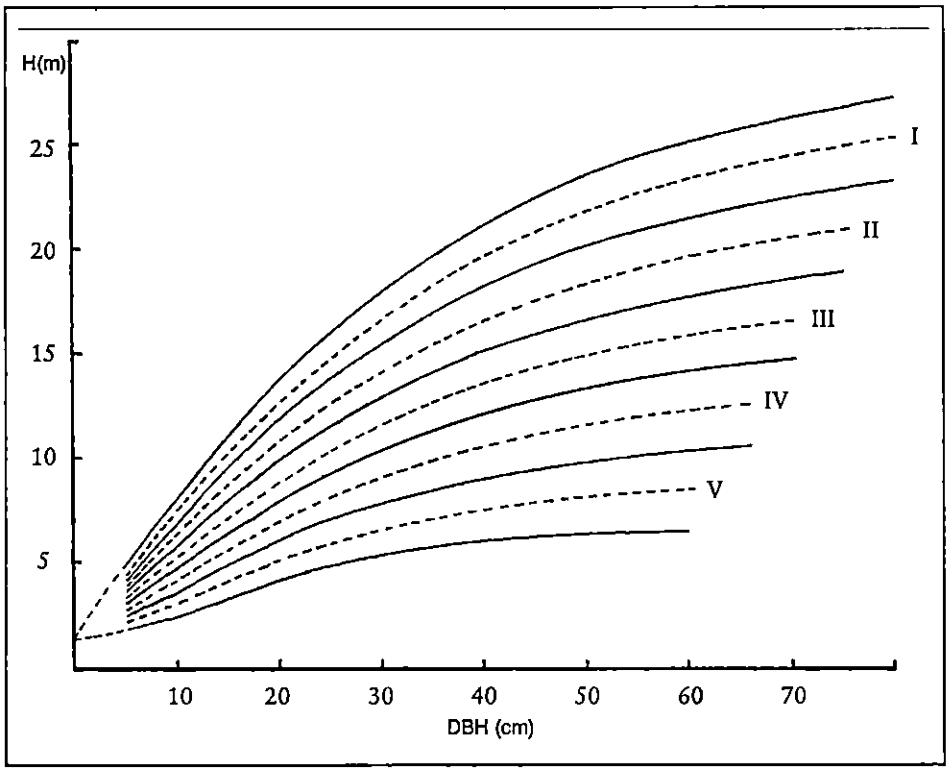
No. of plot *Broj plohe*	Soil type *Tip tla*	Age *Dob*	Timber mass *Volumen* (m^3)			Average age increment *Prosječni dobni prirast* (m^3)		
			Bos. pine *Munika*	Other *Ostalo*	Total *Ukupno*	Bos. pine *Munika*	Other *Ostalo*	Total *Ukupno*
1	Brown on limestone *Smeđe na vapnencu*	43	128.00	-	128.00	2.98	-	2.98
		58	214.31	-	214.31	3.70	-	3.70
2	Humus on limestone *Crnica na vapnencu*	47	85.00	5.00	85.00	1.81	0.11	1.92
		62	117.31	7.85	125.16	1.89	0.13	2.02
3	Rendzina on dolomite *Rendzina na dolomitu*	23	85.00	5.00	90.00	3.70	0.22	3.92
		38	127.18	7.70	134.88	3.35	0.21	

tree species and stands" by D. Klepac, Zagreb 1963. For each of the experimental plots, one tree was analysed using the accepted methodology and practice. The results and the indicators for all analysed trees are shown in Tables 12, 13, and 14, and in Graphs 4, 5 and 6.

THE RESULTS OF THE RESEARCH
REZULATI ISTRAŽIVANJA

TREE HEIGHTS AND SITE QUALITY CLASS
VISINE STABALA I BONITET STANIŠTA

The mean tree height per diameter degree of 5 cm was calculated on the basis of the measured heights of Bosnian pine trees in the experimental plots. The mean tree breast diameter was also calculated for the same diameter classes as the arithmetic mean of tree diameters of adequate diameter classes. The mean diameter obtained in this way is, as is well known, always lower that the mean diameter calculated by using the basal area. The results were compared with the results for tree heights and site class curves according to Drinić & Prolić 1979. These authors limited the obtained height curves from the bottom and top side with two thicker lines, which should, in their estimation, limit the intervals of tree height variations per diameter degrees in pure stands of Bosnian pine in Herzegovina. To do this, they used the curves of the site class for the black pine (Drinić 1963). They tried to approximate as closely as possible the intervals of tree height variations per diameter degrees for the Bosnian pine in Herzegovina and the black pine in Bosnia. They mentioned two reasons for this: *first*, the Bosnian pine and the black pine are biologically very close tree species, and *second*, their research, like the present research, did not include the best and the worst site conditions in which Bosnian pine occurs in natural stands in Herzegovina. For this reason, the height of Bosnian pines is in general slightly lower than the height of black pines. After that, the obtained intervals were divided according to diameter degrees into five parts of equal width and received a bundle of site class curves for pure stands of Bosnian pine in Herzegovina. Broken lines denote the height of trees in the centre of an adequate site class, and full lines denote the borders between individual site classes. The bundle of site class curves for pure stands of Bosnian pine according to Drinić & Prolić 1979 is shown in Graph 1. Unlevelled mean Bosnian pine heights for all experimental plots, inserted on the basis of mean diameters per diameter degrees, are shown in Graph 2. Bosnian pine stands were classified on the basis of the mentioned bundle of site class curves. The part of the height curve relating to diameter degrees possessing the largest participation of stand volume was decisive. The evaluated site classes of the stands in experimental plots are shown in Table 16. Table 5 shows the heights of Bosnian pine trees in the centre of the related site class (I to V) and the tree volume for the related breast diameter and height, that is, for the



Graph 1. Curves of site quality classes for pure stands of Bosnian pine in Herzegovina (Drinić & Prolić 1979)

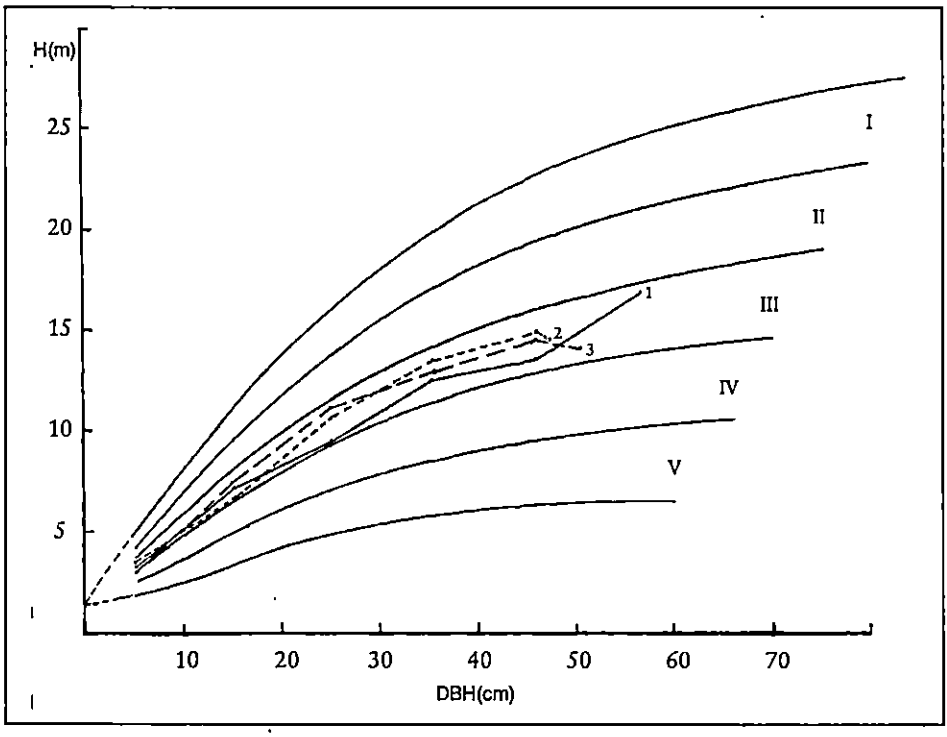
Grafikon 1. Krivulje bonitetnih razreda za čiste munikove sastojine u Hercegovini (Drinić & Prolić 1979)

site class according to Drinić & Prolić (1979). The table was marked as a volume table for Bosnian pine in Herzegovina because, in our opinion, the table can be used for management purposes in these forests. The tree volume in the table is expressed in total timber mass (with small branches). The tree volume was obtained, as already said, by using Bohmerl's tables for the black pine.

The differences in the height of Bosnian pine and black pine in Herzegovina are seen from the following comparison of mean tree heights for the III site class of both tree species, shown in Table 6.

Table 5. Drinić & Prolić, 1979. Volume tables for Bosnian pine in Herzegovina
Tablica 5. Drinić & Prolić, 1979. Volumne tablice za muniku u Hercegovini

DBH *Prsni promjeri* (cm)	Site class - *Bonitetni razred*									
	I		II		III		IV		V	
	Height *Visina* (m)	Volume *Volumen* (m^3)	Height *Visina* (m)	Volume *Volumen* (m^3)	Height *Visina* (m)	Volume *Volumen* (m^3)	Height *Visina* (m)	Volume *Volumen* (m^3)	Height *Visina* (m)	Volume *Volumen* (m^3)
5	4.3	0.0083	3.7	0.0066	3.2	0.0051	2.6	0.0035	2.1	0.0023
6	4.9	0.0147	4.3	0.0114	3.5	0.0087	2.9	0.0072	2.2	0.0049
7	5.6	0.0222	4.8	0.0200	3.8	0.0172	3.2	0.0156	2.4	0.0132
8	6.3	0.0300	5.3	0.0272	4.2	0.0240	3.5	0.0220	2.6	0.0193
9	6.9	0.0379	5.8	0.0348	4,7	0.0315	3.8	0.0288	2.8	0.0259
10	7.4	0.0461	6.3	0.0434	5.2	0.0400	4.1	0.0365	3.0	0.0330
12	8.6	0.0660	7.3	0.0607	5.9	0.0558	4.7	0.0516	3.4	0.0490
14	9.7	0.0973	8.3	0.0886	6.6	0.0796	5.3	0.0734	3.9	0.0730
16	10.7	0.1364	9.2	0.1258	7.3	0.1122	5.9	0.1036	4.4	0.1020
18	11.7	0.1819	10.0	0.1674	8.0	0.1514	6.5	0.1391	4.8	0.1310
20	12.6	0.2346	10.8	0.2150	8.8	0.1946	7.0	0.1770	5.1	0.1670
22	13.5	0.297	11.5	0.269	9.4	0.242	7.4	0.217	5.5	0.200
24	14.3	0.368	12.2	0.331	10.0	0.295	7.8	0.258	5.8	0.234
26	15.1	0.454	12.8	0.402	10.6	0.356	8.2	0.305	6.1	0.271
28	15.9	0.543	13.4	0.483	11.1	0.427	8.6	0.362	6.3	0.315
30	16.6	0.645	14.0	0.575	11.5	0.499	9.0	0.428	6.5	0.358
32	17.3	0.760	14.6	0.670	12.0	0.581	9.4	0.495	6.8	0.409
34	17.9	0.879	15.2	0.775	12.4	0.669	9.7	0.560	7.0	0.465
36	18.5	1.009	15.7	0.884	12.8	0.765	10.0	0.641	7.2	0.532
38	19.1	1.145	16.1	1.002	13.2	0.868	10.3	0.737	7.4	0.610
40	19.6	1.285	16.5	1.126	13.5	0.975	10.5	0.825	7.5	0.691
42	20.1	1.454	16.9	1.261	13.8	1.086	10.7	0.917	7.7	0.779
44	20.5	1.621	17.3	1.411	14.1	1.211	10.9	1.015	7.8	0.872
46	20.9	1.794	17.7	1.571	14.4	1.336	11.1	1.114	7.9	0.970
48	21.3	1.986	18.0	1.731	14.7	1.470	11.3	1.226	8.0	1.070
50	21.7	2.181	18.3	1.901	14.9	1.612	11.5	1.335	8.1	1.172
52	22.0	2.389	18.6	2.071	15.2	1.760	11.7	1.443	8.2	1.277
54	22.3	2.600	18.9	2.252	15.4	1.898	11.9	1.529	8.3	1.385
56	22.6	2.826	19.1	2.442	15.6	2.063	12.0	1.670	8.4	1.495
58	22.9	3.061	19.3	2.647	15.8	2.236	12.1	1.797	8.5	1.605
60	23.2	3.311	19.5	2.852	15.9	2.407	12.2	1.931	8.5	1.715
62	23.5	3.577	19.7	3.072	16.1	2.594	12.3	2.065		
64	23.7	3.845	19.9	3.300	16.3	2.789	12.4	2.233		
66	23.9	4.115	20.1	3.537	16.4	2.981				
68	24.1	4.395	20.3	3.784	16.5	3.162				
70	24.3	4.695	20.5	4.039	16.6	3.358				
72	24.5	4.989	20.7	4.289						
74	24.7	5.303	20.8	4.531						
76	24.9	5.570								
78	25.1	5.809								
80	25.2	6.031								



Graph 2. Mean unadjusted heights of Bosnian pine trees in experimental plots of site quality classes (Drinić & Prolić 1979)
Grafikon 2. Srednje neizravnate visine munikovih stabala na pokusnim plohama bonitetnih razreda (Drinić & Prolić 1979)

Table 6. The height of Bosnian pine and black pine
Tablica 6. Visina stabala munike i crnoga bora

DBH *Prsni promjer stabla*	(cm)		
	10	30	50
Mean height of Bosnian pine for the III site class *Srednja visina stabala munike za III. bonitetni razred* (m)	5.7	10.1	12.8
Mean height of black pine for the III site class *Srednja visina stabala crnoga bora za III. bonitetni razred* (m)	6.8	11.8	15.0
Difference between mean heights of Bosnian pine and black pine *Razlika između srednjih visina stabala munike i crnoga bora* (m)	1.1	1.7	2.2

The mean values of Bosnian and black pine tree heights for the third site class on the mountain Čvrsnica in Herzegovina are shown in Table 6. According to Drinić 1979, tree heights in pure Bosnian pine stands in Herzegovina are lower than tree heights in pure stands of black pine outside Herzegovina by about one third. This is

basically the result of worse site conditions in which the Bosnian pine stands in Herzegovina grow. When we compare the mean tree height measured in a 58-year-old Bosnian pine stand in experimental plot Number 1, compartment 23, subcompartment "a", and the mean tree height measured in a 64-year-old stand of black pine in experimental plot Number 4, compartment 26, subcompartment "a", we see that the difference in height decreases considerably. The trees in the pure stand of Bosnian pine are by about one-sixth shorter than the trees in the pure stand of black pine in Herzegovina. The basic reason is that the site conditions of black pine stands in Herzegovina are worse than those of black pine stands outside Herzegovina. Therefore, our results show a smaller difference in mean heights of Bosnian pine for the area of Čvrsnica in Herzegovina compared to the mean heights of black pine according to Drinić 1963. The difference in mean heights of Bosnian pine and black pine would be even smaller if the stands of these tree species were of the same age.

EXPERIMENTAL TREE MARKING
PROBNA DOZNAKA STABALA

The principles have already been mentioned on which so-called experimental tree marking was carried out in the experimental plots of Bosnian pine and comments have been made on the initial assumptions referring to the management system. Experimental tree marking was aimed at obtaining information on the possible extent of cutting and on the proportion of the existing volume to be removed from the stands and replaced by the new volume in the regeneration process. Finally, the dynamics at which all this could be carried out was determined. The diameter and qualitative structure of tree volumes in experimental marking is shown in Table 7.

Table 7. Structure of tree volumes in experimental tree marking
Tablica 7. Struktura volumena stabala probne doznake

Diameter degree *Debljinski stupanj* (cm)	Quality classes *Kvalitetni razredi*			Total *Ukupno* (m^3)	%
	I	II	III		
	Experimental marking per hectare (m^3) *Probna doznaka po hektaru* (m^3)				
5 - 30	-	0.6	4.5	5.1	10.8
30 - 50	0.1	2.4	9.6	12.1	25.7
Over 50	-	5.0	24.9	29.9	63.5
Total - *Ukupno*	0.1	8.0	39.0	47.1	100.0
%	0.2	17.0	82.8	100.0	

It can be concluded from the above that on average, the tree volume encompassed by experimental marking is 47.1 m^3/ha of the total timber mass. This is about 30% of the present average stand volume, which is 152.93 m^3/ha, or approxi-

mately a thirteen-year average volume increment, which is 3.5 m³/ha/year. Trees over 50 cm in diameter account for almost two-thirds (63.5%) of the tree volume encompassed by experimental marking. The trees in the third silvicultural-technical quality class account for over four-fifths (82.8%) of the volume, while the trees in the first silvicultural-technical quality class were not even marked. This approach is logical, because experimental marking primarily included trees of poor quality. Of these, the thicker ones were marked. The spatial arrangement of all existing trees in experimental plots was also taken into account, as well as the management system - the kinds of felling and regeneration methods - which it was assumed were applied in the studied stands.

YOUNG GROWTH IN BOSNIAN PINE STANDS
POMLADAK U SASTOJINAMA MUNIKE

The method of counting the quantity of young growth (trees below the taxation limit of 5 cm) used in the research on experimental plots of Bosnian pine was mentioned earlier. In the studied stands, the number of young trees varies considerably. In some stands, the number of young trees ranged from 2,896 to 4,748 (3,822 trees on average per hectare). The number of young spruces varied from 21 to 576, with an average of 299 trees per hectare. There were between 124 and 432 young firs, averaging 278 trees per hectare. The number of young beeches ranged from 78 to 495, making an average of 287 trees per hectare. Other conifers are classified with trees of Bosnian pine, and other deciduous trees with young beeches. The average number of young trees for all stands in experimental plots per classes and tree species is shown in Table 8.

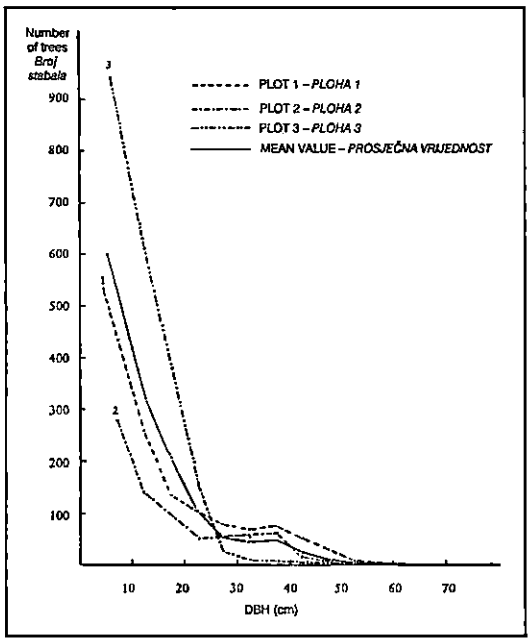
Table 8. Number of young trees in Bosnian pine stands
Tablica 8. Broj biljaka pomlatka u sastojinama munike

Tree species *Vrsta drveća*	Height classes *Visinske klase*		Diameter *Promjer*	Total *Ukupno*
	10-50 cm	50-130 cm	0-5 cm	
	Number of young trees per hectare *Broj biljaka pomlatka po hektaru*			
Bosnian pine *Munika*	1,324	1,128	1,370	3,822
Other conifers *Ostale četinjače*	212	196	169	577
Beech *Bukva*	107	97	83	287
Other deciduous *Ostale listače*	18	25	32	75
Total *Ukupno*	1,661	1,446	1,654	4,761

Needless to say, such numbers of young trees allow the studied stands of Bosnian pine to regenerate successfully in a natural way.

NUMBER OF TREES IN A STAND
BROJ STABALA U SASTOJINI

The number of trees per hectare in the studied stands varies from 785 to 2,060 trees. For all studied stands, the average number of Bosnian pines per hectare is 1,377 trees. The number of trees per hectare above the taxation limit of 5 cm is shown in Table 9. The table does not include deciduous trees and dwarf pines (plot no. 3) found in the experimental plots with Bosnian pine stands. On average, there are 58 trees of this kind per hectare. On the basis of the research results shown in the mentioned table, a "sloping" diameter structure of the trees in all experimental plots is apparent. Trees in the first diameter degree (7.5 cm on average) account for the biggest relative proportion of all trees. As the number of young trees immediately below the taxation limit (trees with a breast diameter of 0 to 5 cm) vastly exceeds the number of trees in the first (and the second) diameter class, (with the exception of plot no. 3), it can be concluded with a high degree of certainty that the arrangement of trees per diameter classes is "sloping". Apart from this, in some experimental plots (plots no. 1 and 2) there is a mild tendency to form the so-called other tree culminations in a higher diameter class (37.5 cm). However, this mild culmination (in compartments 22 and 23) comes as a result of the direct mutual height differentiation of trees. In other words, two storeys were formed. After the results were obtained, a question arose whether the "sloping" diameter structure of trees in the studied stands of Bosnian pine was a logical natural phenomenon. This seems likely, considering the relatively large size of the studied stands (the surface area of the smallest compartment is 24 ha, and the biggest 91 ha). Bosnian pines in these areas are represented in larger or smaller groups of trees. In individual groups, the trees are more or less equal in diameter and age. However, there are considerable differences in tree dimensions and ages among individual groups. Therefore, if we observe the entire stand in a large area or several stands together, it is logical that there are a larger number of thinner trees than thicker ones, or that the diameter structure in the stands of Bosnian pines is "sloping". Apart from this, it sometimes happens that only trees with almost equal diameters (dimensions) and ages occur in one stand or in a larger part of it. These are large, almost even-aged groups of trees, in which the diameter tree structure is characteristic for such stands. The diameter structure of Bosnian pines for all experimental plots individually, and the average diameter structure of Bosnian pines in all the studied stands are shown in Graph 3. The number of individual silvicultural-technical quality classes for all studied stands on average is shown in Table 10.



Graph 3. Diameter structure of trees in Bosnian pine stands
Grafikon 3. Debljinska struktura stabala u munikovim sastojinama

Table 9. Diameter structure of trees in the stand
Tablica 9. Debljinska struktura stabala sastojina

Name of area *Naziv predjela*	No of plot *Broj plohe*	Diameter degree - *Debljinski stupanj* (cm)											Total *Ukupno*	Trees per hectare *Stabala po hektaru*
		7.5	12.5	17.5	22.5	27.5	32.5	37.5	42.5	47.5	52.5	57.5		
		Number of trees - *Broj stabala* (%)												
Šestiver	1	34.1	20.3	11.0	8.4	6.4	5.6	6.2	4.4	2.6	0.9	0.1	100.0	1,287
Kraljeva kleka	2	36.1	17.8	12.6	7.3	7.3	7.4	8.2	2.8	0.5	-	-	100.0	785
Orlov kuk	3	42.2	29.3	18.6	7.9	1.4	0.5	-	-	0.1	-	-	100.0	2,060
Total - *Ukupno*		37.5	22.5	14.1	7.8	5.0	4.5	4.8	2.4	1.1	0.3	-	100.0	1,377

Table 10. The number of trees in silvicultural-technical quality classes
Tablica 10. Broj stabala uzgojno-tehničkih kvalitetnih klasa

Diameter class *Debljinski stupanj* (cm)	Quaity classes *Kvalitetni razredi*			Total *Ukupno*	%
	I	II	III		
	Number of trees per hectare *Broj stabala po hektaru*				
5 - 30	186	620	433	1,239	90.0
30 - 50	13	47	74	134	9.7
Over 50	-	2	2	4	0.3
Total - *Ukupno*	199	669	509	1,377	100.0
%	14.4	48.6	37.0	100.0	

The results shown in the table above allow us to conclude that a little over one third of the total number of trees in the studied stands of Bosnian pine occur in the third quality class. This class denotes those trees which should not even be in the forest in terms of quality tree production. Therefore, the quality of trees in Bosnian pine stands is slightly lower. The reason for this lies in adverse site conditions, where high altitude is the key factor. At such altitudes, trees are relatively small, tapering and distinctly knotty.

TREE GROWTH AND INCREMENT
RAZVOJ I PRIRAST STABLA

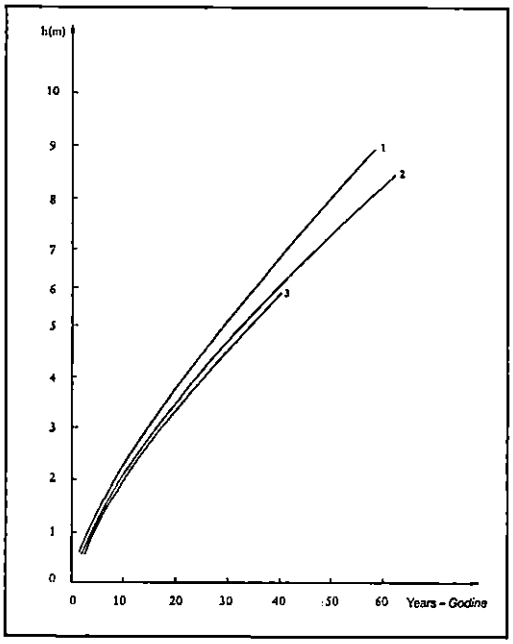
In this research, one tree from each of the experimental plots was analysed. The indicators of tree analyses are shown in Tables 11, 12, 13 and *14*, and in Graphs 4, *5* and 6.

Table 11. Diameter (d), height (h) and volume (v) growth of analysed trees
Tablica 11. Debljinski (d), visinski (h) i volumni (v) rast analiziranih stabala

No. of plot *Broj plohe*	Age *Dob*	Diameter at the age of - *Promjer u dobi od* (cm) / Height at the age of - *Visina u dobi od* (m)							
		Without bark *Bez kore*						With bark *S korom*	
		10	20	30	40	50	60	Present age *Sadašnja dob*	
1	58	2.6 / 2.2	6.8 / 3.7	10.3 / 5.1	13.3 / 6.3	15.9 / 7.5	- / -	17.5 / 8.4	18.6 / 8.4
2	62	2.4 / 2.1	6.2 / 3.4	9.4 / 4.7	12.2 / 5.9	14.7 / 6.8	16.7 / 7.7	17.0 / 7.9	18.0 / 7.9
3	38	2.3 / 2.0	5.9 / 3.3	8.9 / 4.5	- / -	- / -	- / -	11.0 / 5.4	11.7 / 5.4

Table 12. Timber mass of analysed trees
Tablica 12. Volumen analiziranih stabala

No. of plot *Broj plohe*	Age *Dob*	Timber mass (m^3) at the age of - *Volumen* (m^3) *u dobi od godina*								Bark *Kora*	
		Without bark *Bez kore*							With bark *S korom*		
		10	20	30	40	50	60	Present age *Sadašnja dob*		m^3	%
1	58	0.0013	0.0075	0.0216	0.0487	0.0968	-	0.1541	0.1638	0.0097	5.9
2	62	0.0011	0.0054	0.0181	0.0430	0.0805	0.1304	0.1429	0.1514	0.0085	5.6
3	38	0.0010	0.0052	0.0205	-	-	-	0.0502	0.0534	0.0032	6.0



Graph 4. Curves of height growth of analysed trees
Grafikon 4. Krivulje visinskoga rasta analiziranih stabala

Table 13. Diameter (i_d), height (i_h), and volume (i_v) increment of analysed trees
Tablica 13. Debljinski (i_d), visinski (i_h) i volumni (i_v) prirast analiziranih stabala

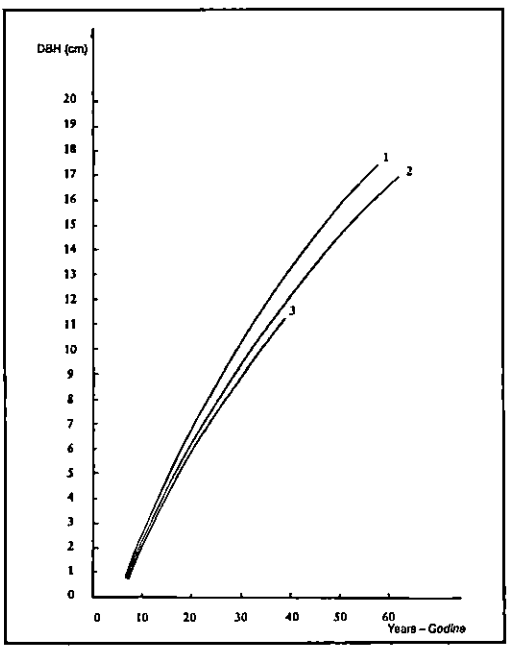
No of plot *Broj plohe*	Age *Dob*	Increment - *Prirast* diameter - *promjera* (cm) / height - *visine* (m) between individual years below *između pojedinih niže navedenih godina*						Average age - *prosječni dobni* With bark - *s korom*
		0 - 10	10 - 20	20 - 30	30 - 40	40 - 50	50 - 60	
1	58	0.26 --- 0.22	0.42 --- 0.15	0.35 --- 0.14	0.30 --- 0.12	0.26 --- 0.12	- --- -	0.32 --- 0.14
2	62	0.24 --- 0.21	0.38 --- 0.13	0.32 --- 0.13	0.28 --- 0.11	0.25 --- 0.10	0.30 --- 0.09	0.29 --- 0.13
3	38	0.23 --- 0.20	0.36 --- 0.13	0.30 --- 0.12	- --- -	- --- -	- --- -	0.31 --- 0.14

Table 14. Timber mass average increment of analysed trees
Tablica 14. Prosječni prirast volumena analiziranih stabala

No. of plot *Broj plohe*	Age *Dob*	Average increment of timber mass (m^3) between years below *Prosječni prirast volumena* (m^3) *između pojedinih niže navedenih godina*						Average age increment with bark *Prosječni dobni prirast s korom* (m^3)
		0 - 10	10 - 20	20 - 30	30 - 40	40 - 50	50 - 60	
1	58	0.0001	0.0006	0.0014	0.0027	0.0048	-	0.0028
2	62	0.0001	0.0004	0.0013	0.0025	0.0038	0.0050	0.0024
3	38	0.0001	0.0004	0.0015	-	-	-	0.0014

Tree growth and height increment
Razvoj i prirast stabla u visinu

Tree growth and increment in height at an early age was observed in the young growth found in the experimental plots of natural stands of Bosnian pine in Herzegovina. In June 1998, the height of 255 young trees was measured and an average height of 17.5 cm for all experimental plots was obtained. The height was measured on trees of two years of age. In all experimental plots the height increment on 255 young trees aged 6 - 8 years was measured. To determine the relative age of Bosnian pines, reliance was given to the assumption that the Bosnian pine as a tree species has regular branch whorls. This assumption was confirmed during the research, and was practically applied in determining the relative age of the young growth. The height increment during the first 6 to 8 years of young trees in all experimental plots was about 20 cm a year on average. Further growth and increment in height were observed in the analysed trees for each of the experimental plots. On the basis of the indicators shown in Tables 11 and 13, and in Graph 4, the following can be concluded: height increment at a young age is slightly more intensive until the age of about thirty, and later remains steady or even slightly lower until the age of sixty. The culmination of height increment in the analysed trees occurred when the trees were between 0 and 10 years old. Bosnian pines in all experimental plots achieved the highest current annual height increment between



Graph 5. Curves of diameter growth of analysed trees
Grafikon 5. Krivulje debljinskoga rasta analiziranih stabala

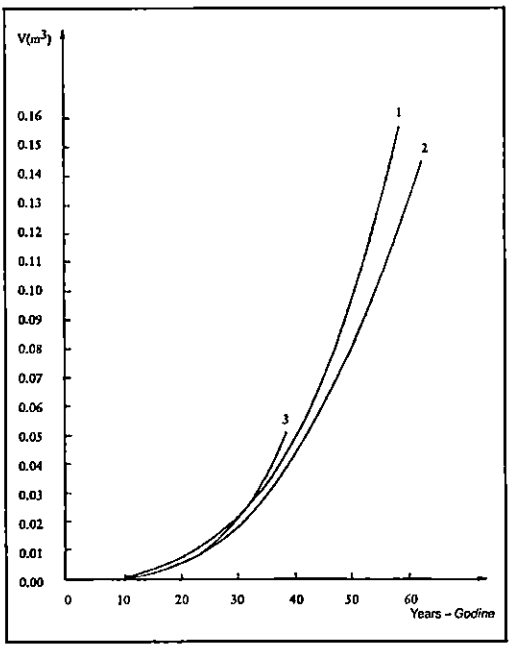
0 and 10 years of age. In plot No. 1 (Šestivar), the height increment was 0.22 m, in plot No. 2 (Kraljevska Kleka) it was 0.21 m, and in plot No. 3 (Orlov Kuk) it was 0.20 m. As a species, the Bosnian pine lives long and grows slowly, especially at a young age. Under optimal conditions in its natural distribution area it can theoretically reach a height of 30 m and a diameter of 1 m. The tallest tree, reaching 18 m, was found in plot No. 1.

Tree growth and increment in diameter
Razvoj i prirast stabla u debljinu

In all observed experimental plots the growth and increment in diameter is rather balanced, which is understandable considering the fact that pure natural stands of Bosnian pine in Herzegovina grow under similar natural conditions. Some individual deviations are the result of age differences in the stands, the number of trees per surface unit and the pronounced micro-spatial changeability of the production capacity of the soil under Bosnian pines. In general, Bosnian pine grows more slowly in diameter, especially in its youth, and retains this slow growth until its older age. As it has a narrow crown, this species does not require much space for diameter growth. Under optimal conditions, Bosnian pines can achieve a breast diameter of up to 1 m. The thickest tree, with a breast diameter of 56 cm, was measured in plot No. 1. Since Bosnian pine grows slowly, it can be concluded that no interventions and silvicultural treatments are needed in young stands. However, at a later stage, after the selection structure and several storeys have been differentiated in pure natural stands of Bosnian pine, suitable treatments should be undertaken to assist the successful natural regeneration of stands and of smaller groups of trees. The analysed Bosnian pine in plot No. 3 exhibited a mild decrease in diameter increment. The reason for this is a large number of trees per surface unit and the tall stand cover in this plot. The analysed Bosnian pine in plot No. 1 also exhibits a mild decrease in diameter increment, although this stand is much less stocked than the former one, and has a differentiated selection structure and two storeys. In our opinion, suitable measures should be undertaken in this stand involving low-intensity interventions in the upper storey, so that the understorey receives more light and space. In this way, individual trees from the understorey would respond with an increased diameter increment, and an opportunity for the balanced natural regeneration of the stand would be provided. Based on the indicators shown in Tables 11 and 13 and in Graph 5, the following can be concluded: the culmination of diameter increment in the analysed trees occurred in the period between 10 and 20 years. The diameter increment in middle-aged stands can be increased or at least maintained with silvicultural treatments. The highest current diameter increment of 0.42 cm was found in the analysed tree in plot No. 1 (Šestivar) in the period between 10 and 20 years.

Growth and increment of timber mass
Razvoj i prirast volumena stabla

This research confirmed the already known fact that timber mass increases with an increase in height and diameter, depending on the available space and the quantity of light at the disposal of a tree at a certain age. The curve of timber mass growth is typical, and has the shape of an elongated letter "S". On the basis of the indicators shown in Tables 12 and 14 and Graph 6, it can be concluded that timber mass grew the fastest in plot No. 1 (Šestivar). The total timber mass of the analysed tree in plot No. 1 (Šestivar) was 0.16 m^3 at the age of 58, while the total timber mass in plot No. 2 (Kraljeva Kleka) was 0.15 m^3 at the age of 62. However, if we consider the total timber mass minus bark in all analysed trees at the age of 30, a uniform pattern can be seen: in plot No. 1 the timber mass amounted to 0.022 m^3, in plot No. 2 it amounted to 0.018 m^3, and in plot No. 3 to 0.021 m^3, It can also be noted that the overall timber mass of the analysed tree in experimental plot No. 3 after the age of 30 reached the total timber mass of the analysed tree in experimental plot No. 1. At a certain point in age, it exceeded it. The total timber mass of the analysed tree in experimental plot No. 3 at the age of 38 amounts to 0.050 m^3, and the total timber mass of the analysed trees in experimental plot No. 1 at the age of 40 amounts to 0.049 m^3, and to 0.043 m^3 in experimental plot No. 2. The example in experimental plot No. 3 is due to the fact that the tree in the stand was already differentiated and had penetrated the upper storey, thus receiving more light and space which enabled



Graph 6. Growth curves of analysed trees timber mass
Grafikon 6. Krivulje rasta volumena analiziranih stabala

it to grow faster. The stand in plot No. 3 is in the initial stage of storey differentiation and selection structure. The increment of timber mass is slowed in the early years of life, and very intensive in later years. The culmination of volume increment has not occurred yet in any of the analysed trees, because the volume increment culminates much later than the height and diameter increment. On the basis of research results, it can be concluded that the biggest average annual volume increment was 0.0048 m^3 at the age between 40 and 50 in plot No. 1 (Šestiver), with a tendency of further growth, as seen in Graph 6. The average annual volume increment, amounting to 0.0050 m^3 at the age between 50 and 60 with a tendency of further growth was recorded in a tree in plot No. 2 (Kraljeva Kleka). However, there is little probability that the analysed tree in plot No. 2 will reach the average annual volume increment of the tree in plot No. 1. The analysed tree in plot No. 1 is likely to achieve a higher average annual volume increment of 0.0050 m^3 at the age of 60 than that achieved by the tree in plot No. 2 at the same age.

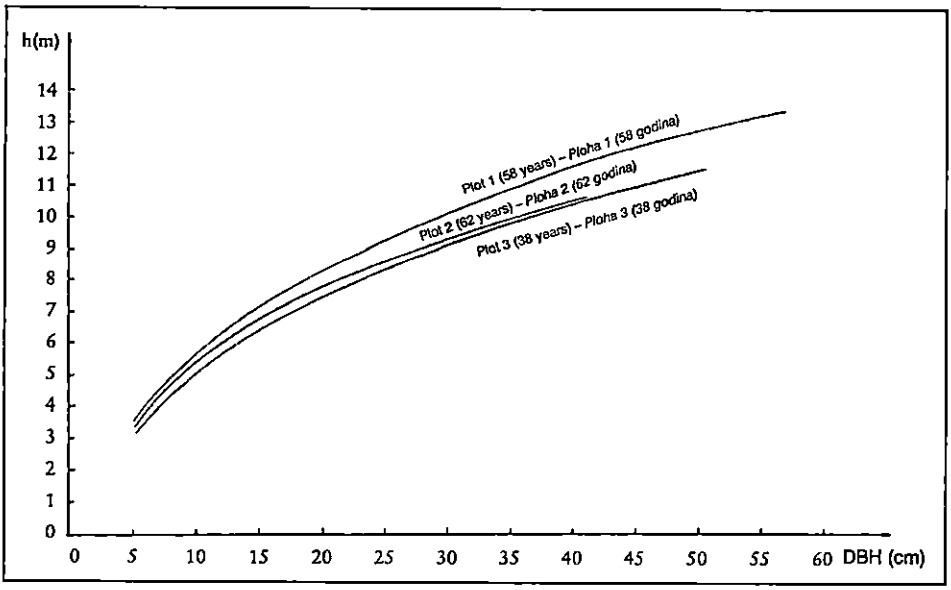
STAND GROWTH AND INCREMENT
RAZVOJ I PRIRAST SASTOJINE

Stand growth and increment in height
Razvoj i prirast sastojine u visinu

Stand growth and increment in height were calculated on the basis of measured tree heights in all experimental plots, and the constructed and measured height curves for individual experimental plots, shown in Graph 7. Indicators in the graph show that the height curve of the youngest stand moved downwards in relation to older stands, and that stand height curves in all experimental plots differed only slightly. The reason for this is that all studied stands are of approximately the same site quality class and that the trees in the youngest stand are of almost equal height and age, and have not yet differentiated into storeys and selection structure. The stand in plot No. 1 (Šestiver), where the soil is the deepest and the most productive, has the highest height curve.

Stand growth and increment in diameter
Razvoj i prirast sastojine u debljinu

Diameter growth and increment of the mean tree in a stand were observed on the basis of two measurements. The indicators shown in Table 2 point to the following: stands in plots 1 and 2 developed best. The largest tree diameter distributions and the highest diameter growth of individual trees in stands were noted here. The stand in plot 3 was the most poorly developed. It is the youngest of all studied stands, has the largest cover and is therefore the thickest. At the age of 38, the diameter of the mean tree was 12.5 cm. According to the indicators in Table 2, the biggest average periodical annual diameter increment of the mean tree of 0.14 cm is found in plot No. 1 (Šestiver). Over a 15-year period, the diameter of the



Graph 7. Height curves of stands
Grafikon 7. Visinske krivulje sastojina

mean tree has grown from 16.6 cm to 18.7 cm in plot No. 1, and the average age increment of the mean tree in diameter, amounting to 2.1 cm, is the biggest.

Growth and increment of stand stemwood
Razvoj i prirast volumena sastojina

The calculation of growth and increment of stand timber mass was based on two inventories. The indicators of these inventories are shown in Tables 3 and 4. The annual stand volume increment in individual plots is shown in Table 15.

Table 15. Annual stand increment of Bosnian pine in plots
Tablica 15. Godišnji prirast sastojina munike na plohama

Plot number *Broj plohe*	Age *Dob*	Annual current increment (m^3) *Godišnji tečajni prirast* (m^3)			Average age increment (m^3) *Prosječni dobni prirast* (m^3)		
		Bos. pine *Munika*	Other *Ostalo*	Total *Ukupno*	Bos. pine *Munika*	Other *Ostalo*	Total *Ukupno*
1	58	5.63	-	5.63	3.70	-	3.70
2	62	2.09	0.18	2.27	1.89	0.13	2.02
3	38	2.79	0.17	2.96	3.35	0.21	3.56

Table 15 shows the total annual current and the total volume average age increment for stands in all experimental plots. The Bosnian pine stand in plot No. 1

(Šestiver) displayed the biggest current annual volume increment of 5.63 m³/ha. This is understandable, because this is a relatively young to middle-aged stand with a good cover growing on deep soil. However, the stand in experimental plot No. 2 (Kraljeva Kleka) displays the lowest current annual volume increment. The reasons are manifold: the cover is 0.53, the number of trees per surface unit is the lowest of all stands in experimental plots, and the productive area is lessened by frequent stone blocks on the surface of the rather shallow soil. If the obtained stand increment of 2.09 m³/ha in plot No. 2 is reduced to the total cover, the size of the increment of 3.94 m³/ha will be obtained, which corresponds to the stand age. According to the obtained indicators, the current annual volume increment has not yet culminated. The current annual volume increment could not reach the culminating point in view of the fact that it culminates long after the height and diameter increments reach their culmination. The culmination time of all mentioned increments in Bosnian pine is moved rightwards, that is, towards the older age. This is due to the biological properties of the species, to extremely bad site conditions and to the altitude at which it naturally occurs in Herzegovina and elsewhere. The survey of taxation element indicators in the studied Bosnian pine stands in Herzegovina (Čvrsnica) is shown in Table 16. The indicators in the table refer to the total timber mass of the studied stands in experimental plots.

Table 16. Indicators of stand taxation elements
Tablica 16. Pokazatelji taksacijskih elemenata sastojina

No. of plot *Broj plohe*	Plot area *Površina plohe* (ha)	Site class *Bonitetni razred*	Stand cover *Obrast sastojine*	Mean DBH *Srednji p.p.* (cm)	Mean height *Srednja visina* (m)	Per hectare *Po hektaru*			
						Number of trees *Broj stabala*	Basal area *Temeljnica* (m^2)	Timber mass *Volumen* (m^3)	Current increment *Tečajni prirast* (m^3/year - *god.*)
1	1,0	3.2	0.82	18.7	8.1	1,287	24.07	214.31	5.63
2	1,0	3.6	0.53	17.9	7.5	785	14.02	117.31	2.09
3	1,0	3.4	0.90	12.5	5.8	2,060	25.80	127.18	2.79
Total *Ukupno*	1,0	3.4	0.75	16.4	7.1	1,377	21.30	152.93	3.50

PRODUCTION
PROIZVODNJA

The annual production of timber mass for experimental plots 1, 2 and 3 was calculated on the basis of two inventories, or two measurements in experimental plots over a period of 15 years. The indicators of the annual production of the studied stands in all plots are shown in Table 17 for the total timber mass. The Bosnian pine stand in experimental plot No. 1 in the forest region of Šestivar is the most productive, with an annual production of total timber mass of 5.75 m³/ha. The young and fully developed stand of Bosnian pine in experimental plot No. 3 has an annual production of 2.99 m³/ha.

Table 17. Annual production of stand timber mass
Tablica 17. Godišnja produkcija drvne mase sastojina

No. of exp. plot *Broj pok. plohe*	Stand age *Dob sastojine*	Annual production (m^3) *Godišnja produkcija* (m^3)			Control period (year) *Kontrolno razdoblje (godina)*
		Bos. pine *Munika*	Other *Ostalo*	Total *Ukupno*	
1	58	5.75	-	5.75	15
2	62	2.15	0.19	2.34	15
3	38	2.81	0.18	2.99	15

CONCLUSION
ZAKLJUČAK

Based on the research into the growth of pure natural stands of Bosnian pine in Herzegovina, the following can be concluded:

- Bosnian pine is an endemic pine species and a Tertiary relict preserved during the glaciation period in the Balkan Peninsula. Its broken and disjunct natural area of 1,528 ha is situated in Herzegovinian mountain ranges 1,000 - 1,900 metres above sea level. The climate of the region is continental-mountainous, which is characterised by long winters and abundant snow, and sub-Mediterranean of a colder type. Bosnian pine has very modest growth requirements, which is seen in the fact that it has no competition from other tree species. This tree is the only species that can grow well and regenerate naturally under extremely harsh conditions and very poor productive capabilities of the soil.
- The wide ecological amplitude of the Bosnian pine enables this species to grow in a region of barren, waterless karst mountains, where even the black pine is absent. The reason for this is that Bosnian pine is a tree species with the lowest requirements in Europe and with distinct pioneering characteristics.
- Stands of Bosnian pine represent a natural, rare forest vegetation with a distinctive *protective (ecological) function* in terms of hydrology, anti-erosion and climate, a social function in terms of tourism, aesthetic beauty and recreation, and a *productive (raw material) function* in terms of the outstanding technical properties of its timber. Finally, its *pioneering function*, encompassing all the characteristic features of Bosnian pine as a tree species, should also be pointed out.
- The following soil types support pure natural stands of Bosnian pine in Herzegovina: brown soil on limestone (Šestiver - plot No. 1), humus on limestone (Kraljeva Kleka - plot No. 2), rendzina on dolomite (Orlov Kuk - plot No. 3), which is neutral to mildly alkaline with a pH of 6.9 to 7.8 (the area of the mountain Čvrsnica) with insufficient phosphorus content. A high per-

centage of free carbonates in rendzinas on dolomite are the result of large quantities of tiny skeletal particles.

- Since the rate of growth and increment of Bosnian pine is slow, the mean tree in a studied stand has a timber mass of only 0.15 m³ at the age of 60. Compared to other pines, and particularly to the black pine to which the Bosnian pine is biologically close, the culmination of height and diameter increment occurs much later, while the culmination of volume increment occurs long after the culmination of height and diameter increment. In Herzegovina, Bosnian pine stands display a current annual increment of 2.3 to 5.6 m³/ha of the total timber mass, while the average age increment of the total timber mass ranges from 2.0 to 3.7 m³/ha at the age of 60. The production of the total timber mass also culminates at a late date. At the age of 60, production in the studied stands reaches 6.0 m³/ha a year. The volume of the total timber mass (with small branches) varies from 127 to 214 m³/ha, averaging 153 m³/ha. The volume of annual current increment expressed in the total timber mass ranges from 2.09 to 5.63 m³ per hectare.
- The average data for volume obtained by this research in pure natural stands of Bosnian pine in Herzegovina (Čvrsnica) (153 m³/ha of the total timber mass on average) concord with the average data for volume obtained by the forest management basis by Ćurić (1967) in pure natural stands of Bosnian pine in Herzegovina (131 m³/ha of large wood) and Čvrsnica (124 m³/ha of large wood). The volume of large wood in pure natural stands of Bosnian pine is about 20% lower than its total timber mass.
- The volume and volume increment of natural stands of Bosnian pine in Herzegovina (Čvrsnica) are considerably lower than the volume and volume increment of natural pure stands of Bosnian pine in Kosovo and Montenegro (Jović, 1971). The deviations of average values in the above mentioned taxation elements are as follows:

	Volume in m³/ha	Volume increment in m³/year/ha
Bosnian pine in Herzegovina	214	5.63
Bosnian pine in Kosovo and Montenegro	380	5.84
Deviation	166	0.21

Pure stands of black pine in Herzegovina (experimental plot No. 4 - locality Lisac on Čvrsnica) confirm that the volume and volume increment there is higher than that in pure stands of Bosnian pine. The deviations are as follows:

	Volume in m³/ha	Volume increment in m³/year/ha
Bosnian pine in Herzegovina	214	5.63
Black pine in Herzegovina	242	6.10
Deviation	28	0.47

The studied stand of black pine is 64 years old on average, and that of Bosnian pine 58. The volume and volume increment of pure Bosnian pine stands in relation to the volume and volume increment of black pine stands is 88.4%, or 92.2%. The actual deviation is close to the estimated deviation, the reason being that the stand of black pine is older and grows in a site of a slightly better class quality. The indicators for the black pine and the Bosnian pine relate to the total timber mass. Compared to the productive capabilities of pure stands (forests) of Bosnian pine in the other regions of its natural distribution area and to those of high forests of other tree species, the productive capabilities of pure stands of Bosnian pine on Čvrsnica in Herzegovina are clearly lower.

- Unlike the single tree selection management applied so far, the system of small-group shelterwood felling with a long regeneration period should be used to manage pure stands of Bosnian pine in Herzegovina. Group selection management is also applicable, but only on very small groups with a long regeneration period. The longer the regeneration period is, the closer the system is to the group selection forest management system. From the standpoint of the better and more efficient protection of pure natural stands of Bosnian pine in Herzegovina, the single tree management system is also suitable on very steep terrains. However, this system is economically questionable.
- From an economical standpoint, an average of 47.1 m^3 of timber mass per hectare should be removed from pure stands of Bosnian pine on Čvrsnica in order to achieve a better quality of stands and better natural regeneration. This quantity of wood mass relates to the volume of trees encompassed in the experimental tree marking in the stand. The timber mass obtained from experimental marking (47.1 m^3/ha) should be exploited over several occasions with a cutting intensity of up to 15% at the most. With regard to the relatively low volume and volume increment and the generally slow rate of growth and development of pure stands of Bosnian pine in the studied area, as well as to bad site conditions, at least 30 to 50 years are needed to exploit the above mentioned timber mass. This is the period needed for a stand to regenerate naturally if the group management system is applied. Artificial regeneration cannot be applied due to bad site conditions.
- According to the results of the research, the stands of Bosnian pine in Herzegovina have a mean diameter of 16.4 cm, a mean height of 7.1 m and a mean site quality class of 3.4 (the taxation border was 5.0 cm). The mean diameter was calculated as the arithmetic mean of the tree diameters, and the mean height as the arithmetic mean of the tree heights in the stands. The mean diameters and heights calculated in this manner are always lower than the mean diameters and heights calculated with basal areas. Apart from this, the mean diameter and height of the studied stands were also partially reduced by the lower taxation border.
- The Bosnian pine in pure natural stands in Herzegovina over an area of 1,528 ha should be protected by special management measures. Not only is

it a rare endemic Tertiary relict, but it also provides a variety of functions. Special attention should be paid to extending the distribution area of Bosnian pine to all ecologically viable places, and primarily to those of high, cold and karst mountain ranges in Herzegovina. The existing pure natural stands should be preserved as the primary nucleus for reproduction and as an outstanding monument of natural rarity.

- Pure natural stands of Bosnian pine in the whole of Herzegovina cannot be managed and regenerated with uniform procedures and methods. The kind of methods and procedures to be used will be the subject of some other research.
- The presented results are aimed at providing additional impetus for further research into the stands of Bosnian pine and at drawing attention to these forests composed of endemic, relict and rare tree species.

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USPIJEVANJE MUNIKE (*Pinus heldreichii* Christ) U HERCEGOVINI

SAŽETAK

U uvodnom dijelu posebice je istaknuto unošenje munike (*Pinus heldreichii* Christ) kao tercijernoga relikta općenito, a na istraživanom području posebno. Postavljeni cilj istraživanja sastoji se u utvrđivanju uvjeta za uspijevanje munike te u utvrđivanju proizvodnih svojstava čistih prirodnih sastojina u Hercegovini. Dosadašnji nazivi pod kojima su autori obrađivali tu vrstu na različitim lokalitetima, na kraju njihovo usaglašavanje oko jedinstvenoga naziva pod kojim se munika i ovdje obrađuje prikazani su u poglavlju o dosadašnjim spoznajama.

Utvrđeno je da se najveći broj radova o munici odnosi na biljnozemljopisna istraživanja, istraživanja tala i biljnih zajednica, dok su istraživanja strukture sastojina i proizvodnih obilježja gotovo neznatna.

Podrobno je opisana prirodna i umjetna rasprostranjenost munike. Svaki je od lokaliteta opisan, a nalaze se na mediteranskim i submedteranskim planinama Balkanskoga poluotoka i u južnoj Italiji. S nalazišta u Hercegovini opisane su četiri fitocenoze u kojima prirodno uspijeva munika. Ukupna je površina na kojoj raste munika bilo u čistim bilo u mješovitim sastojinama 5865 ha. Od toga čiste sastojine zauzimaju 1528 ha. Klima areala u Hercegovini obrađena je temeljem podataka za četiri meteorološke postaje: Mostar, Konjic, Posušje i Tomislavgrad. Ti podaci potvrđuju uspijevanje munike u uvjetima kontinentalno-planinske i izmijenjene submediteranske klime hladnijega pojasa. Analizom tla na pokusnim plohama prikazana su kemijska i mehanička svojstva smeđega tla na vapnencu, crnice na vapnencu i rendzine na dolomitu. Sva spomenuta tla pokazuju manjak fosfora, neutralnu do slabo alkaličnu reakciju (pH 6,9 do 7,8) i velik postotak slobodnih karbonata kod crnica na vapnencu i rendzina na dolomitu, koji je nastao zbog velike količine sitnih skeletnih čestica. Na svim potrebnim ekosustavima obrađena su biološka svojstva, reproduktivnost i adoptivnost, pri čemu je utvrđena jako široka ekološka amplituda munike kao vrste bora.

Sve pokusne plohe (ukupno 4) detaljno su opisane u poglavlju o metodama rada, a opisan je i rad na njima. Na svakoj od pokusnih ploha analizirani su rast i prirast po jednoga stabla sa svake plohe. U dijelu obrade podataka rezultati su tabelično prikazani i za pokusne plohe i za analizirana stabla. Broj stabala u istraživanim sastojinama kretao se od 785 do 2060 komada po hektaru, promjer srednjega stabla munike za glavnu sastojinu kretao se od 12,5 do 18,7 cm, volumen srednjega stabla za glavnu sastojinu kretao se od 0,06 do 0,17 m3, volumen se kretao od 125,16 do 214,31 m3 po hektaru, a sastojine su imale od 38 do 62 godine (tablica 3).

Rezultati istraživanja detaljno su analizirani tako da u prvom redu utvrđuju bonitete staništa na temelju visina stabala na pokusnim plohama u poredbi s bonitetima koje su u svojim radovima izradili Drinić i Prolić 1979. godine, te je

utvrđeno da se sve mjerene sastojine nalaze u trećem bonitetnom razredu. Istražena je i struktura volumena probne doznake u sastojinama, a posebno su značajni utvrđeni rezultati prirodnoga pomlatka u sastojinama. Broj je stabala razvrstan po debljinskoj strukturi i prikazan tabelično i grafički (tablica 9, grafikon 3). Probna doznaka u istraživanim sastojinama munike obavljena je zato da bi se mogla dobiti informacija o mogućem opsegu sječa, odnosno o tome koji bi dio od postojećega volumena trebalo ukloniti kako bi se zamijenio novim volumenom u procesu obnavljanja tih sastojina, te kojom bi se dinamikom sve to moglo provesti i ostvariti. Za sve istraživane sastojine volumen stabala obuhvaćenih probnom doznakom u prosjeku iznosi 47,1 m^3/ha ukupnoga volumena. To čini oko 30 % postojećega volumena sastojina koji iznosi 152,93 m^3/ha ili približno trinaestogodišnji prosječni volumni prirast koji iznosi 3,50 m^3/ha/godišnje. Na stabla deblja od 50 cm otpada gotovo 2/3 ili 63,5 % volumena stabala obuhvaćenih probnom doznakom, a na stabla III. uzgojno-tehničke klase otpada preko 4/5 ili 82,8 % spomenutoga volumena (tablica 7). Broj stabalaca pomlatka munike za sve istraživane sastojine u prosjeku iznosio je 3822 komada/ha. Broj stabalaca pomlatka smreke u prosjeku iznosio je 299 komada/ha. Broj stabalaca pomlatka bukve u prosjeku iznosio je 287 komada/ha, a broj stabalaca pomlatka za sve vrste drveća i sve pokusne plohe u prosjeku iznosio je 4761 komad/ha (tablica 8).

Posebno je ocijenjena kakvoća svih stabala na pokusnim plohama razvrstanih u tri razreda (tablica 10). Za sve istraživane stastojine broj stabala u III. razredu u prosjeku iznosio je nešto malo više od 1/3 ili 37,0 %.

Razvoj i prirast stabala analiziran je i iskazan tablično i grafički (tablica 11, 12, 13, 14, grafikon 4, 5, 6) po ustaljenim kriterijima. To isto vrijedi i za sastojine. Visinski prirast analiziranih stabala oko njihove tridesete godine malo je veći, a nakon toga je isti ili nešto manji. Najveći tečajni godišnji visinski prirast analizirana stabla munike na svim pokusnim plohama imala su u dobi od 0 do 10 godina. On je na 1. plohi iznosio 0,22 m, 2. plohi 0,21 m i na 3. plohi 0,20 m. Razvoj i prirast stabala u debljinu dosta je ujednačen, a najveći tečajni godišnji debljinski prirast iznosio je 0,42 cm kod analiziranoga stabla na 1. plohi u dobi od 10 do 20 godina. Ukupni je volumen analiziranoga stabla na 1. plohi iznosio 0,16 m^3 u dobi od 58 godini, dok je ukupni volumen analiziranoga stabla na 2. plohi iznosio 0,15 m^3 u dobi od 62 godine. Najveći prosječni volumni prirast kod analiziranoga stabla iznosio je 0,0048 m^3 u dobi od 40 do 50 godina na 1. plohi s tendencijom daljnjega porasta. Visinske krivulje sastojina općenito se malo razlikuju, a istodobno najnižu visinsku krivilju imala je najmlađa sastojina. Visinska krivulja sastojine na pokusnoj 1. plohi pomaknuta je znatno naviše. Najbolje se u debljinu razvijala sastojina na 1. plohi, a najveći tečajni godišnji debljinski prirast zabilježilo je srednje stablo također na 1. plohi a iznosio je 0,14 cm. Prosječni dobni prirast srednjega stabla u debljinu najveći je na 1. plohi i iznosio je 2,1 cm. Na 1. plohi sastojina munike zabilježila je najveći tečajni godišnji volumni prirast koji je iznosio 5,63 m^3/ha, a najniži sastojina na 2. plohi koji je iznosio 2,27 m^3/ha. Ta ploha ima najmanji obrast koji iznosi 0,53 (tablica 15).

Pokazatelji taksacijskih elemenata istraživanih sastojina s pokusnih ploha vidi se na tablici ????, a ukupno dobivena proizvodnja na tablici 16.

Bonitetni razred istraživanih munikovih sastojina kretao se od 3,4 do 3,2 (u prosjeku 3,4), obrast se sastojina kretao od 0,53 do 0,82 (u prosjeku 0,75), srednji se promjer kretao od 12,5 do 18,7 cm (u prosjeku 16,4 cm) i srednja visina kretala se od 5,8 do 8,1 m (u prosjeku 7,1 m). Munikova je sastojina na 1. plohi najproduktivnija s godišnjom proizvodnjom drva od 5,75 m^3/ha, a sastojina na 2. plohi svedena na potpuni obrast imala bi ukupnu godišnju proizvodnju drva od 4,42 m^3/ha. Sastojina na 3. plohi imala je godišnju proizvodnju 2,99 m^3/ha (tablica 17). Svi navedeni rezultati dobiveni su pri taksacijskoj granici od 5 cm.

Munika kao vrsta drveća u šumama i šumarstvu u Hercegovini zauzima posebno važno mjesto, posebice u svezi sa staništem i malom površinom koju zauzima, te sa zaštitnom i pionirskom ulogom. Munikove sastojine na istraživanom području čine prirodnu rijetkost šumske vegetacije s izraženom zaštitnom (ekološkom) funkcijom, pri čemu treba naglasiti hidrološku, protuerozijsku i klimatsku ulogu, društvenom (socijalnom) funkcijom, osobito turističkom, estetskom i rekreacijskom ulogu, pionirskom funkcijom, pri čemu treba istaknuti nezamjenjivu ulogu u pošumljavanju vrlo siromašnoga visokoga-planinskoga bezvodnoga krša, gdje crni bor ne dolazi i gdje samo munika može dati normalno izrasla stabla, i na kraju proizvodnom (sirovinskom) funkcijom zbog izvanrednih tehničkih svojstava munikovine.

Zaključci pokazuju da je odgovoreno postavljenom cilju istraživanja. Prikazano je uspijevanje munike kao reliktne i endemne vrste drveća u Hercegovini, gdje nastava terene vrlo surovih uvjeta i slabih proizvodnih mogućnosti tla. U takvim uvjetima ima pionirsku ulogu, štiti tlo i stvara povoljne uvjete za uspijevanje i drugih vrsta drveća. Posebno je vrlo slikovita i atraktivna u pejzažu. Proizvodne su mogućnosti na planini Čvrsnici manje od onih u drugim dijelovima njezine rasprostranjenosti, ali su za dane uvjete zadovoljavajuće s granicama od 2,0 do 6,0 m3 po hektaru godišnje uz prirodnu progresiju na pašnjačke površine.

Ključne riječi: uspijevanje, munika (*Pinus heldreichii* Christ), tercijarni relikt, endemna vrsta, rasprostranjenost, munika u Hrecegovini, klima, tlo, stanište, biološka svojstva, bonitet, pomladak, razvoj i prirast stabala, razvoj i prirast sastojina, produkcija

Photograph 1. Bosnian pine in a pioneering function on barren karst
Fotografija 1. Munika u pionirskoj funkciji na ljutom kršu

Photograph 2. Bosnian pine on the mountain Čvrsnica in the initial stage of natural progression to pastureland
Fotografija 2. Munika na planini Čvrsnici u početnoj fazi prirodne progresije na pašnjačke površine

Photograph 3. Bosnian pine in compartment 26 of the Management Unit Čvrsnica (part) in natural progression to mountain pastureland
Fotografija 3. Munika u odjelu 26 gospodarske jedinice Čvrsnica (dio) u prirodnoj progresiji na površine planinskih livada

Photograph 4. Natural young Bosnian pine in experimental plot 2, compartment 22b in the Management Unit Čvrsnica (part)
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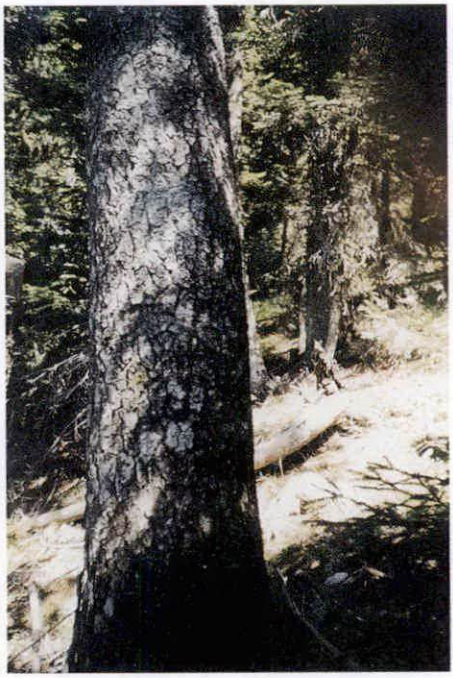

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HABITAT CONDITIONS FOR THE INTRODUCTION OF THE BLACK GROUSE (*Lyrurus tetrix* L.) INTO THE AREA OF GORSKI KOTAR

ISTRAŽIVANJE STANIŠNIH UVJETA ZA NASELJAVANJE MALOGA TETRIJEBA (*Lyrurus tetrix* L.) U GORSKOM KOTARU

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The paper studies the necessary conditions for reintroducing the black grouse into the mountains of Gorski Kotar.

Research focuses on synecological conditions needed for the survival of the black grouse. The chosen localities in which research was conducted included the wider massifs of Risnjak and Snježnik. The conditions and possibilities of raising the black grouse in Gorski Kotar were studied and evaluated.

The position of the black grouse in the classiiication table was shown both textually and graphically, and morphological-biological and ecological properties of the species were dealt with.

The author studied a number of features including climatic, hydrological and geomorphological factors, the degree of pollutants in the soil, vegetation and anthropogenic influences.

Meteorological data from the meteorological stations in the area were used. Fourteen plant communities were found in Gorski Kotar, of which only five were included in the study.

Hunting was also dealt with. A total of 56 animal species included 21 mammal and 35 bird species. Ten furry and 7 feathery predators were studied within the research.

No significant differences were found between the mountainous vegetation of the Alps - the habitat of the black grouse - and the vegetation of the mountains in Gorski Kotar. Therefore, the nutritive potential is satisfactory.

The wealthy flora of the studied area comprises 284 species, of which 28 plant species are important in the diet of the black grouse. The entomofauna in

the studied area is very rich: a total of 19 groups of arthropods were found, among which the order Collembola plays an important role in the black grouse diet.

According to the research, small predators are evenly distributed over the whole area in the summer, while in the winter their presence is higher at lower altitudes, and virtually non-existent at higher ones.

There is almost no influence of anthropogenic factors, since the larger portion of the region is part of the National Park "Risnjak".

This comprehensive research leads to the conclusion that there are favourable conditions for the introduction of the black grouse into the area of Gorski Kotar. The conclusion is based on the existence of optimal habitat conditions.

The meteorological data of the studied habitat and that used for comparison show significant differences.

The vegetation picture of the studied habitat has several advantages over those in Italy or Slovenia.

The wealth of the arthropod fauna, combined with anthropogenic factors, makes this habitat suitable for the growth and survival of the black grouse.

Key words: *Lyrurus tetrix*, synecology, reintroduction, *Collembola*, habitat

INTRODUCTION
UVOD

The borders of Gorski Kotar are difficult to define briefly. It was Pleše who best defined the natural area of Gorski Kotar (1993). According to this author, Gorski Kotar comprises the Čabar and Vrbovsko communes, the former commune of Delnice (now the commune of Skrad), then Ravna Gora, Brod Moravice, Mrkopalj, Fužine, Lokve and Delnice, and the peripheral parts of the communes of Duga Resa, Ogulin, Crikvenica and Rijeka.

The heart of Gorski Kotar, covering an area of 127,300 ha, is made up of the former communes of Delnice, Čabar and Vrbovsko (Klepac 1997).

The issue under study relates to the area of the Čabar commune where the highest peaks in Gorski Kotar are: Risnjak (1,528 m), Snježnik (1,506 m), Guslica (1,490 m), Jelenc (1,442 m) and others.

It is important to point out that there are only 18.5 inhabitants per 1 km^2 in the commune, compared to the Croatian average of 84.6 inhabitants per 1 km^2. The management of the economy over many years and a poor national policy in the past have changed the way of life. There is no extensive cattle breeding, and agricultural homesteads are being abandoned.

The area of Gorski Kotar is inhabited by all kinds of big and small game listed in the Hunting Act. Attempts are being made to study the conditions for the enrichment of the already wealthy fauna in Gorski Kotar with another forest species - the black grouse.

A number of European countries have begun introducing forest birds both into old and new habitats.

The idea of introducing the black grouse into Gorski Kotar is not new. In fact, it was first expressed in the middle of the 19th century. In the 1960s, research was directed towards mountain massifs ranging from 1,100 to 1,500 m above sea level in the Čabar commune. Habitat conditions in Gorski Kotar are similar to those in Slovenia and Bosnia and Herzegovina. The black grouse and the capercaillie live in similar habitats; consequently, their feeding and reproduction requirements are also assumed to be similar.

Therefore, it is reasonable to examine the possibility of introducing the black grouse into Risnjak (1,528 m) and Snježnik (1,506 m).

The black grouse is more easily raised than the capercaillie. The artificial raising of these two forest bird species, started in the area of the Forest Office Ravna Gora in 1987, has regretfully been discontinued.

Research into the problem of introducing black grouse into natural habitats is supported by the recommendations contained in the convention on the protection and re-introduction of endangered species.

Mr Marijan Filipović, the owner of hunting grounds in the "Snježnik" area suitable for the study and possible introduction of the black grouse, has undertaken to introduce the black grouse into the area if habitat conditions prove convenient.

For this reason, we have conducted the research entitled "The study of habitat conditions for the introduction of the black grouse (*Lyrurus tetrix* L.) into the area of Gorski Kotar".

There are some written documents, albeit scarce, indicating that the black grouse used to inhabit hunting grounds in Croatia. We still have to answer the following question: are we introducing a species that used to live here before, or are we dealing with a new species in the area?

SUBJECT OF STUDY
PREDMET ISTRAŽIVANJA

Research dealing with synecological conditions for the growth of the black grouse (*Lyrurus tetrix* L.) is aimed at exploring the suitability of the Gorski Kotar region for its introduction. This will be achieved by carrying out comprehensive synecological research.

In order to study the ecology of the species, our own research and insights will be combined with very valuable past research and results.

It is very difficult to include all biotic and abiotic factors in one paper, especially as there is a very broad vertical and horizontal distribution pattern of the species in the world.

The following question remains to be answered: is the subject of the research the return of a past autochthonous species, or is it the study of all the conditions necessary for the introduction of the black grouse as a new species?

The ecology of the black grouse indicates that the mountain massifs of Gorski Kotar might provide potential habitats for the species.

After consulting experts on the problem of the management and growth of this species in the Alpine region, analysing the results of Croatian researchers and scientists, and studying relevant literature, the following localities were chosen: Veliki and Mali Risnjak, Snježnik, Međuvrh, Guslica and Jelenc. Wider regions of Croatia, such as other peaks in Gorski Kotar or the Velebit range, have not been included in the paper.

RESEARCH GOAL
CILJ ISTRAŽIVANJA

The movement for the protection of nature in the world gained momentum at the end of the 19th century. The protection of nature is a broad notion, and so associations and movements dealing with specialised aspects of the problem have been founded. One of these is concerned with the domestication of endangered animal species. The introduction of endangered species is particularly recommended for those species that are not capable of settling into new regions naturally. One of the goals of this research is to enrich the fauna of Gorski Kotar with a new species, the black grouse. There are written records that this species inhabited Croatian mountains, and even lowland areas around rivers.

The research received financial support from the new owner of the state hunting ground "Snježnik", whose obligation to introduce new species is laid down in the hunting ground management contract. The aim of the research is threefold: to prove that the introduction of black grouse is ecologically justified, to serve as a foundation for drawing up a new, scientifically based introduction programme, and to study and analyse all aspects of the permanent settling of the new species. Croatian and foreign research results and insights have been used to achieve these aims.

DISTRIBUTION OF BLACK GROUSE IN EUROPE
RASPROSTRANJENOST MALOGA TETRIJEBA U EUROPI

The living area of the black grouse is limited to the Holarctic region. It is distributed across the Boreal and sub-Arctic forests in northern Europe and a part of central Europe, with some isolated populations in the Alps and some other mountainous regions (primarily as a Tertiary relict). It is also distributed in western Europe.

In Scandinavian countries, the population of black grouse ranges between 300,000 and 330,000 birds, while in central and western Europe the numbers vary greatly. Most of the birds in this part of Europe, amounting to about 290,000 samples, are found in Poland, followed by Great Britain with 10,000 birds. A considerably smaller number of birds are found in the Czech Republic and Western Germany, followed by Belgium with only about 400 individual birds, and the Netherlands with about 250. The smallest population of only about 50 birds exists in Denmark.

In Slovenia, the nearest potential black grouse habitat to Croatia, the species lives mostly in the Alps (the Julian Alps, the Kamniško-Savinjske and the Karavanke Alps, in which it is especially endangered, and in Kobariški Stol and Kolovrat (Mikuletić 1984).

Until recently, the black grouse was also found in the mountains of Bosnia and Herzegovina, from where it has now completely disappeared, and in the mountains of Montenegro, where it was even artificially introduced into the area of the Durmitor Mountain.

With regard to Alpine populations of black grouse, data are only known for Austria, where it is estimated that there are about 14,000 birds, and for France, with about 1,000 birds. The black grouse also exists in Italy and Switzerland. However, the data are not reliable, because some authors cite the number of observed cocks, while others cite the number of couples. What is important is that in its entire range of distribution, the black grouse is not endangered, with the exception of some isolated populations whose existence is under serious threat. A decline in the population was noted on the edges of the Holarctic region, and particularly in its lowland part, where a change in the use of land has diminished the area of the ecosystem important for the survival of the black grouse (Cayford 1987).

According to Muller (1987), the main cause of such a progressive decline in the black grouse population in central Europe lies in an increase of isolated black grouse habitat enclaves. These enclaves should be mutually linked so that genetic contact among all or some isolated populations can be re-established. The same author claims that protection measures, including those against hunting in "dancing grounds" called "leks", sometimes come too late. Black grouse populations in the Alps are more stable due to a much smaller extent of decline (Bauer 1984). There, black grouse habitats are located at higher altitudes (1,500 – 2,000 mm) where there is very little activity by man, and consequently, natural habitats are better preserved.

A number of authors (Meile 1982, Meile et al., 1984, Gossow 1987, Miquet 1987) suggest that Alpine populations are most affected by tourism, cattle-breeding and hunting.

Meile (1982) compares the physiological effects of disturbances in the winter period on a population decrease with a decrease resulting from birds' deaths after colliding with the metal ropes of cable cars and ski lifts.

The destruction of the natural environment caused by building infrastructure or by other aspects of human activities has brought about stressful conditions (Božić 1983).

POSSIBLE PRESENCE OF BLACK GROUSE IN CROATIA IN THE PAST
DOSADAŠNJE SPOZNAJE O EVENTUALNOJ PRISUSTNOSTI MALOGA TETRIJEBA U HRVATSKOJ

Although black grouse is classified as game by the Hunting Act of the Republic of Croatia, at present this forest species is non-existent in the country. However, there are written documents on its past existence in these regions. Among these

texts, there is no mention of Gorski Kotar, although it offers the best conditions for its growth and survival.

There are indications that the black grouse lived in the forests of the Croatian Military Border (Ettinger 1857), and that it favoured mountain forests to lowland ones. Several black grouse birds flew from Bosnia into Slavonia around 1850 and settled in the vicinity of Nova Gradiška. They remained in shrub-covered meadows and thickets for three years until hunters wiped them out with over-hunting. The same author says that the black grouse also inhabited Mount Motajica (Bosnia and Herzegovina), from which birds later flew into the surroundings of Nova Gradiška.

Prof. Đurašin cites the data by Prof. Brusina, according to which three or four pairs of black grouse settled in the Croatian Zagorje region in the autumn of 1887, where they nested in 1888, and then moved away.

According to Knotek, the hunting chronicler of that period, individual birds were shot during their sojourn in Dalmatia. They were also spotted in the districts of Bihać and Cazin, in the nearest vicinity of Croatian Banija and Kordun.

Until the end of the last century, there was a considerable number of black grouse in Bosnian Posavina, from where they disappeared for unknown reasons. According to Đurašin and Knotek, the last bird was shot near Bosanska Dubica in 1885, while they were last seen in the Banja Luka area in 1886. These data are important because the regions are located in the nearest vicinity of Croatia.

Black grouse disappeared from these regions as a result of the Austrian colonisation after the occupation of Bosnia (Knotek 1889).

The colony of three or four pairs of black grouse that settled in the Croatian Zagorje did not survive. Despite being protected by Count Bombelles, the owner at that time of hunting grounds in the area, one bird was shot as "an unknown bird species". It seems the small colony could not be left in peace even 110 years ago (Gjurašin 1901).

As seen from the above, although data on the existence of the black grouse in Croatia are scarce, they testify to their past presence in Croatia and serve as an incentive to introduce them in the future.

MORPHOLOGICAL AND ECOLOGICAL PROPERTIES OF BLACK GROUSE
MORFOLOŠKO-EKOLOŠKE OSOBITOSTI MALOGA TETRIJEBA

CLASSIFICATION OF THE SPECIES (*Taxonomy*)
SISTEMATIKA VRSTE (*taksonomija*)

The black grouse belongs to the class birds (*Aves*). There are 24 orders in the class. Starting from the oldest fossil forms in the Jurassic period, of which we know the prehistoric bird, different variations have evolved, resulting in the present or-

ders. These variations are shown in the birds' genera tree. The size of certain branches not only denotes the number of living species, but also the approximate numerical development in the course of Earth's history. A small number of orders containing many species (for example, *Passeriformes*) are shown in a much smaller area than the number of their taxons requires.

A darker colour on the scheme denotes 18 orders whose representatives live in Europe, and a lighter colour denotes 6 non-European orders. From the middle of the semi-circle, the orders are arranged first leftwards (adapted birds, mostly maritime, order I - XII) and then from the middle rightwards (up to Passeriformes, order XIV - XXIV).

According to Bernd and Meise (1952), the class birds is divided into two subclasses:

1. subclass: *Palaeornithes* - these are extinct species, including both *Archaeopteryx* and *Archaeornis* with a long tail spine.
2. subclass: *Neornithes* - these have a typical bird's tail, and are divided into two orders.

I supra-order: terrestrial and marsh birds (*Geornithes*), living on the ground or in the water. They include the following orders:

order: *Crypturi*, they have no representative in Europe
order: *Ratitae*, they have no representative in Europe
order: *Galli*
order: *Grues*
order: *Limicolae-Lari*
order: *Anseres*
order: *Phoenicopti*
order: *Cressores*
order: *Accipitres*
order: *Stegonopes*
order: *Tubinares*
order: *Sphenisci*
order: *Pygodes*

All are shown on the fowl genera tree.

II supra-order: birds living in trees and bushes (*Dendromithes*). They consist of the following orders:

order: *Cuculi*
order: *Columbae*
order: *Psittaci*, they have no representative in Europe
order: *Striges*
order: *Caprimulgi*
order: *Trogons*, they have no representative in Europe
order: *Coracii*
order: *Colli*, they have no representative in Europe
order: *Macrochires*

order: *Pici*
order: *Passeres*
order: *Galli*

On the hypothetical fowl genera tree (according to W. Meise, 1952), groups (in this case families and subfamilies) living in Europe are marked with a darker colour. The distribution across the earth's surface is presented with small circles. The bottom left part of the circle, marked red, shows the distribution across the Western Hemisphere, for example North America. The top right part of the circle shows Europe and North Asia, while the old world south of the Himalayas and (or) south of the Sahara is shown in the bottom right part of the circle. A grey and blue-green colour denotes areas where fossils were found.

The black grouse was classified in the family of real fowl (*Phasaninae*), which has several genera. One of these is the genus *Lyrurus*, to which *Lyrurus tetrix* belongs.

GEOGRAPHICAL SUBSPECIES OF THE BLACK GROUSE
GEOGRAFSKE PODVRSTE MALOGA TETRIJEBA ILI TETRIJEBA RUŠEVCA

Naturalists differentiate between two species of black grouse: *Lyrurus tetrix* L. and *Lyrurus mlokosiewiczi* Tacz. which lives only in the Caucasus.

A large number of mutually different geographical subspecies have been formed in a wide belt of the *Lyrurus tetrix* habitat. The only exception is *Lyrurus tetrix viridanus*.

The following geographical subspecies are listed in specialist literature (Fuschiberger, Boback, 1956):

1. *Lyrurus tetrix* L. - lives in Western Europe, except in Great Britain, Scandinavia and Finland. With regard to its large distribution range, this subspecies is distinctly uniform. The only difference is seen in hens, which are mostly grey in the western part of the distribution range.
2. *Lyrurus tetrix britannicus* - is an endemic subspecies of black grouse living only in Scotland and Great Britain. It is characterised by glossy reddish feathers, while the plumage in hens is very dark. It is smaller than the *Lyrurus tetrix*; the cock weighs about 1,200 g and the hen about 1,000 g.
3. *Lyrurus tetrix viridanus* - lives in a forest-steppe belt in south-west Russia between the rivers Don and Irtish. It is characterised by a metal-greenish sheen of plumage in cocks. The colour of the upper-side plumage in adult cocks is similar to that in hens (brown with light stripes). Cocks weigh about 1,100 g, and hens about 900 g.
4. *Lyrurus tetrix jenisseensis* - inhabits south Siberia, from Irkutsk in the west to north Altai in the south. Cocks have plumage with a violet sheen.
5. *Lyrurus tetrix mongolicus* - is slightly larger and heavier than the above birds. It lives in forest regions around Tian Shan, Alatan, Tarbagataia and north-west Mongolia.
6. *Lyrurus tetrix baicalensis* - is the largest subspecies of black grouse. Its range of distribution extends around the Baikal Lake up to north-west Mon-

golia. Male birds reach an average weight of up to 1,380 g and females a weight of 1,030 g, although some shot birds weighted over 2,460 g. Similar to the *Lyrurus tetrix viridanus*, these birds also have a distinct greenish metallic sheen of plumage.

7. A subspecies of the *Lyrurus tetrix ussuriensis* inhabits the westernmost region encompassing Manchuria, the river Ussuri and a part of the river Amur. Cocks have a distinct olive-green sheen, and hens are characterised by bright ginger-reddish plumage.

The other species, *Lyrurus mlohosiewiczi* Tacz., or the Caucasian grouse, lives in the Caucasian region completely isolated from the former species. It differs greatly from all the above mentioned subspecies. Its mostly black plumage has no gloss, Its tail feathers are longer, and the lyre-shaped tail feathers are indistinct. There are no subspecies.

A comparison of individual subspecies reveals some differences. The colour of plumage in females reflects the climate: south-eastern Russian subspecies have a dark colour, while eastern ones have an even darker one. A green sheen in the plumage of western male birds changes into a blue one in European subspecies.

In eastern subspecies, tail feathers are longer, and outer feathers are less curved. It could be concluded that in the past, the black grouse spread from the east towards the west. Even before the beginning of the Ice Age, it spread as far as the west coast of Europe, where a British subspecies was formed in the course of a long period.

MORPHOLOGICAL FEATURES OF THE BLACK GROUSE
MORFOLOŠKE OSOBITOSTI MALOGA TETRIJEBA

As in the capercaillie, there is a distinct difference (sexual dimorphism) between males and females of the black grouse. Male birds are predominantly black and brown in colour with black and white stripes. A white stripe stretches along the upper feathers, while the plumage on the belly is grey to white. In addition, the black grouse has a white patch on the wing joint.

The most important feathers are the tail feathers, of which four are curved in the shape of a lyre. In some rare cases, very old male birds have five curved feathers on the outer part of the tail. Some cocks have short, wide and very curved tail feathers, while others have long, narrow and less curved tail feathers. Grouse of three or more years have fully developed tails, A dark-metallic sheen on the feathers are characteristic of older cocks.

Young males have dark-brown plumage on the back and wings.

The female is black to ginger-brown, mottled with numerous whitish stripes and patches. Such colour provides ideal protection, so a hen sitting on eggs is difficult to notice. Young hens are lighter in colour and old ones have darker, more colourful and distinct plumage.

Chicks are brown, with a lighter under-side. Chicks of the black grouse are characterised by a dark patch on the head, which differentiates them from chicks of the capercaillie.

All game birds have wattles, fleshy areas of skin above the eyes, which are bright red in male birds. In the breeding season, wattles are especially prominent and may cover the crown of the head. In the moulting period, these fleshy pendulums grow much smaller.

Similarly to the capercaillie, the black grouse also has feather-covered legs. It does not have calcars. There are horny wattled growths on the side of the claws; these are stunted feathers that fall off during moulting, to be replaced by new ones that grow in the autumn. A male bird differs from a female in size. A cock is 58 - 65 cm long, and has a wing span between 90 and 100 cm. A hen is 45 - 50 cm long, and its wing span reaches 75 cm. Males weigh from 1.10 to 1.15 kg, and only rarely 2 kg.

Henrich (1969) weighed 453 male birds killed in Austria and obtained the following numbers:

Table 1. Weight of male birds (Henrich 1964)
Tablica 1. Težinski raspon izvaganih pijevaca (Henrich 1964)

Ordinal number *Redni broj*	Weight range *Raspon težine*	Number of weighed male birds *Broj izvaganih pijevaca*	%	Cross weight (g) *Prosječna težina (g)*
1.	820- 980	12	2.64	920
2.	1000-1090	23	5.07	1031
3.	1100-1190	131	28.91	1157
4.	1200-1290	167	36.86	1232
5.	1300-1390	77	17.00	1348
6.	1400-1490	31	6.86	1408
7.	1500	5	2.66	1500
8.	1550	1	2.66	1550
9.	1600	2	2.66	1600
10.	1800	2	2.66	1800
11.	1870	1	2.66	1870
12.	1900	1	2.66	1900
Total - *Ukupno:*		453		1232.63

Most males were in the fourth group, for which the cross weight of all examined birds was taken. It should be pointed out that low weight in young males is common. When winters are harsh and birds fail to find a sufficient number of gastric stones (gastrolites), they are forced to feed on low-calorie food, and their organisms resort to their own reserves.

ECOLOGICAL CONDITIONS FOR THE DEVELOPMENT OF THE SPECIES
EKOLOŠKI UVJETI RAZVOJA VRSTE

In Croatia, the habitats of the black grouse and capercaillie are located in high mountainous regions. Both the black grouse and capercaillie inhabit the massifs in the Alps, which is confirmed by the fact that black grouse are found in the Slovenian

mountains located near Croatia. The massifs are characterised by the plant association *Lonicero-Pinetum mugi* Ht. The habitat of the black grouse also extends into the area of the association *Homogino sylvestris-Fagetum sylvaticae* Ht.

The black grouse in the Carpathians also lives in the belt in which forests fight for survival. This is the area of the upper border of forests 1,600 - 2,000 m above sea level. The border of forest vegetation in the locality under study is lower, and reaches 1,300 to 1,400 m.

Important vegetation of grouse habitats consists primarily of mugho pine (*Lonicero Pinetum mugi* Ht.). In Slovenia, this vegetation is called *ruševje*, hence the local name tetrijeb *ruševac* (black grouse). Apart from the pine, other shrub species are also important for the survival of black grouse. These are juniper (*Juniperus nana* L.), mountain ash (*Sorbus aucuparia* L.), *Rododendron hirsutum* L., and, in acid soils, cowberry (*Vaccinium vitis idaea* L.) and bilberry (*Vaccinium myrtilus* L.). Similarly to the mugho pine (*Pinus mugo* T.), beech (*Fagus sylvatica* L.) also plays an important role, but it does not provide sufficient wind protection. Of tree species in Slovenia, the most important is the European larch (*Larix europea* L.), which grows individually or in smaller, rarefied groups.

The climate of the black grouse's living space is harsh and severe, characterised by low temperatures, long winters, abundant snow and strong, frequent winds. However, the black grouse has adapted relatively well to these conditions. Problems arise from insufficient quantities of the gastric stone reserves the grouse needs to process tough plant food in the winter period.

NUTRITION
PREHRANA

The black grouse basically feeds on food of plant and animal origin. Food of plant origin is consumed throughout the year, while that of animal origin only during snow-free periods and higher temperatures. Food of animal origin is essential for chicks, especially in their first months of life. Adult birds need animal food in the moulting period.

There are several methods of finding out what the black grouse feeds on:

- by examining the stomach contents of killed birds
- by examining and analysing birds' droppings
- by observations in nature.

Research dealing with the kind of plant and animal food consumed by the black grouse has been conducted in Switzerland, Denmark, Norway and Russia. Some research carried out in Slovenia (Šušterić 1955) is of special interest for our region. In each of the studied countries, the food content was different because it reflected the different vegetation of these regions. The same applies to some small animals that the black grouse feeds on.

The results obtained by the Russian researchers Lobačev and Ščerbakov, who examined the crops of 142 grouse, are very useful (Mikuletić 1984).

Table 2. The number of examined crops of grouse killed in Russia
Tablica 2. Broj istraženih volja tetrijebova odstrijeljenih u Rusiji

Month - *Mjesec*	I.	II.	III.	IV.	V.	VI.	VII.	VIII.	IX.	X.	XI.	XII.
Number of examined crops *Broj istraženih volja*	10	7	1	14	12	8	15	24	11	34	4	2

The food consisted of a large number of plant species (62) or their parts (buds, leaves, needles, fruits and seed) and a smaller number of animal species (36). Among the former, needles of common pine were the most numerous, followed by the fruits and leaves of various plants, mostly blueberry and cranberry, while among the latter, the most frequently found were the remains of ants.

As was mentioned before, food of animal origin, usually ants, prevailed in the crops of chicks. Similar research was done in Scotland (Mikuletić 1984) and the findings were identical, with the only exception of animal food. This was lacking, because the grouse were killed in the winter period when no animal food is available.

Slovenian analyses also correspond with the ones above, with the only difference being that the crops of the examined grouse there also contained beech and willow buds. The pH values of used food have a significant percentage, ranging from 5.5 to pH 6 (Mikuletić 1984).

Four crops of capercaillie and one of black grouse were examined at the Veterinarian Faculty of Zagreb University (Koritnik 1960), with the following results:

1. The crop of a capercaillie (Gorski Kotar) was examined on 10 May 1956. The content: mostly spruce and fir needles, a distinct smell of turpentine oil, pH = 5.
2. The crop of capercaillie (Slovenia) was examined on 11 May 1956. The content: spruce and fir needles, a distinct smell of turpentine oil, pH = 5.5.
3. The crops of two capercaillies (Gorski Kotar) were examined on 12 May 1956. They contained mostly spruce needles and grass. A pronounced smell of turpentine oil, pH = 5.5 - 6.
4. The crop of a black grouse killed in Slovenia contained needles of mugho pine and various grasses. A distinct smell of turpentine oil, pH = 6.

These data are given because the future black grouse habitats in Croatia, now populated by capercaillie, have identical nutritive potentials as do the habitats in neighbouring Slovenia (pH values of examined food in crops are identical).

Food plays a major role in the survival of the population, chicks in particular. In the first days after the chicks are hatched, the hens feed them with the tips of grasses and leaves, various seeds, ants' eggs, insect larvae and insects until the young birds start looking for food themselves. A mother grouse tears off the tops of leaves with its bill and feeds the young from the bill. This is the difference between the feeding patterns of domesticated chicks and grouse chicks, although domesticated females also possess a rudimentary instinct; when it catches a small fly, it gathers its young with the intention of feeding them from its bill. This manner of fee-

ding the young from the bill does not last long, and the young quickly learn to feed by themselves.

CALLING AND BREEDING
GLASANJE I PARENJE

The breeding season begins at the end of March and lasts for six to seven weeks. A grouse itself chooses a suitable breeding place that is always on the ground, called the lek. It is located at north-eastern expositions in bare swards or poorly inhabited groups of trees. During the mating period, a grouse lets out specific cries.

Several authors have described the specific nature of these cries. In his comprehensive monograph on the black grouse, Fuschberger (1956) mentions a cry that sounds like "*krokataka*". Some authors suggest that such a cry has an aggressive character and is used only when the bird defends its territory (Boback 1968).

Slovenian authors divide the cry into two parts: whistling and high-pitched calling (Mikuletić 1984).

During the breeding process early in the morning, a male lets out a kind of whistling sound. When "whistling", the grouse usually stands on the ground with its constricted throat turned upwards and its bill open. Sometimes, as mating draws to its climax, the bird conducts short flights and jumps in the air fluttering its wings. Towards the end of the mating process, these flights grow longer and can cover several hundred metres.

The most important part of the cry is "gruljenje" (high-pitched sounds). It lasts the longest and is heard the farthest. Unlike the capercaillie, during the singing phase the black grouse can see and hear extremely well, which has led hunters to say: when a black grouse sings, it has an eye on each of its feathers.

Most singing during the mating season is done in morning hours. When the weather is calm, singing may last several hours a day at the peak of mating.

When daily singing is over and female birds are drawn to the area, a cock and hens fly to a chosen lek where the reproductive process is accomplished.

In the winter period, black grouse birds assemble in larger or smaller groups. These groups are sometimes single-sexed and sometimes mixed. In Finland and Russia groups of several dozen birds are common, but there have been cases of several hundred birds together. With time, the grouse leave their groups (flocks) and visit leks, where they finally remain.

Leks are permanent territories where cocks display by sounding their "nuptial" cries and mate. In Finland, male grouse often display on frozen lakes.

If there are several grouse in a lek, each tries to conquer and retain a certain territory for itself. One grouse signals to another its readiness to defend the area by spreading its tail and lowering its wings. Fights among males are quite common, with the defeated bird withdrawing from the battlefield - lek - and looking for another suitable mating place.

Female grouse move to leks when territorial boundaries are not yet defined. At this stage they do not show any interest for males. Their interest is aroused only af-

ter the territories have been defined, which is signalled by high-pitched cries from the males. If a new male flies into another male's territory, the original male becomes restless and often jumps up in the air and conducts short flights.

Females usually choose their mating partners from the males which have secured the best leks, that is, the strongest and the most active males. An active grouse can fertilize up to four females in one morning, while its neighbour, despite having its own lek, may not fertilize any. Therefore, male birds which females choose for mating should nót be killed in hunting. When females are fertilized, mating and singing are over, and the leks are occupied by young males that were not allowed access to the grounds in the presence of older ones (Mikuletić 1984)..

NESTING, EGGS, CHICKS
GNIJEŽĐENJE, JAJA, PILIĆI

When breeding is accomplished, a hen finds a suitable sheltered place and builds a nest on the ground. The nest is a shallow hole in the ground lined with dry leaves, grass, moss and an occasional hen feather. A female may lay 6 - 12 red-brown eggs mottled with dark brown patches. During this process it frequently leaves the nest. When the last egg is laid, the hen starts sitting on them, and chicks are hatched after 25 - 27 days. In that period, the hen constantly sits on the eggs and hardly ever leaves the nest, even in the face of imminent danger, which might end fatally for the hen and the nest.

Chicks are yellow-brown in colour with a dark brown stripe on the head. Immediately upon hatching they are capable of following the extremely caring mother. Wing feathers grow very fast, and chicks can fly short distances as early as a few weeks after being hatched.

In the first days of life chicks feed exclusively on food of animal origin: larvae and worms of various forest insects and ants. They start feeding on food of vegetable origin at a later stage.

For the first few days of their life, the chicks usually stay under their mother's body, as they need warmth to survive.

Later, the periods of remaining under the mother's wings grow shorter and those of looking for food, playing and staying in the sun bevome longer.

When the third week is over, the hen does not allow the chicks to be warmed under its body, but forces them to lead more independent lives, but still in the family circle. With the coming of spring, families separate and go their own ways, thus beginning the life cycle anew.

THREAT TO THE POPULATION
UGROŽENOST

The black grouse finds it extremely difficult to adapt and is quick to react to negative factors. In less favourable habitats this species survives if young chicks have good conditions for growing up (warmth and dry weather). If these require-

ments are met, new habitats can be formed, but they are abandoned as soon as the necessary conditions are disturbed.

The climate has a profound influence on the survival or death of the population. Decisive climatic factors in grouse habitats include long-lasting and severe winters accompanied by icy rains, harsh late frosts, thick fogs, high air humidity, sudden hail and other factors. The greatest losses, caused mainly by late frosts and sudden drops in temperatures, occur in the developmental stage of chicks.

Apart from climatic influences, the stability of the population can be adversely affected by other biotic factors. In this sense, some animal species inhabiting or passing through black grouse habitats are particularly important. These are: the stone marten (*Martes foina* L.), weasel (*Mustela nivalis* L.), fox (*Vulpes vulpes* L.), lynx (*Lynx lynx* L.), wild boar (*Sus scrofa* L.), hawk (*Acipitridae*), eagle (*Aquila*) and others. Goshawks (*Accipiter gentilis* L.) are especially dangerous, because 90% of their prey are forest birds (Wilkman, Linden 1981).

The mainly harmful influence of man on black grouse habitats (hunting, forest management, winter tourism, infrastructure, mountaineering, etc) adds to the negative trends in the survival and development of grouse populations. Some of the mentioned activities have caused the black grouse to completely disappear from permanent habitats in Central Europe.

Parts of habitats on forest edges are the first to decline, followed by those in central parts.

In general, the negative impacts on the survival of black grouse populations can be divided into four groups:

- short-term impacts - enemies
- long-term impacts - habitat formation
- impacts that are difficult to deal with - diseases
- impacts that cannot be influenced - climate.

Positive effects on the survival of the black grouse can be achieved primarily by reducing the number of carnivores to an acceptable level. However, the intensive hunting and destruction of these animals is strictly forbidden, as this might lead to the extinction of a species.

Popp (1974) examined the causes of the disappearance of the capercaillie in Western Germany in 1967 and 1968, and concluded that the death of the capercaillie was caused by:

wire fences	27%
goshawks	23%
foxes	20%
martens	13%
racoons	7%
unknown	10%

As the habitats of the capercaillie and black grouse often overlap or exist side by side, it can be assumed that these percentages also relate to the disappearance of the black grouse.

Data obtained from some other research show that losses in capercaillie and black grouse populations are extremely high. In Russia, it was found that on average 40% of nests perish, followed by a further loss of 40% of hatched chicks in the next three weeks. These losses are responsible for the final reproduction rate of about 20%.

Muler-Using (1965) carried out a survey in a 1,000-ha experimental plot and found that foxes, martens and goshawks destroyed 1/3 of the capercaillie and black grouse population per year.

The goshawk (*Accipiter gentilis* L.) is dangerous only in lowland regions of Northern Europe, because its living space does not extend to the upper border of forests, although it might occasionally venture there.

The golden eagle (*Aquila chrysaetos* L.), whose living space concords with that of the grouse, may also have a negative impact on the population. In Germany, an examination of the remains of 302 animals caught by golden eagles revealed the remains of 16 black grouse (5.6%), while that of 5,111 animals caught by long-eared owls included 16 black grouse, or 0.31%.

Hunters report that a singing grouse stops its cry when a long-eared owl is heard.

The development of a black grouse population is strongly affected by human activities, such as hunting, cattle breeding, forestry, skiing tourism, mountaineering and other factors. In regions with highly developed winter tourism natural grouse habitats are seriously threatened. Glutz von Blotzheim (1972) found that several dozen black grouse used to sing simultaneously on the Riederfurk saddle in Austria. When ski lifts were built there, the number of leks and grouse were halved, and only three birds remained.

One of the negative factors that have an adverse effect on breeding processes is over-hunting. Mistakes are usually made in areas where leks are found close to hunting grounds. In such cases, each hunting ground authority counts the number of birds in their own hunting grounds (however, animals do not recognize administrative borders) and plans the number of birds to be killed on the basis of such counts. Another big mistake in planned hunting occurs when the best (dominant) male bird is killed before mating. When this happens, females are left without their best mating partners and do not reproduce.

Climate does not affect grown birds, because they are usually well adapted to harsh weather conditions in their living space. When winters are particularly severe and temperatures low, a black grouse makes burrows in the snow and shelters there, because snow is an excellent thermal insulator. Some Russian scientists found that the temperature in a snow burrow dug by a hazel grouse was -10°C, while in the open it was -48°C.

MY OWN RESEARCH
VLASTITA ISTRAŽIVANJA

GENERAL OBSERVATIONS ON THE AREA UNDER STUDY
OPĆENITO O ISTRAŽIVANOM PODRUČJU

According to available written sources, the black grouse is distributed across the whole of Europe. Foreign research is useful for making analyses and comparisons. Using foreign results, detailed research has been done and descriptions made of numerous factors important for the survival and undisturbed development of black grouse populations in the mountains of Gorski Kotar, in the first place Risnjak and Snježnik.

The idea of introducing black grouse into Croatia is not new. In 1960, the Institute of Research in Forestry and Hunting, Zagreb, Republic of Croatia, dealing with this issue, recommended the following mountain peaks in south-west Croatia as suitable habitats for this species: Risnjak, Snježnik, Guslica, Međuvrh, and Jelenc. These mountain massifs are the subjects of our research.

The research area includes a small part of Gorski Kotar. This area has suffered heavily from industrial air, water and soil pollution for over 20 years, and so it was necessary to establish whether these factors were still within tolerance limits for the introduction of the black grouse. Since habitat conditions are very stable, our research focused on climatic, hydrographic, pedological and vegetatitive characteristics. The survival of a black grouse population can also be adversely influenced by other animal species, primarily by predators, so this problem was also included in the research.

Man has always tried to change and adapt natural processes to suit his own needs without much regard for possible detrimental impacts on the survival of numerous animal species. His irrational actions have often changed a landscape to such an extent that many plant and animal species have become endangered or even eradicated.

Gorski Kotar is unfortunately a storage place for all the harmful substances from neighbouring industrial centres in the country and abroad. The most dangerous effects come from coal-driven electric power stations, followed by motorcar exhaust fumes that contain sulphuric and nitrogenous compounds responsible for acid rain and acid snow. As a result, a decline of forests in Gorski Kotar has assumed such proportions that there are fears of an ecological catastrophe and a "dusk of Gorski Kotar forests" (Pleše 1993).

Man's influence is not limited only to indirect impacts via pollutants, but also to a direct influence on the population of black grouse. This can be crucially important both in a positive and a negative sense. Therefore, our research pays special attention to anthropogenic factors as well.

Habitat conditions
Stanišne prilike

The survival of any species is determined by animate and inanimate site factors. Crucial factors for the topic in question are the geographical position and borders, climatic factors, hydrological relationships, soil and vegetation, hunting activities and the more important animal species in the region.

All of the factors mentioned above were dealt with in detail, because all play an important role in the survival of the species.

Despite the fact that hunting is less important for the topic at this stage, special emphasis was still put on the hunting history and culture in the region. We believe that the black grouse will soon be the subject of hunting management.

Geographical position and borders
Zemljopisni položaj i granice

Gorski Kotar is situated in western Croatia. In the north and north-west it borders with Slovenia, in the south-west and south with the Croatian Littoral, and in the east with the Ogulin area. The northern, north-western, south-western and southern borders of Gorski Kotar are determined by natural and political-administrative borders.

In the words of Hirc (1918), enamoured with Gorski Kotar,

"*This part of our beautiful homeland, bounded in the north by the rivers Kupa and Čabranka, in the south by the Adriatic Sea, in the west by Istrian and Slovenian mountains, and in the east by the Senj Ridge, has been called Gorski Kotar from time immemorial.*"

Laszowski (1923) was slightly more precise in describing the borders of Gorski Kotar:

"*In order to define the main borders of this region (Gorski Kotar), a line should be drawn from Trsat to Prezid, from there south-east to Brod, and then along the Kupa as far as Podstjen, from there to Vrbovsko and Mrkopalj, then to Lič, and from Lič straight to the boundary with the Senj region and the sea.*"

Neither is this definition precise enough, because it does not include several parts of Gorski Kotar. It was Burić (1983) and Pleše (1993) who gave a much more accurate description of the Gorski Kotar boundaries. In their view, the natural borders of Gorski Kotar in the north are the rivers Kupa with Čabranka, while in the west the border mostly follows the Roman wall from Prezid to Klana.

The eastern border to Netretić encompasses Vukova Gorica and the Bosiljevo region, that is, the left banks of the Dobra from Sarov to Gojak, then to Lajnik (495) and Jalvice (551) as far as the point where the stream Vitunjčica joins the river Dobra. The border then follows the lower course of the Vitunjčica and the Crni Potok under the slopes of Klek up to elevation 528, encompasses Sovenice, and then continues along the Puškarići - Bjelsko road for about 2 km. It continues

along elevation 741 to Kojnica (692), Grbin Vrh (904), Praščevac (608), then along elevation 582 to Lepi Vrh (1,006), Tri Kape (983), Ričičko Bilo (1,288), Desimetar (770), and elevation 638 to Dražica (674) as the southernmost point in Gorski Kotar.

In the north-west, the border follows the ridges in the direction of Oštra (655) - Tikvena (591), continues along elevation 713 to Potkraj (744), Čedač (826), Štipač (873), Mali Tič (851), Koveni (932), Kurilovac (842), Kamenjak (837), Plase (781), Hus (976), Nebesa (1,131), Vidalj (1,190) and Čurina (858), encircles the Paklenica Reserve, and then continues along elevations 906 and 917 to Strane (858), Paka (929) and the Katarin peak (1,083), which is the westernmost point in Gorski Kotar.

Geographical co-ordinates encircling Gorski Kotar are as follows:

E - 15°24' 22" eastern longitude by Greenwich (300 m east of Breković Draga)
N - 45°40' 24" northern latitude (350 m north of elevation 1,067, that is 3,800 m north of Prezid)
W - 14°24' 37" eastern longitude by Greenwich (the Katalin Peak, 1,083 m)
S - 45°09' 25" northern latitude (the Dražice Peak, 674 m)

Hunting and important game species in Gorski Kotar
Lovstvo i značajnije lovne vrste u Gorskom kotaru

As the subject of the present research is connected with hunting, this issue will be treated in more detail. A historical survey will be given, and the development and organisation of hunting presented. Animal species playing an important role in hunting management, whether as economically important hunting species (roe deer, deer, chamois, boar, bear, and lately moufflon), or as predators (lynx, wolf), will be discussed.

There are very few areas in Croatia or abroad that can boast of such wealth and variety of the animal world as Gorski Kotar. This relatively small-sized area with its well-preserved habitats is the home of diverse plant and animal species living in balanced harmony.

The diversity and indentation of the terrain with altitude differences ranging from 220 to 1,528 m above sea level offer ideal conditions for the undisturbed development and survival of animal species. Compared to other continents, Europe is poor in animal species in terms of zoogeography. The region of Gorski Kotar is an exception. Intensive agriculture, cattle breeding or industry has never been developed here, which is one of the reasons why such a rich animal world has survived for centuries. Another factor contributing to the diversity and wealth of the plant and animal world in the region is the fact that the population of Gorski Kotar (127,000 ha) is only about 30,000 people.

The people settling these regions in the 15th century made their living by hunting. There have been very few studies of the oldest history of Gorski Kotar, and those modest ones testify to the presence of prehistoric hunters who hunted the game of the period: cave bears, snow leopards and snow hares, but also those that

still inhabit the region. There are no written records relating to Gorski Kotar until the end of the 15th century, so it can only be assumed that the population of the time hunted game for meat, hide and fur (Frković 1981), as in other parts of the country.

Hunting furry and feathery game was banned by the law of the Austro-Hungarian Monarchy from the beginning of the 16th century. When feudal lords later settled into Gorski Kotar, they took over lands and granted themselves the right to hunt game. That feudal aristocracy of the time indulged in hunting is testified by coats of arms depicting hunting details or game. The present coat of arms of the town Čabar, featuring the head of a deer, speaks of the hunting tradition.

Two well-known counts of the time in Gorski Kotar were Nikola and Petar Zrinski, who were believed to be excellent hunters. Petar Zrinski employed two hunting and fishing officials in his castle in Brod upon Kupa (Laszowski 1923).

Game and hunting management suffered a setback in 1848, when all hunting regulations valid until then were changed. By the Royal Decree of 7 October 1848, communes were granted the right to manage hunting grounds. Hunting villeinage was abolished by the Hunting Decree of 7 March 1849, and all landowners with at least 200 acres of land were granted the right of free hunting. This sudden liberty resulted in an almost complete annihilation of game. As a consequence of free hunting, the last deer was caught in the Drgomalje forests in 1848, and in the Severin and Čabar forests in 1850 (Hirc, Pleško 1902). The Čabar region was characterised by a wealth of game. In his book "Gorski Kotar, Dragutin Hirc, the naturalist, describes how forest keepers hunted female capercaillie for food. This region was known for its multitude of roe deer and grouse, but free hunting and frequent poaching caused this game to almost disappear. The last lynx was killed at the end of 1850 in Županjska Draga, and the last chamois was killed in Crna Gora in 1880. Hunting was not limited to big game, but also extended to a multitude of predators. The bordering area between Gorski Kotar and Velika Kapela was rich in wolves (Marinović 1930). 120 bears and 1,650 wolves were either killed or poisoned between 1830 and 1841.

The deep, closed and peaceful forests were ideal habitats for bears. According to statistics, 136 bears were killed in the period 1895 - 1910, of which almost 1/3 in the area of Gorski Kotar. These negative trends gave rise to ideas on the growth and protection of big game. The forerunners of this movement were the squire family of Ghyczy in Čabar, who managed a hunting ground of 30,700 cadastral acres. Special attention was paid to the raising and protection of deer game, which until then was mostly hunted with dogs or killed with pellets. As this kind of hunting, especially with dogs, had negative effects on the game, a stop was put to it and roebucks could only be hunted by stalking.

These positive measures resulted in an increase in game. An anonymous critic of hunting conditions in the Čabar county wrote in the Hunting-Fishing Journal of 1902: "During roebuck hunting in 1901, five hunters observed about 50 adult roebucks in only three days in a relatively small hunting area. There were no stalking paths in the area, and 30 roebucks were killed and 14 caught".

In the spring of that year, the staff of the Čabar county estate counted some 120 adult capercaillie, of which 20 were hunted down (Bonel 1901, Pleško 1902).

Soon afterwards, the First World War broke out, bringing no good to the game in Gorski Kotar. No care was given to the game, and poaching was rampant, endangering mostly the roebuck population. The consequence of every war is a disturbance in natural conditions and an increase in predators, which considerably reduces the number of game.

The new period in hunting in Gorski Kotar began in 1945. In order to protect individual endangered species, the Ministry of Agriculture and Forestry of the Federal Republic of Croatia banned the hunting of all game species in Gorski Kotar on 11 September 1945.

In order to reduce excessive numbers of predators, People's Councils organised large-scale hunting campaigns, but with poor results. In larger settlements, such as Delnice, Gerovo, Lokve, Skrad, Čabar, Ravna Gora, Fužine, Vrbovsko and Mrkopalj, seminars were held on reducing carnivorous species by placing poisonous baits. So, for example, wolves of both sexes and all ages could be killed anywhere, at any time, by any means, and substantial prizes were awarded. A report in 1952 by the Mrkopalj Forest Office to a hunting inspector in Rijeka said: " Since 1945 up to this day, 21 wolves have been killed in the area of Mrkopalj."

Table 3. Killed wolves in Gorski Kotar in the period 1945 - 1993
Tablica 3. Ubijeni vukovi u Gorskom kotaru 1945 - 1993

Period *Razdoblje*	Number of wolves per years *Izlučeno vukova po godinama*										
1945-1955	4	6	16	21	20	20	16	12	12	9	9
1956-1965	-	3	7	16	7	9	8	21	27	21	19
1966-1975	-	24	13	13	9	5	18	15	7	22	4
1976-1985	137 wolves were hunted down or killed in other ways *Odstrijeljeno ili na druge načine stečeno 137 vukova*										
1986-1993	20 wolves were hunted down or killed in other ways *Odstrijeljeno ili na druge načine stečeno 20 vukova*										

In the period 1945 - 1993, a total of 560 wolves were destroyed (Frković 1988).

In 1953, an area of 3,014 ha was excluded from the hunting area of Gorski Kotar and joined to the newly proclaimed National Park "Risnjak". In this manner, minimal prerequisites for the reintroduction of chamois were established, and preservation, protection and enhancement in the development of other game achieved.

A large step towards a more successful improvement of hunting management in Gorski Kotar was made in 1962, when the value and economic capacity of all hunting grounds run by hunting societies were determined. The same was done in 1967 for the hunting grounds run by forest-economic organisations.

Hunting tourism had its first modest beginnings at the end of the fifties and the beginning of the sixties. However, this economic activity could not prosper due to low numbers of interesting game and inadequate accommodation for hunters.

In order to enhance the hunting-economic value of Gorski Kotar and hunting in general, forestry organisations undertook to build and adapt forest facilities for hunters.

The disintegration of Yugoslavia and Croatia's fight for independence was accompanied with war destruction over a large part of the country. Fortunately, Gorski Kotar was not too badly affected. Naturally, there were losses in the game population, which either perished as a result of landmines or of uncontrolled hunting. In 1994, the Hunting Act was passed in the independent Republic of Croatia regulating this important issue.

This Act, drawing on the experience of West European countries, allows for the establishment and organisation of both communal and private hunting grounds, and the former, being much larger in number, were given to hunting societies in Gorski Kotar. Seminars for the all members of hunting associations are frequently held, and hunting-management bases for all hunting grounds have been drawn up.

Hunting associations have varying numbers of members, totalling 1,282 persons (Malnar 1997).

Table 4. The number of members in hunting associations in Gorski Kotar per commune
Tablica 4. Broj članova lovačkih društava Gorskoga kotara po općinama

Year - *Godina*	Čabar	Delnice	Vrbovsko	Total - *Ukupno*
1946.	48	115	84	247
1977.	157	329	228	714
1997.	219	590	402	1282

The diversity of the ecosystem and large-sized hunting grounds in Gorski Kotar enable the survival, reproduction and seasonal movements for a large number of different animal species, many of which are treated as game by the Hunting Act of Croatia. From an economic and hunting standpoint, the most important game species in Gorski Kotar are: common deer (*Cervus elaphus*), roe deer (*Capreolus capreolus*), chamois (*Rupicapra rupicapra*), wild boar (*Sus scrofa*), bear (*Ursus arctos*), capercaillie (*Tetrao urogallus*), and lately moufflon (*Ovis musimon*). The capercaillie is the rarest forest fowl in Croatia. Regretfully, the wolf has recently become another rare species. The reintroduced lynx, which has been excluded from the game list due to its low number, has in the last several years significantly reduced the population of ungulate game.

Gorski Kotar is also inhabited by many other game species and animals, which will only be listed here. Some of them are important for hunting management,

among which the woodcock (*Scolapax rustocila* L.) takes the first place. Another very important economic species is the mallard (*Anas platyrhyncos* L.), which was managed until ten years ago in the Gerovo area (Mali Lug).

The most important game species in Gorski Kotar:
deer (*Cervus elaphus* L.)
roe deer (*Capreolus capreolus* L.)
chamois (*Rupicapra rupicapra* L.)
bear (*Ursus arctos* L.)
wild boar (*Sus scrofa* L.)
moufflon (*Ovis musimon* L.)

Other game species permanently settled in Gorski Kotar:
badger (*Meles meles* L.)
stone marten (*Martes foina* Her.)
pine marten (*Martes martes* L.)
common weasel (*Mustela nivalis* L.)
dormouse (*Glis* sp.)
fox (*Vulpes vulpes* L.)
skunk (*Mustela putorios* L.)
hare (*Lepus europeans* L.)
rock dove (*Columba livia* L.)
hooded crow (*Corvus corone cornix* L.)
jay (*Garrulus glandarius* L.)
hazel grouse (*Tetrastes bonasia* L.)
mallard (*Anas platyrhyncos* L.)

Seasonal, temporary and passing game in Gorski Kotar:
quail (*Coturnix coturnix* L.)
woodcock (*Scolopax rusticola* L.)
common snipe (*Gallinago gallinago* L.)
ring dove (*Columba palumbus* L.)
turtle dove (*Streptopelia turtur* L.)
bean goose (*Anser fabalis* Latham)
Anas guerguedula L.
Anas crecca L.

Specially protected animal species:
wolf (*Canis lupus* L.)
squirrel (*Sciurus vulgaris* L.)
Mustela erminea L.
otter (*Lutra lutra* L.)
capercaillie (*Tetrao urogallus* L.)
lynx (*Lynx lynx* L.)
wild cat (*Felis silvestris* L.)
grey heron (*Ardea cinerea* L.)

grebe (*Podiceps sp.* L.)
goshawk (*Accipiter gentilis* L.)
sparrow-hawk (*Accipiter nisus* L.)
buzzard (*Buteo buteo* L.)
golden eagle (*Aquila chrysaetos* L.)
peregrine falcon (*Falco peregrinus* Tunstal)
hover hawk (*Falco tuninculus* L.)
kulang (*Grus grus* L.)
lapwing (*Vanelus vanelus* L.)
owl (*Strix aluco* L.)
hawk owl (*Strix uralensis* Pallas)
carrion crow (*Corvus corax* L.)
cuckoo (*Cuculus canorus* L.)
hoopoe (*Upupa epops* L.)
black woodpecker (*Dryocopus martins* L.)
green woodpecker (*Picis viridis* L.)
lesser spotted woodpecker (*Dendrocopus minor* L.)
great spotted woodpecker (*Dendrocopus major* L.)
stock dove (*Columba cenas* L.)
nutcracker (*Nicifarga caryocatactes* L.)

METHODS OF WORK
METODA ISTRAŽIVANJA

In order to obtain reliable data and information, the research included both field and laboratory work.

Field research was done seasonally because the area under study was inaccessible for the larger part of the year. However, some research was conducted even in the most difficult part of the year. In the hunting ground "Snježnik" we were provided with motor sledges, which helped us to carry out research on the plots.

Laboratory research involved the processing of obtained data. The data were computer-processed and printed. Plant material collected in the area under study was also analysed.

Game-keepers' logs, recording the presence and number of predators, were analysed and processed.

The area of about 3,000 ha in the Risnjak - Snježnik - Lazačka Glavica - Guslice -Jelenc - Škurina direction was inspected in detail. A careful phytocoenological study of the area was carried out and a comprehensive list of species made. However, other requirements also had to be met to introduce the black grouse into the area. The research was monitored and approved by Professor Joso Vukelić, PhD.

Air temperatures and air humidity were measured in the area. The measuring instruments were set up at different altitudes and at various expositions. The measurements were made over five days in May and June. This period was chosen be-

cause it is the most sensitive one for young chicks, and where waste in the black grouse population is the highest. Temperature and air humidity also play a part in this respect. The more unfavourable the factors are, the higher the waste is.

The obtained data were monitored and processed by Professor Zvonimir Seletković, PhD.

Ecological niches were studied in detail, and their suitability for nesting, mating and feeding were ascertained.

The state of predators preying on black grouse was also examined. For this reason, traps for predators were set up in the studied area. The 130 x 50 x 40 cm traps shaped like parallelepipeds are made of metal frames lined with wire netting, There are openings on outer edges of the smaller profile, which are connected to a mechanism in the middle of the trap with a wire. The mechanism acts (snaps) when mechanical pressure is applied. It is important that the traps have openings on both sides, so that the animal can enter the trap more easily. The baits placed in the traps consisted of the meat of dead fowl and hen's eggs. The traps were laid uniformly over the entire area, and the trapped animals were later let free.

The number and content of predators was ascertained not only by traps, but also by the finding and monitoring of dens, traces, faeces and cries.

Animals caught in the traps were monitored, checked and recorded by the gamekeepers in the hunting ground "Snježnik".

According to their logs, foxes, martens, wild boars and bears were very frequent visitors to these areas. Owls, as possible black grouse predators, were also found to nest there. Lynxes, wolves and golden eagles came into the area less frequently, while goshawks were not recorded.

During field research, special attention was paid to anthropogenic influences in the form of forest roads and mountaineers' paths. We tried to establish the degree and intensity of man's interference in potential black grouse habitats.

RESEARCH RESULTS AND DISCUSSION
REZULTATI ISTRAŽIVANJA I RASPRAVA

The research into the highest massifs of Gorski Kotar, the potential black grouse habitats, has provided a wealth of data.

These data do not give a complete picture of the black grouse, but still confirm our hypothesis that this area has the potential of becoming a black grouse habitat. This conclusion is drawn from the fact that it is identical to other areas inhabited by the black grouse. We used all available literature to gain insights into all fundamental features and factors that might influence the survival of the black grouse.

The black grouse is an endangered species which finds it difficult to adapt to changes in its habitat and food resources. Our basic research focused on this, as well as on climatic characteristics, the danger coming from the enemies of the grouse, and negative anthropogenic factors. In order to obtain fully reliable data, it was necessary to carry out a series of field research to confirm our hypothesis that

the Risnjak and Snježnik massifs were suitable grounds for the introduction of the black grouse.

Thorough knowledge of numerous ecological, vegetative, climatic, pedological and other relations related to the studied area was needed to carry out veritable research.

DEFINITION OF A NARROWER AREA
DEFINIRANJE UŽEGA PODRUČJA

Field visits to the National Park "Triglav-Bled" and the hunting ground "Mojstrana-Dovje", managed by the hunting association of the same name, gave us the opportunity to inspect the regions permanently inhabited by the black grouse.

After observing interesting localities and studying their habitat conditions, we immediately concluded that they were identical or very similar to our studied area. We also visited the area Fondo-Trentino in Italy, in the part of the Alps inhabited by the capercaillie and black grouse.

Available literature provided us with ecological, vegetative, climatic, pedological and anthropogenic factors in this area.

The idea to introduce the black grouse into the area of the Risnjak-Snježnik massifs on a scientific basis seems fully acceptable, because some of the factors crucial for the success of the project are in a better relationship in the given area.

I would like to express my thanks to Professor Dominik Raguž, PhD, and Mr Sergio Abram from Italy, who kindly visited the peak areas of Risnjak, Snježnik and Guslica, and wholeheartedly supported my work on the project.

By comparing the areas in Mojstrane, the "Triglav-Bled" National Park and the Italian part of the Alps, we concluded that there were only minimal possibilities to introduce the black grouse into the whole of Gorski Kotar, as most of the peaks are below 1,200 m. Only altitudes above this favour the development and survival of the black grouse. Although black grouse in Slovenia can sometimes be found at elevations below 1,200 m, cases like these are rare.

It is difficult to find and define any large comprehensive units, because the area consists mostly of peaks of varying heights, small-sized mountain clearings and very few Mugho pine enclaves.

The most suitable areas were found to be those of Veliki and Mali Risnjak at altitudes above 1,200m. Between the massifs of Risnjak and Snježnik the border is lower and encircles the mountain clearing of Lazac. The border further follows a north-west direction and touches the peaks and massifs of Snježnik, Lazačka Glavica, Međuvrh, Planine, Guslice, all above 1,200m, and Škurine and Jelenc at its northernmost point. The peaks of Jelenc and Škurina are well covered with Mugho pine.

All these locations with a rich and indented configuration are serially connected, and represent potential habitats of high quality.

In terms of geography, the studied area, covering 3,400 ha, is located on the south-west boundary of Gorski Kotar, which would ensure the survival of the grouse population.

ELEMENTARY NATURAL FEATURES
OSNOVNA PRIRODNA OBILJEŽJA

The Risnjak-Snježnik mountain chain is located in Gorski Kotar, in the westernmost part of the Dinara chain. Its central part is about 15 km from Rijeka, and about 10 km from the source of the Kupa as the crow flies.

The most conspicuous points are the peaks of Veliki Risnjak (1,528m) and Snježnik (1,506m). Most of the peaks have an eastern and south-eastern inclination. Due to its outstanding geomorphological, climatic and vegetative diversity, the Risnjak region was proclaimed a national park in 1956. Snježnik and Guslike were added to the Park in 1997 for the same reason.

From an anthropogenic viewpoint, the fact that a larger part of the studied area was proclaimed a national park speaks in favour of the survival of black grouse in the area.

The geographical position of the Risnjak-Snježnik massif and of the whole of Gorski Kotar makes this region very interesting, because it represents a strong climatic and vegetative barrier between the continental and maritime part of Croatia.

This is the barrier between the area of sessile oak and common hornbeam on the one hand, and the littoral slopes covered with forests and thickets of white and black hornbeam and other species adapted to higher temperatures and summer droughts on the other.

The peaks of Gorski Kotar rise high between these two regions. They are mostly covered with magnificent forests of beech and fir, sub-mountainous forests of beech at higher altitudes, and a belt of Mugho pine forests at the highest points.

This region of a distinctly transitional character is a natural link between the Alps and the Balkan mountains, although it basically represents Balkan vegetation. According to Horvat (1953), the difference between Alpine vegetation and that of the Balkan mountains is due more to the historical development of the flora, and less to the present climatic and geographical conditions. Therefore, the difference is not so marked in the Risnjak - Snježnik massif. In the Glacial period, when Alpine and Arctic species moved towards the Balkan mountains, a large number stopped in the mountains of Gorski Kotar and Velebit. On the other hand, Risnjak and Snježnik represent the westernmost border to numerous Balkan endemic species.

In terms of geomorphology, the area under study belongs to the north-western Dinaric Alps, and has an outstanding morphological appearance, diversity and beauty.

Limestone and dolomites with conspicuous karst landforms occur over almost the entire area. Numerous gradients, hollows, valleys, vales, depressions, sinkholes and funnel-shaped holes in particular, characteristic of the karst region, play a cru-

cial role in the growth and distribution of vegetation, and in the genesis and properties of the soil.

So, for example, depressions, of which the largest are Lazac and Škurina, are located in the fir and beech distribution area, but are covered mostly with spruce or fir and with pastures in place of the previously forested areas. The occurrence of spruce is conditioned by its link to frosty areas, which are in turn conditioned by the configuration of the karst terrain.

Of all karst phenomena, the most distinctive and the most important are funnel-shaped holes marked with significant disturbances in vegetation belts at different altitudes. The bottoms of these holes can be as much as 200 m lower that the surrounding peaks. They are characterised by very specific life conditions, to which the existing vegetation is well adapted. The most important of these landforms are Viljska Ponikva, Snježnička Ponikva and Škurina.

The physiognomy of the area is also characterised by rocky regions and clearings - mountain pastures adapted to a short vegetation season, low temperatures and strong winds.

The geological - lythological structure of the region is defined by two principal kinds of rock formed in different periods and under the impact of different processes. The Risnjak-Snježnik massif itself is mostly composed of lime and dolomite rocks from the Jurassic period. These durable rocks, prone to strong corrosive processes, are responsible for the wealth of the karst landforms. Such ecological-habitat conditions favour the capercaillie.

VEGETATION AND NUTRITIVE POTENTIAL
VEGETACIJA I MOGUĆNOST PREHRANE

The floral composition and vegetation in a part of Risnjak have been analysed and studied in depth by a number of scientists and researchers (Horvat, Rauš, Bertović, Vukelić). The observed area is linked to the area of the Risnjak massif, so it can be assumed that the vegetation-floral composition is the same in the areas of Snježnik, Guslice, Šumarice and Jelenc, too.

There are seven forest associations in the area of the Risnjak National Park, of which four are interesting for our purpose:

- sub-mountainous forests of beech (*Homogino-Fagetum*)
- hilly forests of spruce (*Aremonio-Piceetum*)
- sub-mountainous forests of spruce (*Listero-Piceetum*)
- mugho pine forests (*Lonicero-Pinetum mugi*)

With the help of Professor Joso Vukelić, PhD, it was established that all parts of the narrow area under study have identical forest associations.

The black grouse requires the living area to be of the following size: up to 50 ha for adult males, up to 30 ha for one-year-old male birds, and up to 45 ha for

adult females. The most frequently chosen areas are those above the forest border, which makes the association of mugho pine (Lonicero-Pinetum mugi) the most important habitat of this species.

This association covers very steep upper slopes and peaks in the central and north-west part of the area. It grows best in northern expositions at altitudes of 1,350 - 1,500m. Mugho pine may descend into funnel-shaped holes, where it covers the coldest places, and occasionally even the bottoms.

According to Rauš et al. (1994), the following floral composition was found over a wider studied area:

Abies alba Mill.
Acer platanoides L.
Acer pseudoplatanus L.
Achillea millefolium L.
Aconitum vulparia Rchb.
Actaea spicata L.
Adenostyles alliariae (Gouan) Kerner
Adenostyles glabra (Vill.) DC.
Adoxa moschatellina L.
Agrostis alpina Scop.
Agrostis tenuis Sibth.
Ajuga reptans L.
Allium ochroleucum W. et K.
Allium ursinum L.
Anemone hepatica L.
Anemone nemorosa L.
Angelica sylvestris L.
Antennaria dioica (L.) Gearth
Anthoxanthum odoratum L.
Anthyllis vulneraria L.
Anthyllis vulneraria ssp.alpestris (Kit. ex Schult.)
Aposeris foetida (L.) Less
Arabis scopoliana Boiss
Artctium lappa L.
Arctostaphylos uva-ursi (L.) Spr.
Aremonia agrimonoides (L.) DC.
Arnica montana L.
Arum maculatum L.
Aruncus dioicus (Walter) Fernald
Asarum europaeum L.
Asperula aristata L.ssp.longiflora (W. *et* K.) Hayek
Asperula cynanchica L.
Asplenium adiantum-nigrum (L.)
Asplenium ruta-muraria L.
Asplenium trichomanes L.
Asplenium viride Huds.
Aster bellidiastrum (L.) Scop.
Athyrium filix-femina (L.) Roth
Betula pendula Roth
Blechnum spicant (L.) Wuth.
Blysmus compresus (L.) Panz ex Lk.
Brachypodium sylvaticum (Huds.) Beauv.
Laburnum alpinum (Mill.) Bercth *et* J. Presl
Luzula albida (Hoffm.) DC
Luzula compestris (L) DC.
Luzula forsteri (Sm.) DC
Luzula pilosa (L.) Wiild.
Luzula sylvatica (Huds.) Gaud.
Lycopodium annotinum L.
Lycopodium clavatum L.
Lycopodium selago L.
Lysimachia nemorum L.
Maianthemum bifolium (L.) Schm.
Melampyrum sylvaticum L.
Melica nutans L.
Melitis melissophyllum L.
Mercurialis perennis L.
Milium effusum L.
Moehringia muscosa L.
Molinia litoralis Host.

Mycelis muralis (L.) Rchb.
Myosotis scorpioides L.
Nardus stricta L.
Bromus reptans
Buphtalmum salicifolium L.
Bupleurum sibthorpianum
Calamagrostis arundinacea L. (Roth)
Calamagrostis epigeios (L.) Roth
Calamagrostis varia (Schrad.) Host.
Calamintha grandiflora (L.) Moench
Calluna vulgaris (L.) Hull
Campanula glomerata L.
Campanula scheuchzeri Vill.
Cardamine bulbifera (L.) Crantz
Cardamine enneaphyllos (L.) Grantz
Cardamine polyphylla (W.K.) Schultz
Cardamine savensis O.E. Schultz
Cardamine trifolia L.
Carex alba Scop.
Carex ferruginea Scop.
Carex firma Host.
Carex flava L.
Carex humilis Leys.
Carex oederi Retz.
Carex pallescens L.
Carex pendula Huds.
Lamiastrum galeobdalon (L.) Ehrendtf. *et* Polat.
Lamium orvala L.
Laserpitium latifolium L.
Laserpitium peucedanoides L.
Laserpitium siler L.
Lathyrus laevigatus (W. et K.) Gren.
Lathyrus niger (L.) Bernh.
Lathyrus vernus (L.) Bernh.
Leonthodon hispidus L.
Leontopodium alpinum Cass.
Leucanthemum maximum (Ramond) DC.
Leucrobryum glaucum (L.) Schimpl.
Leucojum vernum L.
Lilium bulbiferum L.
Lilium carniolicum Bernh.
Lilium martagon L.
Listera cordata (L.) R.Br.
Lonicera alpigena L.
Lonicera alpigena L. *var. reticulata* Kit.
Lonicera nigra L.
Lonicera xylosteum L.
Dianthus mananthos
Dicranum scoparium (L.) Hedw.
Doronicum austriacum Jacq.
Dryopteris carthusiana (Vill.) H.P. Fuchs
Dryopteris filix-mas. (L.) Schott.
Edraianthus graminifolius (L.) A. DC.
Epilobium angustifolium (L.) Scop.
Neottia nidus-avis (L.) Rich.
Omphalodes verna Moench.
Ostrya carpinifolia Scop.
Oxalis acetosella L.
Oxytropis sordida
Paris quadrifolia L.
Pernassia palustris L.
Petasites albus (L.) Gaertner
Petasites hybridus (L.) Geartner, Mayer et Scerb.
Peucedanum cervaria (L.) lap.
Peucedanum oreoselinum (L.) Moench
Phyllitis scolopendrium (L.) Newman
Phyteuma orbiculare L.
Phyteuma spicatum L.
Picea abies Karst.
Carex pilulifera L.
Carex remota L.
Cares silvatica Huds.
Centaurea pseudophrygia C. A. Mey. ex. Rpur.
Cerastium arvense L. ssp. *arvense* Vitm.
Chaerophyllum sylvaticum L.
Chamaespartium sagittale (L.) Gibbs
Circaea lutetiana L.
Cirsium erisithales (Jacq.) Scop.
Cladium Mariscus (L.) Pohl.

Clematis alpina (L.) Mill.
Clematis recta L.
Corylus avellana L.
Crataegus monogyna Jacq.
Crepis kerneri Rech
Crepis pontana (L.) DT
Cyclamen purpurescens Mill.
Danthonia decumbens (L.) DC
Daphne laureola L.
Daphne mezereum L.
Deschampsia caespitosa (L.) PB.
Festuca rubra L.
Festuca rubra ssp. *fallax*
Festuca sylvatica L.
Frigaria vesca L.
Fraxinus excelsior L.
Galium lucidum All.
Galium mollugo L.
Galium odoratum (L.) Scop.
Galium rotundifolium L.
Galium sylvaticum L.
Gentiana asclepiadea L.
Gentiana clusii Perr *et* Song
Gentiana symphyandra Murb.
Geranium robertianum L.
Gnaphalium sylvaticum L.
Gymnadenia conopea (L.) R.Br.
Hacquehia epipactis (Scop.) DC.
Hedera helix L.
Heleborus niger L. *spp. macranthus* (Freyn) Schniffner
Helianthemum alpestre (Jacq.) DC.
Helianthemum grandiflorum (Scop.) DC.
Hellborus mulhtifidus Vis.
Pinum mugo Turra
Plantago lanceolata L.
Polygala vulgaris L.
Polygonatum multiflorum (L.) All.
Polygonatum verticillatum (L.) All.
Polypodimu vulgare L.
Polystichum lobatum (Huds.) Press
Polystichum lonchitis (L.) Roth
Polytrichum juniperinum Willd.
Populus tremula L.
Potentila erecta (L.) Rauschel
Prenanthes purpurea L.
Primula elatior (L.) Hill.
Primula halleri J.F. Gmel.
Prunella gradniflora (L.) Scholler
Prunella vulgaris L.
Pteridium aquilinum (L.) hampe
Pulmonaria officinalis L.
Pyrola secunda L.
Ranunculus montanus Willd.
Ranunculus platanfiolius L.
Ranunculus repens L.
Ranunculus thorra L.
Rhamnus alpinus L. *ssp. fallax* (Boiss 9)
Rhinanthus glacialis Personn.
Rhytydiydelphus loreus (L.) Warnst.
Ribes alpinum L.
Rosa canina L.
Rosa pendulina L.
Rosa pimpinellifolia L.
Rubus hirtus Waldst. *et* Kit.
Rubus idaeus L.
Rubus saxatilis L.
Ruscus hypoglossum L.
Salix appendiculata Vill.
Epilobium montanum L.
Epipactis palustris (L.) Cr.
Erica carnea L.
Eringium alpinum L.
Eriophorum latifolium Hoppe.
Euonymus latifolius (L.) Mill.
Euphorbia amygdaloides L.
Euphorbia carniolica Jacq.
Heracleum montanum L.
Heracleum sphondylium L.
Hieracium sylvaticum L.
Hieracium umbellatum L.
Homogyne alpina (L.) Cass.

Homogyne sylvestris (Scop.) cass.
Hypericum peforatum L.
Hypericum richeri Vill.
Hypochoeris radicata L.
Impatiens noli-tangere L.
Juncus fusca ater
Juniperus nana L.
Juniperus sabina L.
Koelaria eriostachya Panč.
Salix caprea L.
Salix silsiaca Willd.
Salvia glutinosa L.
Sambucus nigra L.
Sambucus racemosa L.
Sanicula europaea L.
Saxifraga rotundifolia L.
Scabiosa lucida Vill.
Scopolia carniolica Jacq.
Scrophularia nodosa L.
Senecio doronicum (I.) L.
Senecio fuchsii C.C. Gmelin
Senecio nemorensis L.
Seratula macrochepala Bertol.
Sesleria juncifolia Suffr.
Silene vulgaris (Moench) Gracke
Siler trilobum (Jacp.) Cr.
Solanum dulcamara L.
Solidago virga-aurea L.
Sorbus aria (L.) Cr.
Sorbus aucuparia L.
Sorbus aucaparia L. *glabra* Hedl.
Sorbus chamaemespilus (L.) Cr.
Stachy sylvatica L.
Stellaria nemorum L.
Symphytum tuberosum L.
Taraxacum palustre (Ehrh.) Dahist.
Taxus baccata L.
Thalictrum aquilegifolium L.
Euphrasia salisburgensis Funck *ex* Hoppe
Fagus sylvatica L.
Festuca gigantea (L.) vill.
Festuca polesica Zapp.
Festuca pumila Chaix
Festuca pungens Kit. *ex* Sshult.
Ulmus glabra Huds
Urtica dioica L.
Vaccinium myrtillus L.
Vaccinium vitis idaea L.
Valeriana tripteris L.
Veratrum album L.
Veratrum album ssp. *lobelianum* (Bernh.) Arct.
Veronica montna L.
Veronica officinalis L.
Veronica urticifolia Jacq.
Thelypteris phegopteris L.
Thymus widderi Mach. *ssp.* polytrichus Ronn.
Tilia cordata Mill.
Trifolium pratense L.
Trollius europaeus L.
Tussilago farfara L.
Vicia oroboides Wulf.
Viola biflora L.
Viola canina L.
Viola reichenbachiana Jor. *et* Boreau

The floral composition of the area and a comparison with the Slovenian and Italian Alps show that the floral-vegetative potential is satisfactory and that the nutritive needs of the black grouse are not in question. Most food is of vegetative origin and consists of parts of various plants that the black grouse feeds on. Many of these are only consumed in different phenological stages, and not throughout the whole year (Table 5 - personal data).

Table 5. Plant species and their participation in black grouse nutrition
Tablica 5. Biljne vrste i intenzitet udjela u prehrani maloga tetrijeba

Plant species *Biljna vrsta*	Participation in nutrition *Zastupljenost u prehrani*		
	Shoots *Izbojci*	Leaves, needles, buds *Lišće, iglice, pupovi*	Fruit, seed *Plodovi, sjemenke*
Abies alba	+	+	
Acer pseudo ex platanus		+	
Fagus sylvatica		+	+
Picea abies	+	+	+
Ulmus glabra		+	+
Fraxsinus ex celsior		+	+
Pinus mugo	+	+	+
Betula pendula	+	+	+
Crataegus monogyna			+
Daphne mezereum			+
Vaccinium myrtillus			+
Vaccinium vitis idaea			+
Juniperus nana	+	+	
Salix caprea		+	+
Sambucus nigra		+	+
Sambucus racemosa		+	+
Sorbus aucuparia		+	+
Taxus baccata			+
Ribes alpinum			+
Rosa canina			+
Rosa pendulina			+
Rubus idaeus			+
Fragaria vesca			+

The black grouse feeds on many other plants, but those listed above are the most important. As seen from the table, the shoots of some plants also contribute to black grouse nutrition, particularly in snowy, winter periods. The shoots are rich in cellulose matter that is difficult to digest, but as the area abounds in stone and sandy substrates, the black grouse solves the problem by taking small pieces of stone (gastrolits).

The rich flora is complemented with equally rich entomofauna, an indispensable supplier of protein in nutrition. The quantity of entomofauna is understan-

dably very small, since the microclimate is characterised by low temperatures and high humidity. However, such microclimatic conditions favour the development of some groups of insects.

Research into the quantitative and qualitative composition of arthropods in the area assumed to be a potential black grouse habitat was carried out (Table 6 - Durbešić 1984).

Table 6. Quantity of arthropod groups collected in catching containers (Durberšić 1984)
Tablica 6. Brojnost skupina člankonožaca skupljenih u lovnim posudama (Durbešić 1984)

Group *Skupina*	Quantity in location *Brojnost na lokaciji*	
	Vilje	Lazac
Myriapoda	197	162
Aranea	1349	1108
Acarina	2469	3175
Pseudoscorpiones	55	104
Scorpiones	2	0
Isopoda	525	17
Collembola	19637	45237
Hymenoptera	496	1278
Diptera	2062	3890
Phthyraptera	0	34
Homoptera	12	620
Heteroptera	9	29
Dermoptera	455	77
Saltatoria	253	41
Coleoptera	9600	9283
Lepidoptera	15	67
Thysanoptera	19	8
Mecoptera	15	0
Opilones	19	1500

Not all groups mentioned above are equally important in the food chain of the black grouse. The table shows the diversity and wealth of arthropods, as well as the preserved trophic status within the studied stands.

The well-preserved plant and animal associations (phytocoenosis and zoocoenosis) in the region under study, and the diversity of mutual relations in the still undisturbed habitats, all combine to satisfy the nutritive needs of the black grouse.

MICROCLIMATIC FEATURES
MIKROKLIMATSKA OBILJEŽJA

To present the climate of the region, we used the data from the Meteorological Station Lividraga (Vukelić 1984). The data refer to the period 1971 - 1980. Lividraga is located only several hundred metres from the area under study, and the measurements included all parameters except wind direction and strength.

All climatic features that are important for the habitat of black grouse have been analysed. Some of these may have a crucial role, especially in the hatching period.

Temperature
Temperatura

Temperature is one of the principal climatic and ecological factors regulating every process decisive for the survival of plant and animal species, as well as the ecosystem as a whole.

The mean annual temperature measured in Lividraga is 5.4°C.The highest mean monthly temperature of 14.2°C occurs in July, and the lowest of -2°C in January.

The absolute minimum in the observation period was -28.0°C. Interestingly, it was measured in March of 1976.

The absolute maximum of 28.9°C was measured in July 1972 and in September 1975.

For our purposes, an important feature is the mean air temperature in the hatching period and in the period of the first flight of chicks, which takes place in June-July. The mean temperature in this period is 12.0°C. July has the highest mean temperature of 14.2°C, and April the lowest of -3.4°C. The absolute minimum in the warmer part of the year of - 11.0°C, was recorded in April. It is interesting that an air temperature of -1.0°C was recorded on 24th July, 1978, and of -2.0°C on 24 August, 1980.

This is important because of the frosts that have a highly negative impact on black grouse populations.

Temperature relations are shown in Tables 7 and 8.

Air humidity
Vlaga zraka

According to Juričić (1942), humidity is a very important factor in the survival of all living beings, including the black grouse. The occurrence of rain, frost, fog and other precipitation phenomena is often dependent on humidity.

Mean relative air humidity over a year in Lividraga is 93.7%. It is the lowest in June, - 92.9%, and the highest in October, - 95%.

Air humidity in the Risnjak - Snježnik region, measured against the relative air humidity scale by Juričić, is very high.

Another interesting factor is the number of days in which the relative air humidity at 14.00 hours exceeds 80%. The number of such days is 334 per year, the most in January (30), and the fewest in August (25).

Relative humidity and the number of days with a relative humidity of 80% at 14.00 hours are shown in Tables 9 and 10.

Table 7. Monthly and yearly mean air temperatures (°C) for the Lividraga Meteorological Station (period 1971 - 1980)
Tablica 7. Mjesečne i godišnje srednje temperature zraka (°C) za meteorološku postaju Lividraga (razdoblje 1971 - 1980)

Year of recording / *God. mjerenja* — Month / *Mjesec*	1971.	1972.	1973.	1974.	1975.	1976.	1977.	1978.	1979.	1980.	Average *Prosjek*
I	-2.2	-4.4	-3.2	-0.2	-1.1	-2.2	0.7	-1.8	-3.7	-4.4	-2.0
II	-2.4	0.1	-2.4	1.3	-3.2	-3.5	1.7	-2.7	-2.0	-0.8	-1.4
III	-3.3	2.2	-1.2	1.3	2.1	-3.8	4.5	1.9	2.7	0.8	0.7
IV	4.9	4.3	2.2	3.5	4.5	2.9	3.7	2.8	2.9	2.0	3.4
V	10.7	8.3	9.6	8.3	10.5	8.2	8.5	7.1	10.3	6.5	8.8
VI	12.2	13.1	13.0	11.6	11.7	12.6	13.2	11.5	14.5	11.9	12.5
VII	14.5	14.7	14.3	14.3	14.9	14.8	14.6	13.1	13.5	13.6	14.2
VIII	15.0	12.5	13.7	15.3	14.1	10.7	13.7	11.6	12.6	13.8	13.3
IX	8.3	7.3	11.4	11.2	13.2	9.8	8.0	9.6	10.4	10.8	10.0
X	4.7	4,1	5.4	2.5	4.8	7.4	6.6	5.7	6.3	7.2	5.7
XI	1.4	2.7	0.7	2.8	1.0	3.3	2.9	-1.2	1.9	0.3	1.6
XII	-2.1	-2.5	-1.8	0.4	-1.1	-1.2	-3.4	-0.2	0.6	-4.1	-1.5

Table 8. Number of days with absolute temperature and mean daily temperature below 0°C (Lividraga, period 1971-1980)
Tablica 8. Broj dana s apsolutnom temperaturom i srednjom dnevnom temperaturom nižom od 0°C (Lividraga, razdoblje 1971-1980)

Year of recording / *God. mjerenja* — Month / *Mjesec*	1971.	1972.	1973.	1974.	1975.	1976.	1977.	1978.	1979.	1980.
I	22.20	29.26	30.27	27.16	18.10	28.22	18.10	26.22	25.21	27.24
II	25.20	15.9	25.21	17.8	24.23	29.29	15.5	24.21	22.15	25.19
III	24.19	18.4	30.21	23.14	19.6	31.21	15.3	20.7	14.2	18.9
IV	11	9.3	23.6	18.1	15.1	20.4	20.4	17.7	14.1	19.9
V		3	5	5	1	15	6	5.1	2	3
VI	1			2	1	2	3	1		
VII								1		
VIII										2
IX	3	8	3	1		5	13	6	1	6
X	19.5	9.3	15.7	17.4	11.	5.1	6	14	11.2	8
XI	19.11	19.6	21.16	15.7	16.8	11.7	19.10	27.21	19.11	24.15
XII	27.11	25.22	22.19	25.12	27.22	24.17	29.23	19.12	23.18	30.27

Table 9. Relative humidity by psychrometer (%) (Lividraga, period 1971-1989)
Tablica 9. Relativna vlaga po psihrometru (%) (Lividraga, razdoblje 1971-1980)

Month *Mjesec* / Year of recording *God. mjerenja*	1971.	1972.	1973.	1974.	1975.	1976.	1977.	1978.	1979.	1980.	Average *Prosjek*
I	96	96	95	95	95	91	94	94	88	88	93
II	95	97	93	96	89	90	94	91	92	92	92.9
III	94	97	92	94	93	85	93	94	94	94	93
IV	96	98	94	96	92	94	93	94	94	94	94.5
V	96	98	95	96	93	94	94	95	89	95	94.5
VI	97	97	95	92	92	92	93	93	84	94	92.9
VII	96	97	96	94	90	93	93	93	85	93	93
VIII	97	97	94	94	92	94	94	94	89	91	93.6
IX	98	98	95	96	93	95	94	95	92	93	94.9
X	96	94	93	96	94	95	95	95	97	95	95
XI	97	94	93	95	94	95	94	92	96	94	94.5
XII	95	95	94	93	92	93	91	93	95	90	93.1
Average *Prosjek*	96.1	96.5	94	94.7	92.4	92.6	93.5	93.5	91.4	92.7	93.7

Table 10. Number of days with relative humidity over 80% at 14.00 hours (Lividraga, observation period 1971-1980)
Tablica 10. Broj dana s relativnom vlagom u 14 sati većom od 80 % (Lividraga, razdoblje motrenja 1971-1980)

Month *Mjesec* / Year of recording *God. mjerenja*	1971.	1972.	1973.	1974.	1975.	1976.	1977.	1978.	1979.	1980.	Average *Prosjek*
I	31	30	31	30	30	29	31	31	29	28	30
II	28	29	28	28	27	29	28	29	27	29	27
III	31	31	27	29	30	24	28	31	31	31	29
N	26	29	27	29	27	29	28	30	29	29	28
V	29	31	29	31	26	25	27	31	21	31	28
VI	30	30	25	25	24	23	28	28	17	26	26
VII	30	30	29	25	19	29	30	30	11	26	26
IX	30	28	24	30	27	30	28	30	18	29	27
X	28	29	26	30	29	30	31	31	31	30	29
XI	30	24	29	30	30	30	30	30	30	29	27
XII	30	31	31	29	31	31	31	31	30	30	30
Average *Prosjek*	29	29	27	28	27	28	29	29	24	28	28

As grouse are strongly affected by temperature and air humidity, we measured these two factors ourselves. The measurement periods were chosen to concord with the dates important for the survival and growth of chicks. Measuring instruments were placed at different altitudes, in different expositions and in different areas (clearings or forested areas).

The data were processed and shown in graphs.

The following can be concluded from the graphs on temperature and air humidity trends in the studied area:

- Measuring instruments were placed in five localities at altitudes ranging from 1,076 to 1,489 m. In order to get a better picture of habitat conditions, various expositions were selected as parameters of the relief.
- Significant differences were noted among chosen localities in terms of the temperature factor. During an anti-cyclone, that is, in stable atmospheric conditions, the usual trends in air temperature values were noted. The mean daily air temperatures were the highest in the lowest localities. As altitudes increased, air temperatures dropped, as expected, within a vertical technical gradient.
- The average daily air temperature in the locality Lazac was higher than that in the highest locality by about 2°C. During the day, the aberrations were even bigger.
- Differences in air temperatures in other localities fell within these values with usual aberrations.
- The influence of exposition is best seen in the values of air temperatures in the localities 1,200 and 1,300 m above sea level. The altitude of a south-facing locality is 1,320 m; however, although 120 m higher than a locality at an altitude of 1,200 m, daily air temperatures are identical.
- Monitoring and measuring was also carried out during a cyclone some 10 days before stable weather set in, and there were all the usual phenomena linked to inversive air circulation.
- In the course of the measurements, cold air masses descended into lower areas, leaving the highest localities with clear weather conditions and considerably higher daily air temperatures.
- The highest localities were warmer in certain parts of a day by about 16°C (10.00 am, 5th June 1998). This is a typical picture of temperature differences in mountainous regions, and is especially prominent in the areas frequently influenced by higher climatic regions.
- Air humidity is inversely proportionate to air temperature, which is clearly seen in the graphs obtained from measurements in both periods.

Precipitation
Oborine

Temperature and precipitation are crucial climatic elements. The principal precipitation phenomena are rain and snow, followed by sleet and hail. Their quantity and annual distribution form the climate of the area.

The quantity of precipitation depends mainly on the relief and distance from the sea.

In his study of precipitation in Gorski Kotar, B. Penzar (1959) states: "Gorski Kotar is a part of Croatia with the highest quantity of precipitation." This claim is confirmed by the data from the Meteorological Station Lividraga.

The mean annual precipitation quantity for Lividraga is 3,770 mm. In terms of months, the highest precipitation is in November - 488 mm, and the lowest in August - 166 mm. Precipitation of 2,330 mm occurs in the colder part of the year, while that of 1,440 mm occurs in the growing season.

In the monitoring period, the highest precipitation of 5,112 mm occurred in 1979, and the lowest, amounting to 3,040 mm, in 1971.

As seen in Walter's climate diagram, there are no dry periods. In the period 1934--1940, precipitation quantity was measured on the very top of Risnjak (1,528 m).

The mean annual precipitation quantity for the said period was 3,914 mm, while the annual distribution was very similar to that in Lividraga. This confirms our choice of the Meteorological Station Lividraga as a good indicator of the climate in the Risnjak - Snježnik massif. Precipitation data from the meteorological stations Lividraga and Risnjak are given in Tables 11 and 12.

Table 11. Monthly and annual distribution of precipitation (mm) (Lividraga, monitoring period 1971-1980)

Tablica 11. Mjesečna i godišnja razdioba oborina (mm) (Lividraga, razdoblje motrenja 1971-1980)

Year of recording / *God. mjerenja* — Month / *Mjesec*	1971.	1972.	1973.	1974.	1975.	1976.	1977.	1978.	1979.	1980.	Average *Prosjek*
I	569	231	178	111	197	44	788	506	1135	326	409
II	114	250	358	443	70	249	665	325	458	213	317
III	451	306	36	138	653	142	253	455	721	322	347
IV	335	418	355	257	419	241	233	425	440	260	338
V	186	468	52	364	218	138	183	282	225	173	229
VI	356	115	145	360	387	150	90	409	159	315	249
VII	142	174	357	149	154	121	340	175	129	161	190
VIII	85	163	31	232	229	154	334	132	251	53	166
IX	86	261	365	421	178	625	162	190	281	108	268
X	54	318	397	861	233	354	209	255	292	769	374
XI	584	912	392	366	308	380	553	138	595	653	488
XII	78	195	445	127	277	1219	281	561	399	371	395
Total - *Ukupno*	3040	3811	3111	3819	3323	3817	4091	3853	5112	3724	3770

Table 12. Monthly and annual distribution of precipitation (mm) in Veliki Risnjak (1,528 m) for the period 1934-1940
Tablica 12. Mjesečna i godišnja razdioba oborina (mm) na Velikom Risnjaku (1528 m) za razdoblje 1934-1940

Month / *Mjesec* / Year of recording / *God. mjerenja*	I	II	III	IV	V	VI	VII	VIII	IX	X	XI	XII	Σ
1934.	188	228	669	368	233	431	157	262	233	428	621	645	4463
1935.	113	299	271	251	189	91	119	236	85	580	488	726	3448
1936.	1034	534	293	412	249	313	112	63	256	216	351	131	3964
1937.	354	502	878	260	82	180	178	209	362	346	428	650	4429
1938.	111	34	31	40	286	68	69	257	126	388	230	327	1967
1939.	337	103	109	94	649	273	106	77	422	728	350	244	3492
1940.	83	161	370	195	742	521	444	472	1326	497	668	171	5650
Total - *Ukupno*	317	266	374	231	347	268	169	225	401	455	448	413	3914

Climatic conditions
Klimatske pojave

Climatic conditions include the frequency and duration of rain, snow, fog, frost, thunder and sleet.

In the observation period in Lividraga, the mean annual number of rainy days was 129, of snowy days 54, and snow remained on the ground for 139 days on average.

A maximum of 270 cm of snow was measured in March of 1976. That particular winter was detrimental for the roe deer population in Gorski Kotar. The mean annual number of foggy days is 31, and days with thunder 12.

Days with precipitation in the form of snow and fog are more numerous in the colder part of the year, while days with rain and thunder prevail in the warmer part of the year.

Wind
Vjetar

The Gorski Kotar region is basically affected by two kinds of winds: the cold north-easterly wind called the buran and the warm south-westerly wind.

The buran is particularly strong. The south-westerly wind is humid and warm and is regularly followed by rain. According to S. Frančišković (1973), the temperature in Gorski Kotar may rise by 5°C during that wind. It occurs mostly in the precipitation-rich seasons of spring and autumn, The buran occurs in the cold part of the year. Calm, wind-free conditions are most frequent during summers, but

may also occur in the rest of the year. Winds, regardless of the kind, are strongest in the higher regions of rock and stone vegetation, that is, in the potential area of black grouse distribution.

The area is marked by a temperate climate, abundant rainfall, high air humidity, frequent late spring and early autumn frosts, and a high, long-lasting snow cover. Similar conditions prevail in grouse habitats in Slovenia (National Park Triglav), which favour the development of black grouse populations.

We are aware that the data of the Meteorological Station Lividraga do not fully describe the climate of the narrower area. A height difference of 500 m between the lowest and the highest point, combined with a varied relief and highly diverse areas, make it difficult to assess the climate only on the basis of the data from Lividraga. In order to complement the data for the climate, we measured air temperatures and humidity at different heights in the month of June. This month was chosen because the largest waste in the juvenile black grouse population occurs in the first months of their lives, which is precisely in June.

THREAT FROM PREDATORS AND OTHER ANIMALS
OPASNOST OD PREDATORA I DRUGIH ŽIVOTINJSKIH VRSTA

The survival of the black grouse in an area depends on the preservation and protection of its habitat. The biggest danger comes from predators and some other animal species.

The list of game and other animals shows that the region of Gorski Kotar is very rich in fauna species. The most important and the most dangerous for the black grouse in the narrower study area are: the pine marten, fox, weasel, badger, wild cat, wolf, lynx, goshawk, golden eagle and bear.

By comparing animal species in black grouse habitats in Triglav National Park with those in the potential habitat in Gorski Kotar, it is clear that the situation is almost identical. In summer months, wild boars may roam the area in search of food, thus endangering the black grouse, particularly hens sitting on eggs.

Compared to Slovenian regions, the ones in Croatia are richer in wolves and lynxes.

The quantity of predatory animals and game oscillates during the year. In autumn and winter their number and presence are lower, and in spring and summer the situation is reversed (Table 13).

In order to obtain reliable and authoritative data on the presence of predators in the area, traps were set up in different parts of the year. It was intended for the traps to establish the quantity of marten and fox, two animals considered to be the fiercest enemies of black grouse.

The traps were set up and monitored by the gamekeepers in the hunting ground "Snježnik". A total of ten traps were placed at different altitudes and in different places. The meat of fowl was used as bait.

Table 13. Predators caught in the narrower study area during 1997
Tablica 13. Ulov grabežljive zvjeradi užega područja istraživanja tijekom 1997. godine

Broj lovke	Nadmorska visina	Obraslo	Ulov	
			Ljeto, jedinki/vrsta	Zima, jedinki/vrsta
1	1100	neobraslo		1 lisica
2	1200	obraslo	-	1 kuna
3	1250	obraslo	1 lisica	1 kuna
4	1250	obraslo		1 lisica, 1 kuna
5	1300	neobraslo	1 lisica	-
6	1350	neobraslo	-	-
7	1400	obraslo-neobraslo	-	-
8	1400	neobraslo	1 kuna	-
9	1450	obraslo		-
10	1450	neobraslo	-	-

The traps were placed uniformly over areas covered both by grass and by forests.

The results are very interesting and reflect the laws of nature.

No animals were caught in the snow-covered peaks in the winter period. This means that predators do not live at these heights in winter because there is not enough food, so they move to lower elevations. The winter catch, consisting of three martens and two foxes, was recorded only at elevations below 1,250 m. The catch was monitored in the first week of February and March, and in the first week of June and August.

In summer, the catch was smaller and more uniform over the whole area. No animals were caught above 1,400 m. All in all, the catch was bigger in the winter period, and more martens were trapped. The traps were placed over 50% of the area, which suggests that the number of predators is higher than shown above.

The staff in the hunting ground "Snježnik" also monitored, followed and recorded the traces of other mentioned animal species. It was found that most animals inhabited the area only during one part of the year, and the only permanent residents were martens and foxes. The golden eagle and goshawk, which can seriously threaten the black grouse, are transitory species. In the words of the gamekeepers in the Gerovo Forest Office, the golden eagle has never been recorded nesting in the area.

The chamois has virtually disappeared from the tops of the Risnjak-Snježnik massif. Other ungulate game is absent from higher elevations. As the area does not provide enough food sources for predators, it can be assumed that they will not threaten the survival of the black grouse.

CRUCIAL ANTHROPOGENIC FACTORS IN THE DEVELOPMENT DYNAMICS OF THE BLACK GROUSE
ANTROPOGENI ČIMBENICI PRESUDNI ZA DINAMIKU RAZVOJA MALOGA TETRIJEBA

With the exception of the sports-recreational centre Platak, which touches the narrower study area on its southern side, and where the number of visitors engaging in recreation and climbing is somewhat higher, the study area of Risnjak is relatively peaceful. Some marked mountaineers' paths leading from Platak towards the tops of Risnjak and Snježnik are used in the summer months. There are several cable cars and ski lifts on the edges of the Platak and Snježnik area that attract a considerable number of skiers and visitors in winter months. The steel ropes of the ski lifts can be fatal for all birds, and especially for the black grouse.

The most important, but also the most detrimental, factor for the successful introduction, growth and survival of the black grouse is forest management. The area is partly managed by the National Park Risnjak, and partly by the Public Enterprise "Croatian Forests" through its forest offices Gerovo and Tršće. Forests in the NP Risnjak are not commercially exploited, so felling activities are minimal. The relief of the region, abounding in high massifs with steep inclinations and stones and rocks in the substrate, is conducive to the kind of vegetation that has a protective role. As trees are not felled for reasons of erosion, benefits from forest exploitation are negligible.

The rich and diverse areas managed by the NP Risnjak are excluded from any forest management and exploitation activities. In this way, all negative influences connected to forest exploitation, such as building forest communications, roads and tractor trails, are avoided.

The existing communications follow the edges of the narrower area. The only communication that passes through the area is the Lazac - Vilje road, which divides the region between the Risnjak massif and the Snježnik massif. All communications are used as forest roads and have no public importance. They are closed to any traffic for most of the year.

Feeding sites for game (especially bears) are located outside the boundaries of the narrower area. Therefore, no considerable concentration of predators (foxes, martens) is expected.

The narrower area encompasses parts at higher altitudes away from settlements. The use of forest products by people is almost non-existent, except in the autumn, when mushrooms and raspberries are picked.

From the 1970s until the Croatian War of Independence, nomadic sheep pasturing was an important activity for the inhabitants of Grobinšćina. Their sheep dogs were mostly untrained mongrels that roamed large mountainous clearings. However, nomadic sheep keeping has now completely disappeared.

In recent times, there have been some problems with unattended horses that disturb forest peace by their uncontrolled roaming. The horses belong to several local people, who occasionally sell them in Italy.

The Hunting Act allows dormice hunting from 19 September - 30 October, when beech crops are abundant. In this period, large groups of dormice hunters from the "dormice" villages of Gerovo and Tršće engage in the night hunting of this species. They light bonfires and generally make a lot of noise, which additionally disturbs the peace of all the animals living there. Fortunately, dormice are hunted only in more accessible forest areas closer to forest roads. The configuration and closed forest complexes in the narrower area make such hunting activities difficult. It is therefore expected that this will not affect the black grouse.

There are no settlements inside the narrower area. The ski resort of Platak with its several facilities is located in the bordering part the area. Two mountain chalets were built in the central part of the area: one in the Šloser meadow on Risnjak, and the other under the top of Snježnik. These chalets receive more visitors in summer months, but in late autumn and winter they are closed.

In the 80s, the former Yugoslav Army built an army facility on Guslica, but it was completely destroyed and pulled down during the War of Independence.

Owing to the long hunting tradition and culture in the area, there is virtually no poaching. The game and forest keeping service is well organised, and any possible poaching is successfully curbed.

The facts mentioned above show that some of the activities may have adverse impacts on game management, but their intensity is insignificant.

As this area enjoys all the protective measures given to a national park, it can be used as a habitat of the black grouse.

ASSESSING THE SUITABILITY OF THE AREA AND THE DEGREE OF REPRODUCTIVE SAFETY
OCJENA POGODNOSTI ISTRAŽIVANJA UŽEGA PODRUČJA I STUPANJ SIGURNOSTI REPRODUKCIJE

Research into the possibility of introducing black grouse into the narrower study area was carried out in the period 1996 - 1998. Almost no difference or disparity was detected between these and the existing black grouse habitats in Slovenia and Italy. In Slovenia and north Italy, the population of black grouse is considerably affected by the anthropogenic factor, which may have a crucial role in the preservation of the population. The influence of man is seen in well-developed winter sport and tourism, numerous infrastructural facilities (ski lifts, cable cars, hotels, and other contents), and active and popular mountaineering activities. Active livestock breeding and the small-scale exploitation of forests further threaten grouse habitats in northern Italy.

Hunting is strictly controlled. All these negative factors may suggest that the population of black grouse is endangered. However, contrary to expectations, the development of the population is stable. In comparison with the habitats in northern Italy, the narrower area of Risnjak and Snježnik has numerous advantages. Except for Platak in the border area, there are no winter sport or tourist facilities

with their accompanying infrastructure. Some mountaineering activities take place only during a small part of the year. Livestock breeding and forestry production is almost non-existent. As a larger part of the narrower area is within the boundaries of NP Risnjak, uncontrolled hunting is excluded. Big game hunting is only allowed over a small territory, and is strictly controlled by hunting organisations. Therefore, as the negative impacts of man's activities are reduced to a very small measure, the area is suitable for the survival of the black grouse.

On the whole, climatic factors in the Lividraga region are similar to those in Slovenia (Bled) and northern Italy (Trentino). Therefore, climate cannot be a limiting factor for the introduction of the black grouse into Croatia.

No differences were found between forest associations in the studied area and those in the Alpine part of Slovenia and Italy. The tree species, shrubs and ground vegetation are almost identical, while some important species in grouse nutrition (mugho pine, juniper, strawberry raspberry, dog-rose berry) are more abundant in Croatian habitats.

In comparison with other areas, the number of predators and preying animals is much higher in the studied area. Foxes, martens, weasels, goshawks, owls and golden eagles live both in Croatian habitats and those of Slovenia and northern Italy, but lynx, wolves and bears occur only in Croatia. All these animals feed on the black grouse, but this is not their exclusive food.

Man can easily influence the quantity of predator species. In order to carry out the project, the number of predators and other animal species should be reduced to an acceptable level, all the time taking care not to endanger any of these species.

In conclusion, it has been established that the conditions for the introduction of black grouse into the studied area are very favourable. The only exception is the number of predators, but this is easily dealt with. Therefore, the completion of the project dealing with the introduction of black grouse into the studied area will depend only on man.

CONCLUSIONS
ZAKLJUČCI

Research into the possibility of introducing black grouse into the Risnjak - Snježnik massif has dealt with basic ecological conditions in the area: habitat, climatic conditions, the nutritive potential of the habitat, and the degree of threat to future populations of black grouse.

With regard to ecological conditions, the following can be concluded:

1. The Risnjak-Snježnik region in the zone above 1,200 m has an area of 3,400 ha. The entire area can be considered a suitable living space for the black grouse. The major portion of the area is part of the National Park Risnjak, and abounds in karst phenomena and a vertical vegetation zonality characteristic of the western Dinara mountain range and western part of the Balkan Peninsula.

2. The Risnjak-Snježnik area is made up of rocky peaks and their upper slopes with several clearings, while 80% of the area is covered with forest vegetation. The rock is predominantly Jurassic limestone, and the soil is mostly limestone-dolomite humus.
3. The principal forest associations crucial for the survival of black grouse in the area are mugho pine (*Lonicero-Pinetum mughi*) over about 850 ha, and sub-mountainous beech forests with homogyne (*Homogyno-Fagetum sylvaticae*) over 1,700 ha. There are also sporadic occurrences of willow thickets (*Salicetum grandifoliae*), beech forests with reed grass (*Calamagrostio-Abietetum*) and other associations, which are very important for the diversity they offer.
4. The average annual air temperature of 3.6°C in the belt of mugho pine, and 5.1°C in the belt of sub-mountainous beech forests in Croatia, as well as air temperatures and humidity in the Lazac - Snježnik profile (the difference in altitude is 413 m), reveal a close similarity between the Risnjak - Snježnik region and the black grouse habitats in Slovenia, northern Italy, sub-Alpine and Alpine regions. The same is true for other climatic indicators, which denote a perhumid and cold climate with long winters, high snow cover and intensive air currents.

   As for the nutritive potential of forest associations and habitats, we compared the results of the examination of the crops of killed black grouse in foreign literature and the analyses made at the Veterinarian Faculty in Zagreb. The following can be concluded:
5. Phytocoenological analysis confirmed that the floral composition of forest associations is largely identical to that in the areas of black grouse distribution in Slovenia and northern Italy. This principally refers to the flora from the mugho pine association, which provides 70% of the food for black grouse.
6. The most important species and parts playing a crucial role in the nutrition of the black grouse are: needles of mugho pine, spruce and fir, leaves and buds of beech, sycamore, willow, wych elm and ash, and shoots of juniper. The black grouse also feeds on fruits and seeds of numerous species, such as cranberry, blueberry, rowan, mountain raspberry, mountain rose hip, red elder, raspberry, strawberry and others. These species make up basic forest associations in the Risnjak - Snježnik massif.
7. The studied area abounds in springtails (*Collembola*), an insect species that lives in the leaf-litter. These insects, and a number of other animal species that the black grouse feeds on, provide diverse nutrition in the vegetation period.

   As for negative factors that might influence the development of a black grouse population, the following can be concluded:
8. There are no ski lifts, transmission lines, or economic activities in and out of the forests. Intensity of traffic and other activities that have reduced, endangered and even annihilated black grouse populations in Europe is very

low. The basic biotop of the Risnjak - Snježnik massif will probably not suffer natural regression or devastation in the future, and is estimated to be highly productive for the development of black grouse.

9. Natural enemies that might endanger the survival of black grouse at altitudes up to 1,300 m consist of about 5 foxes and about 6 martens per 1,000 ha. At higher altitudes their numbers are at present much lower. These numbers refer to the vegetation period; in winter, they are almost negligible. Compared to other regions, there are no golden eagles, while goshawks and owls are very rare.
10. All the factors mentioned above indicate that the Risnjak - Snježnik massif is highly suitable for the introduction of the black grouse. Natural conditions, the nutritive potential, peace and other important requirements are satisfied.
11. Black grouse from the Alpine population should be chosen for the introduction of the species, and a three-year adaptation period in a fenced area ensured. In this period, it would be important to reduce the number of foxes and martens in the chosen area by means of traps. At least five pairs should be brought in. After three years, the population should rise to 60 individual birds, which is an optimal number for the Risnjak - Snježnik region.
12. It is crucially important to carry out all necessary observations and measurements during the process, in order to ensure that this beautiful and interesting species finds its home in Gorski Kotar, and later possibly even spreads into suitable areas in Velebit and elsewhere in Croatia.

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ISTRAŽIVANJE STANIŠNIH UVJETA ZA NASELJAVANJE MALOGA TETRIJEBA (*LYRURUS TETRIX* L.) U GORSKOM KOTARU

SAŽETAK

U radu su istraženi uvjeti za moguće naseljavanje maloga terijeba na gorskokotarske planine. Općenito, predmetom su istraživanja sinekološki uvjeti obitavanja maloga tetrijeba. U tu su svrhu odabrani lokaliteti za istraživanje, širi masivi Risnjaka i Snježnika. Cilj je rada istražiti i dokazati uvjete i mogućnosti uzgoja maloga tetrijeba u Gorskom kotaru.

Tekstualo i grafički je prikazano mjesto maloga tetrijeba u sistematici, a također su obrađene i morfološko-biološke i ekološke osobitosti maloga tetrijeba. Vlastitim istraživanjem obrađeni su klimatski, hidrološki i geomorfološki čimbenici, opterećenost tla onečišćivačima, vegeteacija te antropogeni utjecaji.

Upotrijebljeni su meteorološki podaci meteoroloških postaja ovoga područja.

U Gorskom je kotaru istraživanjem utvrđeno 14 biljnih zajednica, od kojih je u predmetu istraživanja izdvojeno samo pet. Promatrano je i lovstvo. Utvrđeno je 56 životinjskih vrsta, odnosno 21 sisavac i 35 vrsta ptica, od kojih je u istraživanju izdvojeno 10 vrsta dlakavih i 7 vrsta pernatih predatora.

Razlika između alpske planinske vegetacije, gdje mali tetrijeb obitava, i vegetacije goranskih planina nisu značajno izražene i nisu različite, pa otuda prehrambeni potencijal zadovoljava.

Istraženo područje obiluje flornim bogatstvom od 284 vrste, a u prehrani maloga tetrijeba značajno je 28 biljnih vrsta. Istraživano se područje odlikuje bogatstvom entomofaune. Pronađeno je 19 skupina člankonožaca, a u prehrani maloga tetrijeba bitna je skupina *Collembola*.

Istraživanjem je utvrđena prisutnost sitnih predatora, kojih ljeti ima ravnomjerno po čitavoj površini, a zimi ih je više na nižim nadmorskim visinama, dok ih na visovima uopće nema.

Antropogeni utjecaji gotovo su isključeni, jer je veći dio područja obuhvaćen Nacionalnim parkom "Risnjak".

Na temelju sveobuhvatnih istraživanja može se zaključiti da postoje uvjeti za naseljavanje maloga tetrijeba na istraživanom području Gorskoga kotara. Temelji za to su optimalni stanišni uvjeti. Meteorološki podaci istraživanoga i uspoređivanoga staništa na kojima mali tetrijeb obitava bitno se razlikuju.

Vegetacijska slika istraživanoga staništa ima određene prednosti pred onima u Italiji ili u Sloveniji.

Također je utvrđeno bogatstvo člankonožaca, što sve zajedno s antropogenim čimbenicima čini stanište prikladnim za uzgoj i opstanak maloga tetrijeba.

Klučne riječi: *Lyrurus tetrix* L., sinekološki uvjeti, reinrodukcija, *Collembola*, stanište

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Knjiga

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Poglavlje iz knjige, monografije, enciklopedije

Lammi, J. O., 1994: Professional ethics in forestry. In: Irland, L. C. (ed.), Ethics in forestry, Timber press, Portland, pp. 49–58.

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