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ZA ŠUMSKE POKUSE

ANNALES
EXPERIMENTIS SILVARUM CULTURAE PROVEHENDIS

39

SVEUČILIŠTE U ZAGREBU
ŠUMARSKI FAKULTET
UNIVERSITAS STUDIORUM ZAGRABIENSIS
FACULTAS FORESTALIS

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Volumen 39

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Original scientific paper
Izvorni znanstveni članak

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REZULTATI ODNOSA MUFLONA (*OVIS AMMON MUSIMON* PAL.) I JELENA AKSISA (*AXIS AXIS ERX.*) PREMA KULTIVIRANIM TRAVNJACIMA I NASADU ČIČOKE (*HELIANTHUS TUBEROSUS* L.) U LOVIŠTU KALIFRONT NA OTOKU RABU

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The paper deals with the utilisation of cultivated grasslands (two localities) and a plantation of Jerusalem artichoke (*Helianthus tuberosus* L.) by mouflon and axis deer. At the time of research, the game counted 99 heads per hectare of cultivated grasslands, and 365 heads per hectare of Jerusalem artichoke plantation. However, during the count, only 17 heads of game on average were found in the grazing areas. With the absence of hunting, mouflon game formed one large herd of 22 heads and several smaller herds, which were concentrated mainly in one grassland area, while axis deer herds, amounting to 9 heads maximum per herd, used both grasslands. It was observed that mouflon took the food from the storages by themselves, damaging the storages in the process. For this reason, food storages need to be protected with fences. During the research, neither mouflon nor axis deer consumed the provided hey, which means that game animals need not be additionally fed with bulky food in

eu-Mediterranean conditions since there is enough dry food in the nature. Mouflon and axis deer used the Jerusalem artichoke exclusively as forage and did not root for tubers. In dry season (summer), the Jerusalem artichoke is an important forage plant in the hunting ground, with the most intensive grazing occurring in early June, while before June, game shows little interest in this plant species. At the beginning of June, game primarily bites off the terminal parts of the shoots, however, with growing drought, it also eats the leaves.

Key words: mouflon (*Ovis ammon musimon* Pal.), Axis deer (*Axis axis* Erx.), cultivated grasslands, Jerusalem artichoke (*Helianthus tuberosus* L.), biting height, forage, herd size

INTRODUCTION
UVOD

Establishing forage areas as an additional food source for game has been practiced in hunting management for decades. As a rule, grassland areas dominate in the diet during the summer, whereas areas supporting diverse forage cultures are primarily intended for game nutrition during the unfavourable part of the year (winter months). For this purpose the cultures are either left un-harvested or the crops are collected and stored.

In the Mediterranean, and especially in the eu-Mediterranean area, unlike continental (Central European) areas, the unfavourable part of the year for game is not winter but summer, when succulent food or even water is absent. The main problem concerns the provision of fresh food in the dry part of the year so that game pressure on forests is alleviated. Forests in the Mediterranean have a predominantly protective and aesthetic function, and harmful impacts of ruminants on the forest ecosystems in this region are well known.

Although the general factors influencing animal feeding behaviour are known, the specific feeding patterns of individual game species in a given habitat and time are still under research.

In the course of evolution, all animal species, including the ancestors of the present domesticated animals, have developed specific feeding strategies based on the principle of selecting the best quality foods from a large quantity of forage, at the same time avoiding lethal dosages of phytotoxins (Havranek 1998, cit. Launchbauch 1996), which has enabled their survival, growth and development (Havranek 1998, cit. Forbes 1995). In other words, animals have developed feeding strategies involving the intake of large quantities of food in as little time and with as little energy as possible and at a minimal risk of predation (Havranek 1998, cit. Forbes 1995).

Despite the differences in the selective behaviour among different plant-eating groups, as well as among species, some general principles of making dietary choices are very similar, but the ways of their implementation are different. In this respect, all animals can be divided into two groups - *generalists* and *specialists* (Figure 1).

According to the available literature in the field of stockbreeding, agriculture, physiology and animal ecology, there are five different, mutually complementary theories that explain the selection of food (Havranek 1998, cit. Provenza & Balph 1990):

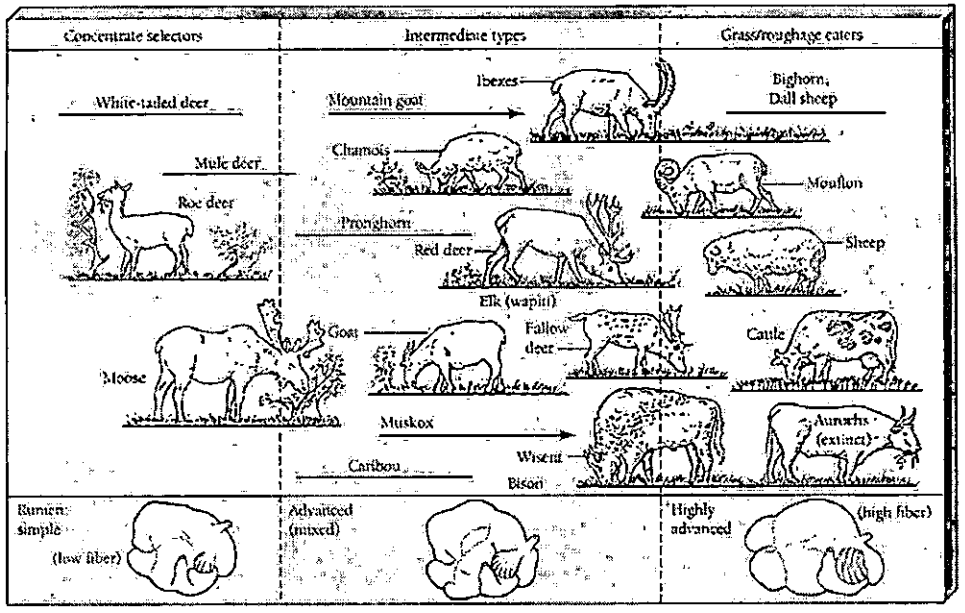


Figure 1. Positions of ruminant species within the system of feeding types
Slika 1. Shematski prikaz prehrambenih strategija različitih vrsta preživača

- Euphagia

This theory is based on the existence of an inherent ability of an organism to select an appropriate nutritious diet

- Hedyphagia

An organism selects food on the principle of palatability with special sensors which have developed during evolution, where nutritious foods become "pleasing" to the senses and toxic or low quality foods become "offensive". It is important to mention that neither euphagia nor hedyphagia take into account the post-ingestive processes.

- Morphophysiology and size of plant and animal

According to this theory, animal intake of foods is based on the differences in the physical and chemical properties of the food. This theory does not explain individual differences within species in consuming identical forage.

- Forage availability

An organism usually selects the food that is available.

- Experience

It is believed that it is much harder and more complicated for ruminants to learn to select

forages due to fermentative nutrient changes in nonglandular stomachs arising from the nutrient ratio in certain foods and the absorbed nutrients.

Taking all these theories into consideration, it can be said that an animal will decide on the selection of a given component in the environment on the basis of the following criteria:

1. Digesta fill
2. Physiology and reproductive condition,
3. Fitness, that is, the condition of body energy and nutrient reserves,
4. Water balance,
5. Nutrient and toxin levels in blood,
6. Experience,
7. Acclimatisation.

Small ruminants use more energy per kilogram of metabolic mass and therefore need a more digestive meal with a high concentration of nutrients. For this reason, small ruminants consume much less cellulose than cattle. Likewise, dry matter dissolves much faster in the rumen of small ruminants than of big ruminants (Havranek 1998, cit. Kleiber 1955, and cit. Van Soest 1994). This research was done on domestic livestock in the savannah, where rearing cattle was of a fully extensive character.

The quantity of consumed forage is also affected by an increase in the volume of abdominal organs, such as the abdominal fat and the uterus with embryo in that they cause a temporary compression of the rumen and a decreased food intake (Havranek 1998, cit. Frame, 1992). Next, at equal size, in obese and heavier animals a correlation between mass and food intake is reversed, while in growing animals it is positive (Havranek 1998, cit. Forbes 1995).

Most scientists today are doubtful about the importance of the senses as it is difficult to define their role (especially the sense of smell and taste, or their interactive relationship), as well as the role of past experience and memory. They claim that the importance of the senses is determined with the methods of their surgical removal, and that it is of little practical value in studying diet selection (Havranek 1998 cit. Lynch *et al.* 1992). However, current insights speak in favour of the importance of the senses in learning to adapt to and consume new foods. Thus, a test with sheep showed that they did not discriminate between the yellow (575 - 600 mn) and green colour (550 - 575 mn) of the same intensity, but could discriminate between colour intensities. It is a known fact that the intensity of the green colour of grass is proportional to the protein content (Havranek 1998, cit. Bazeley & Susan 1989, and cit. Forbes 1995). Other senses are also essential, with the difference that tactile experience is not acquired only with food intake but also with swallowing and chewing food. Together with other sensory properties of a plant, this contributes to the formation of its characteristic sensory picture.

To summarise, animals select the components according to their nutritional value or/and to their organoleptic properties.

The majority of animal studies involved research on their activities over a shorter period (and not over the whole day). This kind of research could not yield definite conclusions on animal behaviour. Observation of animals over longer intervals led to some interesting findings from the standpoint of nutritive strategies. As for feeding itself, it can be seen that animals do not feed only in the sense of continuous food intake, but also that feeding is a complex process

that can further be divided into several mutually related activities, such as:

- Searching for food,
- Catching food,
- Preparing food,
- Eating,
- Moving to a new feeding ground.

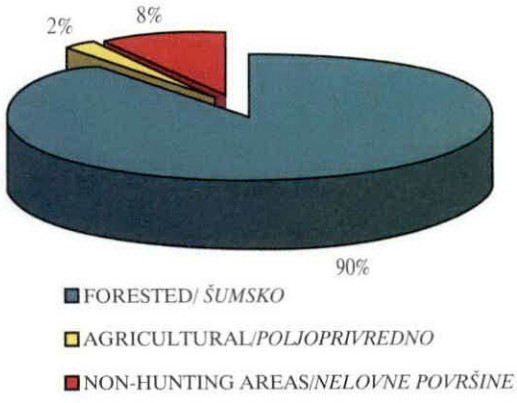
An animal constantly makes decisions on the next step in its behavioural sequences - when to stop with one activity and start with another. To understand these sequences, it is important to study the probability of making a certain decision from the standpoint of optimising a certain factor, such as, for example, the degree of net energy investment.

MATERIAL AND METHODS
MATERIJAL I METODE

AREA OF RESEARCH
PODRUČJE ISTRAŽIVANJA

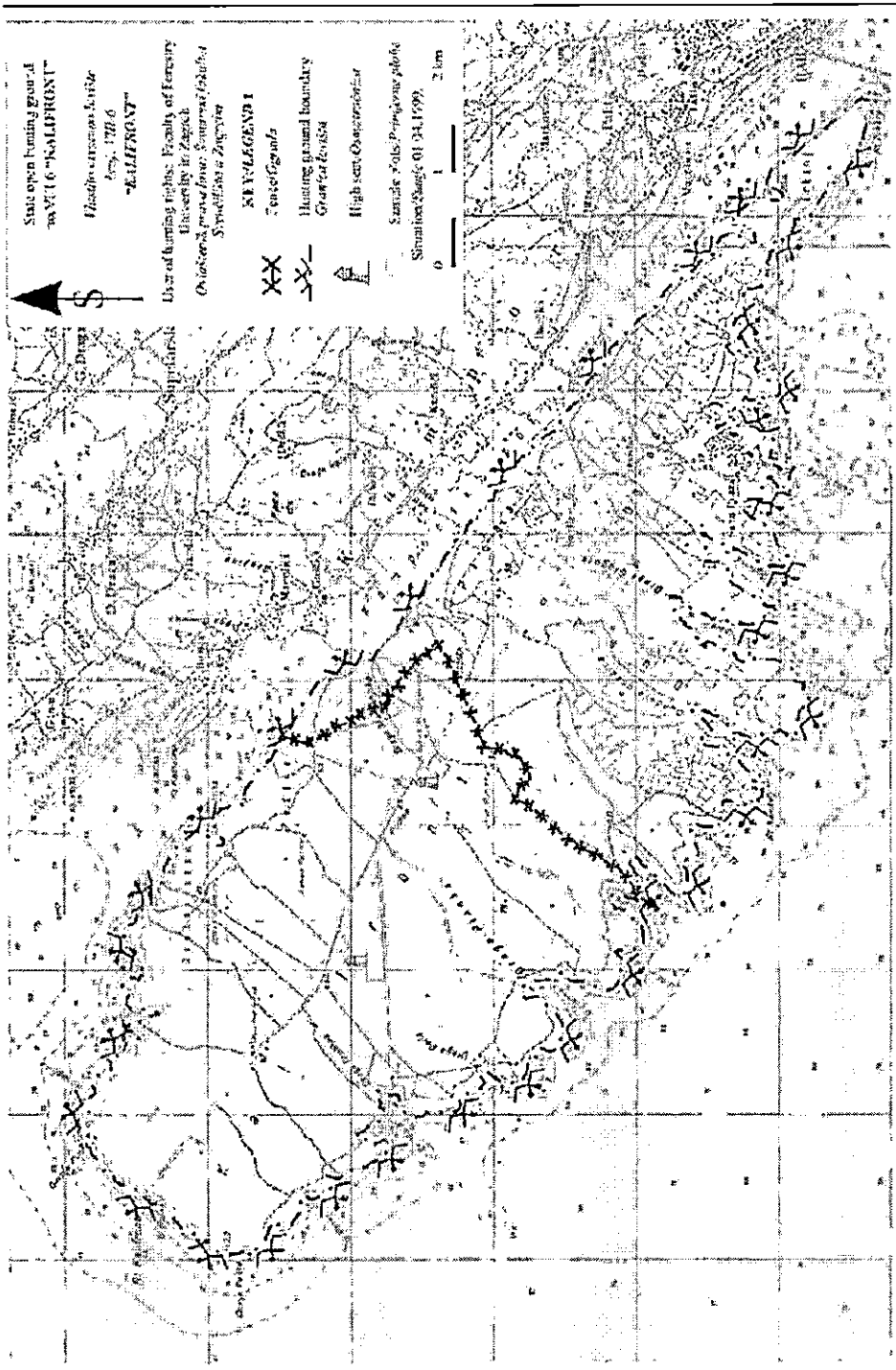
The state hunting ground VIII/6 "Kalifront" (Map 1) is located in the south-west of the island of Rab over a karst plateau of the same name, which is covered with the most valuable forest on the entire island. In relation to the island, Kalifront is a kind of peninsula, since there are two coves stretching deep along Kalifront:

- St. Euphemia in the south-east,
- Kamporska Draga in the north-west.



Graph 1. Percentage share of forested, agricultural and non-hunting areas in the hunting ground "Kalifront"

Grafikon 1. Postotni udio šumskih, poljoprivrednih i nelovnih površina lovišta "Kalifront"



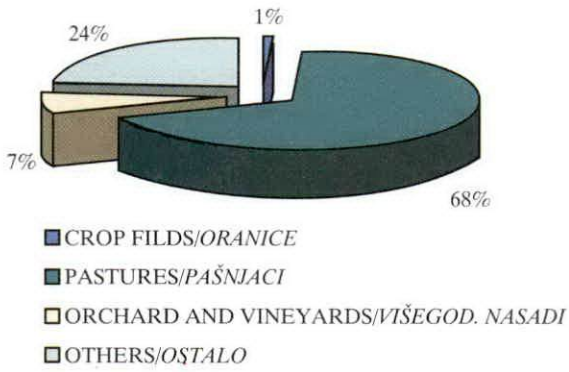
Map 1. The State Hunting Ground VIII/6 "Kalifront"
Karta 1. Državno lovište VIII/6 "Kalifront"

The hunting ground lies in the southeast - northwest direction in the length of 9 km from Frkanj promontory in the south-east to Kalifront promontory in the northwest. Its widest point of 3 km (2,950 m to be precise) is found between Planka promontory and Kamporska Uvala. Territorially, it belongs to the County of Primorje-Gorski Kotar, while from the hunting aspect it belongs to the Adriatic hunting area.

The boundary of the hunting ground begins on the promontory of Kalifront. From there it follows the coast towards the north-east over the Gornja Punta cove, and then south-east along the Kamporska Draga coast, then along the edge of the forest, or Kamporsko Polje, to the cove of St. Euphemia, and on along the coast to end with the starting point on the promontory of Kalifront. Based on the data from the Hunting Ground Foundation Act, the hunting ground covers 1,475 ha, of which 1,319 ha is forestland, 32 ha agricultural land and 124 ha constitutes non-hunting areas (Graph 1).

Graph 1 shows that 90% of the hunting ground is made up of forests, which favours natural rearing of wild even-toad ungulates. The small share of agricultural land in the hunting ground forces the breeder to construct and maintain light strips in the ground in order to provide the wildlife with sufficient quantities of forage.

In terms of the percentage share of agricultural areas by cultures (Graph 2), the share of crop fields is distinctly small. They cannot be used for the production of game food because they are privately owned and cultivated by the local population.



Graph 2. Percentage share of agricultural areas by cultures

Grafikon 2. Postotni udio poljoprivrednih površina po kulturama

Since the entire hunting ground is located on the peninsula, the central part is divided with a partition (3.4 km long). However, the partitioning of the hunting ground has profoundly changed the share of land by categories. Of a total of 840 ha of the enclosed area, about 825 ha (98%) belong to forests and the remaining 15 ha to roads (8.8 ha), light strips (5.9 ha) and grass areas - the nursery Topolje and the nursery A. Petračić (1.5 ha). It was for this reason precisely that forage areas were established for feeding the game in the hunting ground, because it was assumed that the game would not be able to satisfy its nutritional requirements in forest areas only.

In the enclosed part of the hunting ground during collecting the data for this paper, there were

45 heads of mouflon game and 22 heads of axis deer in all. Together, this makes a population density of all big game of 8 heads per 100 ha of the total ground area. According to Table 1, in the year of measurement the game population was suited to the carrying capacity. The enclosed part in which research was done has an area of 840 ha, and the concrete number of heads relates to the count in this part of the hunting ground.

Table 1. Site class, carrying capacity and growing area (GA) for mouflon and axis deer in the hunting ground "Kalifront"[1]

Tablica 1. Bonitet, kapacitet staništa te LPP za muflona i jelena aksisa u lovištu "Kalifront"[1]

Parameters *Parametri*	Mouflon *Muflon*		Axis deer *Jelen aksis*	
	From the working *Plan iz osnove*	Concrete situation *Stvarno stanje*	From the working *Plan iz osnove*	Concrete situation *Stvarno stanje*
GA[1] *LPP*[2]	861 ha	840 ha	930 ha	840 ha
Site class *Bonitet*	First *Prvi*		Second *Drugi*	
Number of heads per 100 ha *Broj grla na 100 ha*	5	5	3	3
Commercial capacity *Gospodarski kapacitet*	43	45	28	22
Hunting capacity *Lovnogosp. kapacitet*	57	51	36	28

[1] 01. April 1999

[2] GA=growing area/*LPP=lovnoproduktivna površina*

THE METHODOLOGY OF DATA COLLECTING
METODOLOGIJA PRIKUPLJANJA PODATAKA

GAME – CULTIVATED GRASSLANDS INTERACTION
INTERAKCIJA DIVLJAČ – KULTIVIRANI TRAVNJACI

During March 1998, the nursery Topolje and the nursery Andrija Petračić were ploughed over and clover grass mixtures of the following species were sown (Šoštarić-Pisačić 1967),

- Cock's foot (*Dactylis glomerata* L.)
- Italian rye-grass (*Lolium italicum* A. Br.)

- Smooth meadow-grass (*Poa pratensis* L.)
- Meadow fescue (*Festuca pratensis* A. Huds.)
- White clover (*Trifolium repens* L.)
- Lucerne (*Medicago sativa* L. 'Elga')

The sowing density is shown in Table 2 (Šoštarić-Pisačić 1967). The concrete sowing norms were obtained in the following way: the quantity of seed was divided with the spatial share each species would cover if it were sown as pure culture.

A total of 1,450 m² of grass mixtures were sown in Topolje, and 3,800 m² of grass mixtures and 2,500 m² of white clover and lucerne mixture were sown in the nursery Andrija Petračić. However, mouflon game concentrated on the nursery Topolje, resulting in all the grass being grazed or trampled in the first year. Of grass species, only cock's foot and Italian rye-grass occurred in both localities. White clover sprouted both in the nursery Topolje and in the nursery A. Petračić, and so did lucerne. In the latter nursery, white clover and lucerne achieved a cover of 90% as early as the first year.

Phytocoenology discriminates between two kinds of plant cover (Rauš & Vukelić 1998):

- Concrete cover - is the cover that a plant achieves after the removal of its above-ground parts and is independent of yearly seasons,
- Projected cover - represents the projection of all above-soil parts of a plant and changes during the vegetation period, but also during the grazing period.

Table 2. The quantity of sown seed by grass species
Tablica 2. Količina zasijanoga sjemena po vrstama travnjačkih biljaka

Species *Vrsta*	Mass *Količina* (kg)	Area *Površina* ha	Concrete norm *Stvarni normativ*	Recommended norm *Preporučljiv normativ*
			(kg/ha)	
Cock's foot *Klupčasta oštrica*	8	0.54	37	30
Italian rye-grass *Talijanski ljulj*	3	0.54	28	25
Smooth meadow-grass *Livadna vlasnjača*	3	0.54	37	32
Meadow fescue *Livadna vlasulja*	5	0.54	37	50
White clover *Bijela djetelina*	2	0.25	40	16
Lucerne 'Elga' *Lucerna 'Elga'*	8	0.25	40	30

The majority of the researchers use the projected cover because it clearly shows natural relationships in a stand in the peak period of its development. Therefore, the projected cover was used here to determine the pasture cover.

For easier cover sampling, the areas in the nursery A. Petračić were divided in three plots as shown in Figure 2, and in the nursery Topolje in two plots (Figure 3). Since the game grazed poorly in the nursery A. Petračić, the grass had to be mowed. During 1999, the same areas were mowed four times in all: once in May, once in July, once in early September and once in early

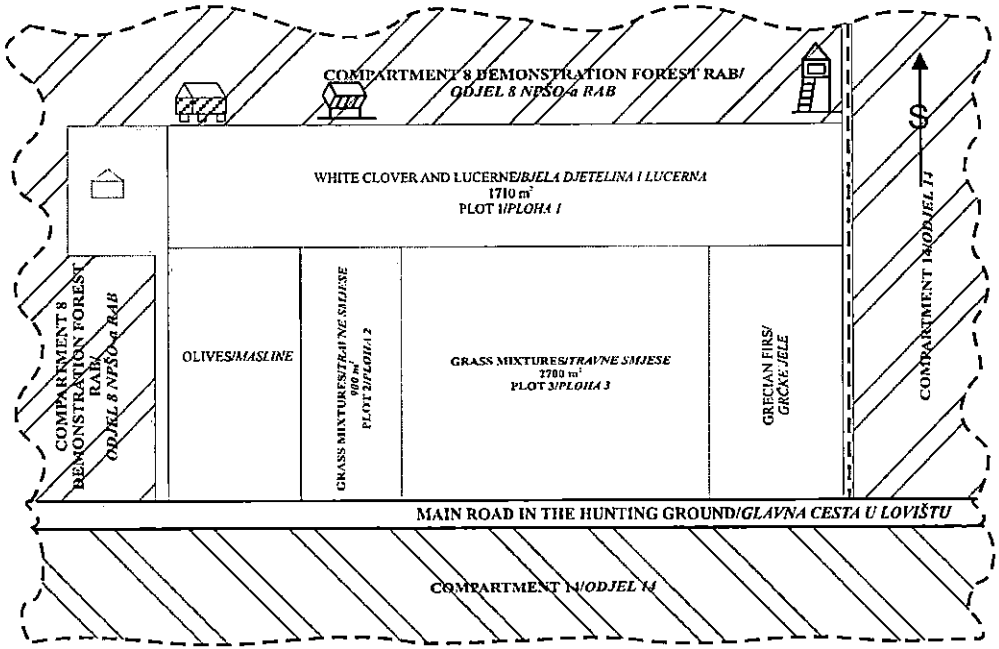


Figure 2. Plan of area distribution in the nursery A. Petračić
Slika 2. Shematski prikaz rasporeda površina u rasadniku A. Petračić

October. The grass areas in the nursery Topolje were never mowed as it was not necessary. The hay from these areas was bundled and offered to game in feeding places - hay racks.

During May 1999, one part of Topolje was ploughed over, and only plot 1 remained covered with grass, so that the grass cover was assessed only in this plot.

The grass cover was assessed in October 1999. At that time of the year, grass vegetation was well developed after summer droughts. To assess the grass cover, a wooden frame (square) with 1 x 1 m sides (1 m²) was constructed. For more accurate reading of the cover, thick thread was used to further divide the square into 100 regular smaller squares sized 1 dm² (Figures 4 and 5). The cover was assessed for each square decimetre. Sample plots were set up at the diagonal transect for each grassy plot. The sampling intensity was 10% for the plot in Topolje (higher variability) and 1% for the plots in the nursery A. Petračić. Table 3 shows plot distribution by cover.

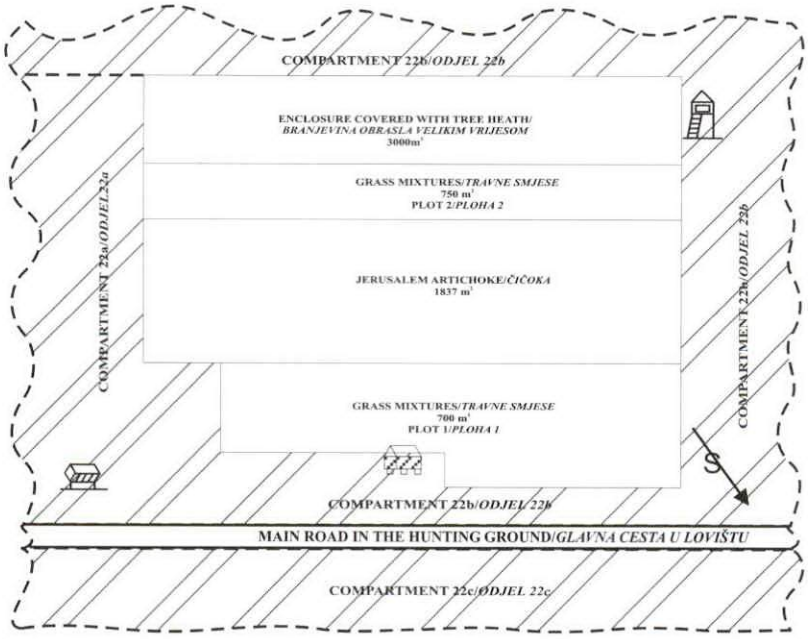


Figure 3. Plan of area distribution in the nursery Topolje
Slika 3. Shematski prikaz rasporeda površina u rasadniku Topolje

Figure 4. The lowest grassland cover in the nursery Topolje
Slika 4. Najmanja pokrovnost travnjaka izmjerena u rasadniku Topolje

Figure 5. The highest grassland cover in the nursery A. Petračić
Slika 5. Najveća pokrovnost travnjaka izmjerena u rasadniku A. Petračić

Table 3. Cover share by plots (1 plot = 1 dm²)
Tablica 3. Prikaz zastupljenosti pokrovnosti po plohama (1 ploha = 1 dm²)

Cover *Pokrovnost*	Plot distribution by cover *Distribucija ploha po pokrovnosti*			
	Plot t *Ploha t*	Plot 1 *Ploha 1*	Plot 2 *Ploha 2*	Plot 3 *Ploha 3*
0 - 10 %	237	10	2	14
10 - 20 %	99	42	22	55
20 - 30 %	65	34	4	75
30 - 40 %	65	43	0	61
40 - 50 %	56	72	50	151
50 - 60 %	69	59	44	300
60 - 70 %	106	84	50	269
70 - 80 %	91	188	103	479
80 - 90 %	98	224	197	742
90 - 100 %	114	1044	428	554
Total *Ukupno*	1000	1800	900	2700

In order to establish the grassland capacity, during 1999 game was monitored from closed observation posts placed in each nursery. In both observation posts, the game was monitored

at the same time one day in the morning and the next day before evening. Monitoring was done every Thursday from 1 April 1999 to 28 October 1999. There were 31 monitoring sessions in all.

GAME - JERUSALEM ARTICHOKE *(HELIANTHUS TUBEROSUS L.)* INTERACTION

INTERAKCIJA DIVLJAČ – ČIČOKA *(HELIANTHUS TUBEROSUS L.)*

According to Grlić (1986), Jerusalem artichoke is a perennial plant achieving a height of up to 2 m. It is related to and resembling the sunflower, with an erect, hirsute stalk, which is bushy at the top and with knobbly tubers on underground stems. The flower heads develop from September to November. It is native to North America. It was introduced to England in 1616, and has become naturalised in the whole of Europe. It is used as livestock food, as a vegetable and as an ornamental plant. It frequently grows in the wild. The tubers are very nutritious and are dug out in late autumn.

Jerusalem artichoke has proved to be an excellent culture for game nutrition. It has very modest soil requirements, is resistant to many diseases, and apart from the tubers, it also forms a large above-ground mass. According to Timarac (2000), wild ruminants like to eat young stems, but before, after and during the blossoming period the stems become hard and the leaves hirsute, so the game avoids it. The same author recommends the stems to be used as silage or dried. It is important to mention that, if there is sufficient food, game avoids Jerusalem artichoke. Table 4 gives the chemical content of different parts of Jerusalem artichoke.

Table 4. Cemical content of Jerusalem artichoke
Tablica 4. Kemijski sastav čičoke

Cemical composition *Kemijski sastav*	Percentage share of individual matter *Postotni udio pojedinih tvari*	
	Stem *Nadzemni dio*	Tubers *Gomolji*
Dry matter *Suha tvar*	16.5	15 - 25
Sugars *Šećeri*	-	13 - 20
Raw protein *Dušične tvari*	1.8 - 2.7	1.7
Raw fibers *Gruba vlakna*	2.0 - 3.9	1.0
Fat *Masnoća*	0.5 - 0.21	0.10 - 0.15
Ash *Pepeo*	2.2 - 7.6	1.0 - 2.0

Source/*Izvor*: Timarac (2000)

According to Table 4, the stem is almost as nutritious as the tubers. The intake of Jerusalem artichoke by game was analysed in the mentioned hunting ground for this reason. Jerusalem artichoke was brought to this ground by some hunters of Rab.

Figure 6. Jerusalem artichoke plantation in September 1998
Slika 6. Nasad čičoke u rujnu 1998. godine

Figure 7. Jerusalem artichoke in June 1999
Slika 7. Biljke čičoke u lipnju 1999. godine

The chronology of Jerusalem artichoke grazing after introducing mouflon game in the hunting ground is as follows:

- The plot of Jerusalem artichoke, covering an area of 1,837 m^2, was left in the original condition. After introducing the mouflon from the quarantine, the game literally devastated the whole culture (Figure 6). In September 1998, the remains of Jerusalem artichoke stems were as thick as straw and bitten off 15 cm from the ground.
- In May 1999, the field was ploughed over and 25 kg of artificial fertilizers of the 15-15-15 NPK formulation were used. In order to assess the tuber size, hazelnut-size tubers of several plants were dug out. That same year, Jerusalem artichoke developed well (Figure 7).

Two measurements were made in order to see in which period the game grazed on Jerusalem artichoke most. The first was made on 2 June 1999, and the second on 31 July 1999. The measurements were made in sample plots sized 1 m^2. There were 7 sample plots in all. Both measurements were made in the same plots. The measurements involved counting the leaves and measuring the height from the

ground to the top of a plant. The plants were divided into damaged and undamaged groups. In the leaf count, all undamaged leaves were counted.

RESEARCH RESULTS
REZULTATI ISTRAŽIVANJA

GAME – CULTIVATED GRASSLANDS INTERACTION
INTERAKCIJA DIVLJAČ – KULTIVIRANI TRAVNJACI

The percentage share of grass species (by number) in the nurseries was as follows: Topolje (Plot T, Figure 8) - *Lolium multiflorum* participated with 10% and so did *Dactylis glomerata*, while the rest of the plot was taken by the following plant species: *Cynodon dactylon, Digitaria sanguinalis, Setaria glauca, Setaria viridis, Echinocloa crus-galli, Trifolium repens, Achillea* sp., etc.

Figure 8. The impact of game on the plant cover in the nursery Topolje
Slika 8. Utjecaj divljači na pokrovnost biljaka u rasadniku Topolje

The nursery A. Petračić:

- Plot 1 (Figure 9) - about 80% of the plot was taken by *Agropyron* sp., while about 20% of the plot was taken by *Trifolium repens* and *Medicago sativa*,

Figure 9. Plant cover in Plot 1
Slika 9. Pokrovnost biljaka na plohi 1

- Plot 2 (Figure 10) - about 20% of the plot was taken by *Dactylis glomerata* and *Lolium multiflorum*, and about 80% by other plant species (the same as in Topolje),

Figure 10. Plant cover in Plot 2
Slika 10. Pokrovnost biljaka na plohi 2

• Plot 3 (Figure 11) - about 30% of the plot was taken by *Dactylis glomerata* and *Lolium multiflorum*, 10% was taken by *Artemisia vulgaris*, and the rest of the plot was taken by other plant species (the same as in Topolje),

Figure 11. Plant cover in Plot 3
Slika 11. Pokrovnost biljaka na plohi 3

Table 5. Statistical parameters of grass cover
Tablica 5. Statistički parametri pokrovnosti trava

Parameters *Parametri*	Plot T *Ploha T*	Plot 1 *Ploha 1*	Plot 2 *Ploha 2*	Plot 3 *Ploha 3*
Mean *Arit. sredina*	5	9	9	8
Standard error *Stand. pogreška*	0.10	0.05	0.06	0.04
Median *Median*	5	10	9	8
Mode *Mod*	1	10	10	9
Stand. deviation *Stand. devijacija*	3.3	2.1	1.9	2.0
Sample variance *Varijanca*	10.7	4.5	3.5	4.2
Range *Opseg*	9	9	9	9
Minimum	1	1	1	1
Maximum	10	10	10	10
Sum *Suma*	5076	15630	7799	21081
Count *n*	1000	1800	900	2700

Table 5 shows that the grass area in the nursery Topolje has the lowest cover (40 to 50%), while plots 1 and 2 in the nursery A. Petračić have the highest cover (80 to 90%), and plot 3 in the same nursery has a cover between 70 and 80%.

Apart from the differences in the cover, which is obvious and need not, therefore, be tested with statistical tests, there is also a difference in standard plot cover deviations. The plot in the nursery Topolje displays high variability in the cover (s_x = 3.3), unlike the plots in the nursery A. Petračić, where variability is much lower (s_x =1.9 to s_x = 2.1). This is supported by Figure 4, taken in the nursery Topolje, which shows that there were even subplots in which the cover was 0% (placed in class 1). Figure 5 shows a much higher cover. In the same plots, higher cover classes were better represented.

GAME - JERUSALEM ARTICHOKE *(HELIANTHUS TUBEROSUS L.)* INTERACTION
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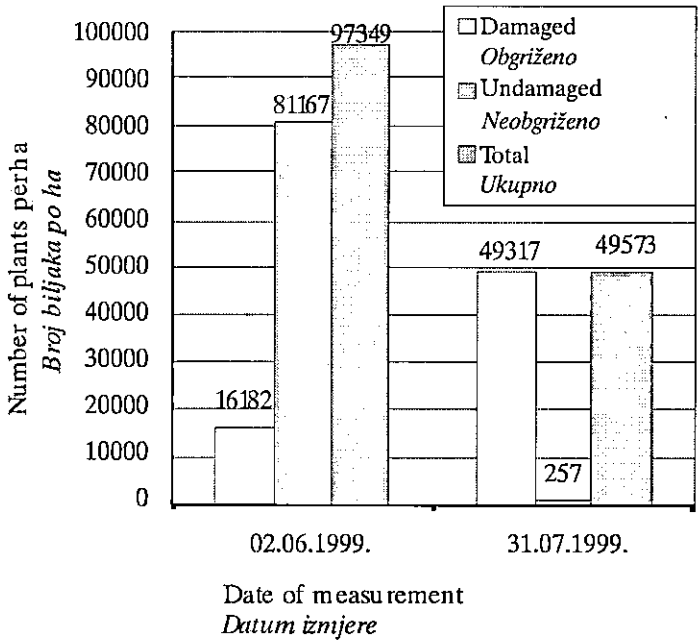
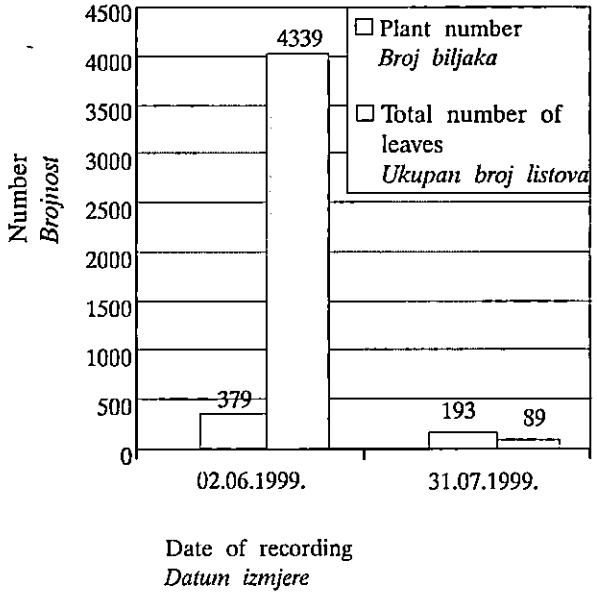
According to Graph 3, of 97,349 plants/ha, 16,182 plants/ha were damaged by game (17%) by the beginning of June. Due to high game pressure on Jerusalem artichoke over a period of two months (June and July), 51% of the plants perished. As a result, 49,573 plants/ha were recorded, of which 49,317 (99%) were damaged.



Graph 3. The share of damaged and undamaged plants of Jerusalem artichoke in sample plots

Grafikon 3. Udio oštećenih i neoštećenih biljaka čičoke na primjernim plohama



Graph 4. Leaf and plant number ratio in sample plotss
Grafikon 4. Odnos broja listova i biljaka na primjernim plohama

The sample plots contained plants whose vegetation tops were not bitten off, but whose leaves were damaged. For this reason, the number of leaves for each plant in the sample plot was counted. Graph 4 shows that by the beginning of June, each plant had 11 leaves on average, while during June and July, the number of leaves on a plant dropped to 0.5, or one in two plants in the sample had only one undamaged leaf.

In order to determine the height at which game bites the plants, the measured plants were divided into:

- undamaged - these were the plants whose tops were not damaged (this category also included plants whose leaves were damaged but the vegetation tops were not damaged),
- damaged - this category included plants with bitten stems, that is, those in which the vegetation tops of terminal shoots were bitten off.

Measurements of plant heights from the ground vertically to the vegetation top, that is, to the biting point, showed that the plants with undamaged tops were 38.2 cm tall on average, while the biting height was 47.0 cm on average. In Table 6, animals exhibit deviations in biting heights, since s_x =12.33 on 2 June 1999, or s_x = 17.61 on 31 July 1999.

To get a better insight into plant biting heights, the plants were placed into height classes of 10 cm according to the height and the biting height, as shown in Table 6.

Table 6. Biting height of Jerusalem artichoke
Tablica 6. Visina odgrizanja biljaka čičoke

Statistical parameters *Statistički parametri*	Date of measurement: *Datum izmjere:* 02.06.1999.		Date of measurement: *Datum izmjere:* 31.07.1999.
	Undamaged *Neoštećene*	Damaged *Oštećene*	Damaged *Oštećene*
Mean *Arit. sredina*	38.2	47.0	35.3
Standard error *Stand. pogreška*	1.32	1.55	1.27
Median *Median*	32	50	34
Mode *Mod*	16	28	34
Stand. deviation *Stand. devijacija*	23.50	12.33	17.61
Sample variance *Varijanca*	552.29	152.14	309.93
Range *Opseg*	102	62	96
Minimum	4	10	4
Maximum	106	72	100
Sum *Suma*	12075	2958	6780
Count . n	316	63	192

Table 6 shows that the average height of damaged plants exceeded that of undamaged plants. It is also clear that the height of damaged plants at the beginning of June exceeded the height of plants measured at the end of July.

To determine the significance of the difference, a U-test was made in order to confirm the above result. The hypotheses are as follows:

- Testing the difference between damaged and undamaged plants (measurement date: 2 June 1999)

$$H_0;\ \overline{h}_N = \overline{h}_O$$
$$H_1;\ \overline{h}_N > \overline{h}_O$$

where

$\overline{h}_N$ = average height of undamaged plants

$\overline{h}_O$ = average height of plants with bitten tops (biting height).

- Testing the difference between damaged plants measured on 2 June 1999 and 31 July 1999 (Table 10).

$$H_0;\ \overline{h}_{O1} = \overline{h}_{O2}$$
$$H_1;\ \overline{h}_{O1} > \overline{h}_{O2}$$

where

$\overline{h}_{O1}$ = average height of damaged plants (2 June 1999)

$\overline{h}_{O2}$ = average height of damaged plants (31 July 1997).

Table 7. Distribution of Jerusalem artichoke by height classes
Tablica 7. Distribucija biljaka čičoke po visinskim razredima

Height classes *Visinski razredi* (cm)	Date: *Datum:* 02.06.1999.		Total *Ukupno*	Date: *Datum:* 31.07.1999.		Total *Ukupno*
	Damaged *Oštećene*	Undamaged *Neoštećene*		Damaged *Oštećene*	Undamaged *Neoštećene*	
0-10	1	16	17	14	0	14
10-20	0	78	78	29	1	30
20-30	7	58	65	31	0	31
30-40	10	41	51	54	0	54
40-50	17	34	51	34	0	34
50-60	20	39	59	15	0	15
60-70	7	20	27	8	0	8
70-80	1	10	11	5	0	5
80-90	0	4	4	1	0	1
90-100	0	13	13	1	0	1
100-110	0	3	3	0	0	0
Total *Ukupno*	63	316	379	192	1	193

The U-test showed (with the significance boundary of 99%) that by 2 June 1999, game preferred to damage higher plants. The test also showed that by the end of July, game significantly lowered the biting height by 11 cm on average.

The intake of different plant parts is essential for knowing the feeding habits of an animal species. For this reason, we wanted to ascertain whether game preferred the shoots and stems of Jerusalem artichoke, or its leaves, and in which period it preferred some of these categories. For this purpose, all plants with undamaged stems and leaves were placed in the category of undamaged plants, while those with damaged stems or leaves were placed in the category of damaged plants.

Table 8. U-test for Jerusalem artichoke height category
Tablica 8. U-test za kategoriju visina biljaka čičoke (cm)

Statistical parameters *Statistički parametri*	Plant height *Visina biljaka* - 02.06.1999.	
	Undamaged *Neoštećene*	Damaged *Oštećene*
Mean *Arit. sredina*	38.2	47.0
Sample variance *Varijanca*	552.29	152.14
Count *n*	316	63
$u_{izr.}$	-4.28	
$u_{tab.}$	2.33	
Statistical parameters *Statistički parametri*	Damaged- plant height *Oštećene -visina biljaka*	
	02.06.1999	31.07.1999
Mean *Arit. sredina*	47.0	35.3
Sample variance *Varijanca*	152.14	309.93
Count *n*	63	192
$u_{izr.}$	5.799	
$u_{tab.}$	2.326	

Table 8 shows that the plants with damaged leaves (2 June 1999) still had a higher number of leaves ($\overline{n}$ = 13.4) than undamaged plants (10.4). Also, damaged plants were taller on average ($\overline{h}_N$ = 38.3) than undamaged plants ($\overline{h}_O$ = 42.3). A U-test was made in order to find out whether there was a significant difference between the leaf number and the heights, or the biting heights in damaged and undamaged plants, and damaged plants at the beginning of June and the end of July. The following hypotheses were made:

* Testing the difference between the number of leaves in damaged and undamaged plants of Jerusalem artichoke damaged by 2 June 1999.

$$H_0;\ \overline{n}_N = \overline{n}_O$$

$$H_1;\ \overline{n}_N > \overline{n}_O,$$

where

$\overline{n}_N$ = average number of leaves on Jerusalem artichoke plants whose leaves were not damaged,

$\overline{n}_O$ = average number of leaves on Jerusalem artichoke plants whose leaves were damaged.

- Testing the difference between the number of leaves of Jerusalem artichoke damaged by 2 June and those damaged by 31 July 1999.

$$H_0,\ \overline{n}_{O1} = \overline{n}_{O2}$$

$$H_1,\ \overline{n}_{O1} > \overline{n}_{O2},$$

where

$\overline{n}_{O1}$ = average number of leaves on Jerusalem artichoke plants whose leaves were damaged (measurement data: 2 June 1999)

$\overline{n}_{O2}$ = average number of leaves on Jerusalem artichoke plants whose leaves were damaged (measurement date: 31 July 1999).

Table 9. Leaf number and heights of damage and undamaged plants of Jerusalem artichoke

Tablica 9. Broj listova i visine biljaka oštećenih i neoštećenih biljaka čičoke

Statistical parameters *Statistički parametri*	Date of measurement: *Datum izmjere:* 02.06.1999.				Date of measurement: *Datum izmjere:* 31.07.1999.	
	Undamaged *Neoštećene*		Damaged *Oštećene*		Damaged *Oštećene*	
	Plant height *Visina biljaka*	Leaf number *Broj listova*	Plant height *Visina biljaka*	Leaf number *Broj listova*	Plant height *Visina biljaka*	Leaf number *Broj listova*
Mean *Arit. sredina*	38.3	10.4	42.3	13.4	35.2	0.5
Standard error *Stand. pogreška*	1.44	0.37	1.86	0.98	1.27	0.05
Median *Median*	35	10	44	9	34	0
Mode *Mod*	16	8	17	7	34	0

Statistical parameters *Statistički parametri*	Date of measurement: *Datum izmjere:* 02.06.1999.				Date of measurement: *Datum izmjere:* 31.07.1999.	
	Undamaged *Neoštećene*		Damaged *Oštećene*		Damaged *Oštećene*	
	Plant height *Visina biljaka*	Leaf number *Broj listova*	Plant height *Visina biljaka*	Leaf number *Broj listova*	Plant height *Visina biljaka*	Leaf number *Broj listova*
Stand. deviation *Stand. deviacija*	22.70	5.84	21.26	11.22	17.63	0.75
Sample variance *Varijanca*	515.43	34.16	451.80	125.78	310.67	0.56
Range *Opseg*	102	46	93	59	96	3
Minimum	4	4	10	4	4	0
Maximum	106	50	103	63	100	3
Sum *Suma*	9494	2584	5539	1755	6794	89
Count *n*	248	248	131	131	193	193

Table 10. U-test for Jerusalem artichoke leaf number

Tablica 10. U-test za kategoriju broj listova na biljkama čičoke

Statistical parameters *Statistički parametri*	Leaf number *Broj listova* 02.06.1999.	
	Undamaged *Neoštećene*	Damaged *Oštećene*
Mean *Arit. sredina*	10.4	13.4
Sample variance *Varijanca*	34.1554133	125.7797
Count *n*	248	131
$u_{izr.}$	-2.84	
$u_{tab.}$	2.33	
Statistical parameters *Statistički parametri*	Leaf number- damaged *Broj listova-oštećeni*	
	02.06.1999	31.07.1999
Mean *Arit. sredina*	13.4	0.5
Sample variance *Varijanca*	125.78	0.56
Count *n*	131	193
$u_{izr.}$	13.18	
$u_{tab.}$	2.33	

The U-test showed (with the significance boundary of 99%) a significant difference in the average number of leaves per plant. This is undoubtedly caused by the fact that damaged plants also had higher heights (42.3 cm) than undamaged plants (38.3 cm). The test also showed that until the end of July game preferred to consume leaves.

DISCUSION
RASPRAVA

In Western and Central Europe, grass areas are mainly established to accommodate small field or possibly roe deer game. Grass areas in this hunting ground are gaining value for the fact that they support a population of brown hare (*Lepus europaeus* Pall.), which has for many years now been at a minimal number (there is a total of 7 tails in the entire area of the hunting ground). Such a condition of the hare population results exclusively from the unfavourable structure of the area, where open spaces fare less than 1% (7.4 ha).

Open spaces are not important only as production areas of game forage (it is assumed that game satisfies its browse requirements in the forest), but they also:

- Provide breeding space,
- Provide denning sites for the young,
- Enable wildlife animals easier drying from rain,
- Ease game stalking and hunting:
- Offer the protective function - namely, the established forage areas in central parts of the hunting ground lure animals there, thus preventing them from wandering to the coastal area for grazing, where they frequently fall prey to poachers who shoot at them from boats at sea.

Only grasses and clovers listed in Table 6 were sown with the purpose of establishing grass areas. However, the nutritive value of grass was enhanced with the addition of some herbaceous plants in the mixture, which, apart from being more palatable for the game, also prolong the grassland vegetation, making it available for a longer period.

During summer until mid-October, the grasslands and Jerusalem artichoke in this hunting ground are dry and make poor forage for the game. This is generally a problem of arid habitats, as there is a shortage of water and fresh food in this period. Yet, not all ruminants are dependent exclusively on water. So, for example, mouflon rarely drink water (Piegert 1999), as they compensate for the water through food. It should be mentioned that as early as the first year after introducing mouflon game in this habitat, it was noted that the bark was stripped from manna ash (*Fraxinus ornus* L.) and holm oak (*Quercus ilex* L.) - the tree species with smooth bark, as well as from broad-leaved phillyrea (*Phillyrea latifolia* L.) and, to a lesser degree, from strawberry tree (*Arbutus unedo* L.). Similar problems were noted by Tschiderer (1974) in Austria, who points out that this occurrence was most probably linked to water shortage.

There is little written data on axis deer. In this game species, the most interesting facts are the size of herd, the social structure and the way of life. In thickets and in grasslands, a herd size correlates with the quantity of precipitation. In terms of precipitation quantity, the correlation is

negative, but in terms of the number of wild fruit trees and leaf litter availability it is positive. In summer, or in dry season, the population density is more than two times higher in forests than in open spaces. If some nutritive components are dispersed, or the habitat is closed, bigger herds are formed (Raman 1997).

Telemetric observation of 12 does and 7 bucks of this species in Nepal (Barolia National Park) showed that annual and seasonal home ranges were relatively small, and that males had a bigger action radius than females in the monsoon part of the year and in the hot part of dry season. The area consists of sever types of habitats which are relatively regularly arranged in the form of smaller areas. During hot and dry season, and especially during night, the does preferred grasslands, where *Imperata cylindrica* was the dominant species. During cold and dry season and hot and dry season, the bucks stayed in floodplain forests, and in the monsoon period and partly during a part of cold and dry season in the forests of salty terrains (Moe and Wegge 1994).

Table 11. The number of game in grass areas
Tablica 11. Broj divljači na travnatim površinama

Statistical parameters *Statistički parametri*	Topolje			A. Petračić
	Mouflon *Muflon*		Axis deer *Aksis*	Axis deer *Aksis*
	Morning *Jutro*	Evening *Večer*	Evening *Večer*	Evening *Večer*
Mean *Arit. sredina*	9	2	2	4
Standard error *Stand. pogreška*	1.4	1.0	0.5	0.8
Median *Median*	10	0	1	5
Mode *Mod*	12	0	1	0
Stand. deviation *Stand. deviacija*	5.5	3.8	1.8	3.2
Sample variance *Varijanca*	30.4	14.2	3,3	10.6
Range *Opseg*	22	12	5	9
Minimum	0	0	0	0
Maximum	22	12	5	9
Sum *Suma*	149	26	28	58
Count *n*	16	15	15	15

The interaction between axis deer and forest ecosystems is also interesting. In many regions where axis deer is an autochthonous species, there is a distinct problem of successful forest regeneration. Thus, the impact of this game on the regeneration of mangrove forests was monitored in Bangladesh (the Sundarkans area). Plants (aged 10 months) of the following tree

species were planted: *Heritiera fomes, Xylocarpus mekongensis, Brugiera sexangula, Ceriops decandra, Avicenia officinalis* and *Exoecearia agallocha*. As early as after the first year, damage assessment showed that this game critically damaged all plants in the unfenced area. The survival percentage was nil for the species *Xylocarpus mekongensis, Brugiera sexangula,* and *Avicenia officinalis.* The survival percentage of the three remaining species reached 40% (Siddiqi 1996).

Similar studies of this interaction on Hawaii showed that axis deer made a considerable impact on the success of afforestation with the species *Leucaena diversifolia.* Four-month-old seedlings were planted in the mixture with eucalyptus (*Eucaliptus saligna*). *Leucaena diversifolia* was completely destroyed, whereas axis deer did not damage eucalyptus plants (which is toxic, Krapinec), and so they prospered well. It is important to point out that axis deer in Latin America did not damage plants of *Leucaena diversifolia*, but this tree species is autochthonous there (Brewbaker 1988).

In the grass areas of the hunting ground "Kalifront", axis deer was observed in differently-sized herds. Calves herded by bucks were frequently noted, while one buck with three does was also sometimes observed. With regard to the time of the day, as a rule, axis deer grazed at night (Table 11).

GAME – CULTIVATED GRASSLANDS INTERACTION
INTERAKCIJA DIVLJAČ – KULTIVIRANI TRAVNJACI

To get a better notion of grassland use in the hunting ground in 1999, the game was monitored from two closed high seats, of which one was placed in each nursery.

Table 11 was made to simplify the issue. It should be mentioned that mouflon did not appear in the nursery A. Petračić, but regularly did so in the nursery Topolje. Axis deer foraged only in the evening and remained in the grassland all night. Mouflon usually grazed early in the morning. The hour of grazing changed over the year. According to Table 11, on average 13 heads of game, of which 11 were mouflon and 2 were axis deer, grazed in the nursery Topolje, while 4 heads of axis deer grazed in the nursery A. Petračić on average. This number of game in the nursery Topolje highly correlates with the low cover, because the size of the mouflon herd grazing in the nursery ranged from 3 to 22 heads, and of axis deer from 1 to 5 heads. This significantly reduced the nutritive potential of the grassland, and so they had to be re-ploughed and re-sown with grass mixtures. It should be pointed out that in forage areas, and especially in grasslands, large biomass does not have big importance as the game tramples over most of it, causing the food to perish. Therefore, it is more important to have a smaller quantity of biomass distributed over a larger area. Likewise, the term of the first sowing did not endanger the growth of selected grasses, clovers and lucerne. Their growth was primarily influenced by game activity, which gathered here in larger numbers for several reasons:

- The vicinity of the fence - after the fence - partition was erected in the hunting ground, most game tracks continued to follow the fence itself, which means that the game probably searches for non-existent gates.
- Immediately next to the meadow on the other side of the main road there is a holm oak enclosure, providing excellent shelter for the game, especially for axis deer

(it is almost impenetrable for man), from which game makes nocturnal visits to the nursery.

- South-east from the nursery there is an old quarry, where mouflon has immediately settled and from which it usually goes on forage sprees.
- The stretch of the forest between the nursery Topolje and the road serves as a partition sheltering the game from man. This is the main road in the hunting ground used by cars and tourists (Figure 2 and 3).
- The game was attracted to this plot by the Jerusalem artichoke plantation and the food storage (corn), and it also grazed in the grasslands (Figure 2 and 3).
- The absence of hunting allowed mouflon to form a large herd (consisting of as many as 40 heads already in the first year), always led by the same old ewe. In the hunting sense, in such cases a herd must be broken into several smaller ones by eliminating a herd leader. In our case, the herd size is probably the consequence of transporting the game together, keeping them in the quarantine and introducing them into the new habitat, rather than of poor nutritive conditions in the hunting ground.

Plant composition and grassland cover are influenced by the game in several ways:

- Game grazing and trampling destroys the plant cover,
- Game urine and defecations fertilise the soil, thus improving the conditions for plant growth.

The breaking up of mouflon herds and the formation of more grass areas would relieve the nursery Topolje and decrease game rearing costs, because grass species would need to be regenerated (re-sown) much less frequently (every four or five years). Interestingly, the game did not consume the hay in the feeding points or hay stacks, nor did it lick salt from salt licks (rock salt was offered). This means that during the year animals have enough natural dry food and that no additional bulky food need be ensured for mouflon and axis deer in eu-Mediterranean conditions. The data concerning hay and salt consumption were not measured since these were not consumed. Corn storages need to be enclosed to keep the game away for two reasons:

- the game was noted to extract corn cobs itself, damaging the hunting facility in the process,
- when the game extracts food, the cobs fall on the ground. The animals eat them from the ground, which represents a hazard from the aspect of pathology and health prevention. Around the storages there are animal faeces (non-polluted), but in contact with the food on the ground, may become the breeding ground of vario infections. To prevent this, grain food must be put into troughs.

Of other plant species in the nursery Topolje, game consumed the following: *Setaria viridis, Setaria glauca, Achilea* sp. (only flower heads), *Holcus lanatus, Digitaria sanguinalis, Cynodon dactylon, Echinocloa crus-galli, Erigeron canadensis, Stenactis annua, Polygonum*

lapathifolium, Polygonum aviculare, Solidago serotina, Rumex acetosa, Rumex acetosella, Chenopodium album and *Hypericum veronense*, while the species *Inula viscosa* was not foraged. *Artemis vulgaris* began spreading in the nursery A. Petračić, but the game did not graze it.

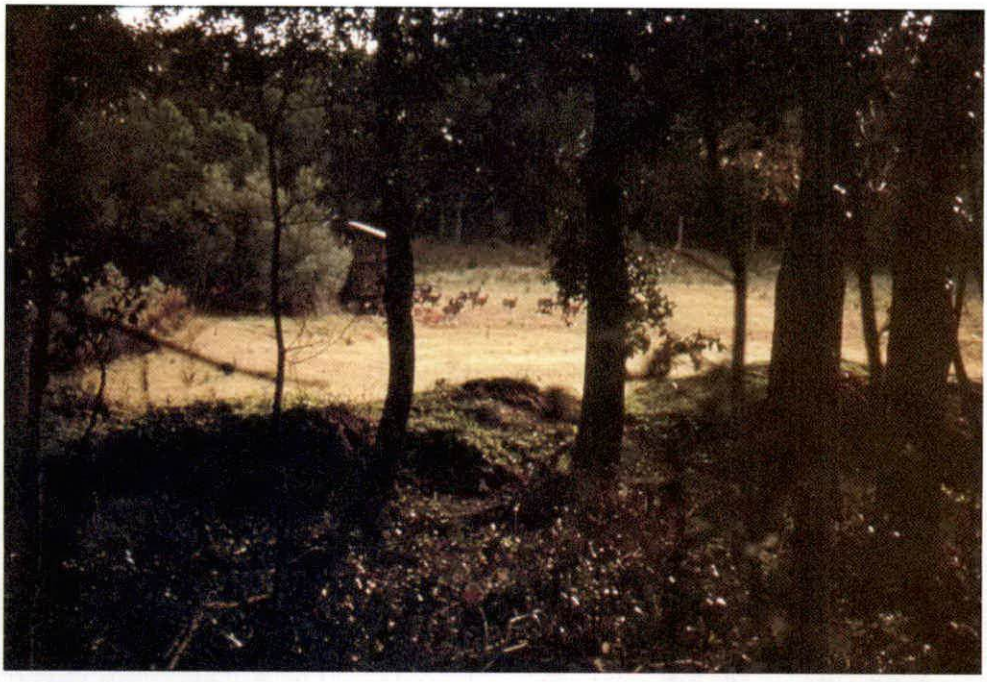


Figure 12. Mouflon distribution in the nursery Topolje
Slika 12. Raspored muflonske divljači pri korištenju rasadnika Topolje

GAME - JERUSALEM ARTICHOKE (*HELIANTHUS TUBEROSUS* L.) INTERACTION

INTERAKCIJA DIVLJAČ – ČIČOKA *(HELIANTHUS TUBEROSUS L.)*

By June, plants of Jerusalem artichoke were well developed, which is shown in Figure 8, however, by the end of July half of the plants were destroyed by game. The destruction was caused by leaf consumption, after which plants became too hard to forage. Table 11 can be used to assess the Jerusalem artichoke plot capacity. The plant was not grazed only by mouflon (11 heads a day on average), but also by axis deer (2 heads a day on average). The use of Jerusalem artichoke as forage is mentioned by Gleich *et al.* (1998) in connection with rearing the fallow deer (*Dama dama* L.) in Eberswald (Germany).

In summer months, Jerusalem artichoke makes forage of very good quality and is for this reason recommended for Mediterranean hunting grounds, especially in view of the fact that

mouflon game is a poor water drinker. It is not necessary to plant thick tubers, because game satisfies its nutritional needs by foraging and not by rooting out and consuming the tubers. Planting a larger number of smaller tubers per unit area may result in Jerusalem artichoke plantations used exclusively as forage. Fertilisation is important. In our case, fertilizing with 125 kg/ha of 15-15-15 NPK fertilizer increased the yield considerably. However, it was seen that the area was not big enough to supply enough game food as total area devastation took place as early as mid-July (Figure 13). Establishing larger plantations of Jerusalem artichoke in several locations would provide more than sufficient food for consumption, which would alleviate the pressure on the stands in the regeneration stage.

Figure 13. Jerusalem artichoke in mid-July 1999

Slika 13. Biljke čičoke sredinom srpnja 1999.

Data from the recording made at the beginning of June show poor grazing on Jerusalem artichoke until early summer, therefore, it is not necessary to enclose the plantations. It is only with the onset of dry conditions and the desiccation of most grasses and herbaceous plants that game begins to forage on Jerusalem artichoke, starting with the tops and the stems and later biting off the leaves rather than the stems.

The biting height of Jerusalem artichoke (47 cm) coincides approximately with the results obtained by Sajfert (2001), who measured the biting height of hawkweed ox-tongue (*Picris hieracioides* L.), reaching 45 cm. In the period of intensive Jerusalem artichoke grazing, the biting height dropped to 35 cm, which means that the game, following worsening living

conditions, started consuming the stalks. The comparison of the heights of damaged and undamaged plants at the beginning of June shows a significant difference, the plants with bitten tops were taller than undamaged plants. This could be explained with the following: the height of 47 cm is optimal for biting because the game not only bites the best quality part of the plant, but also has the maximal field of sight at this height, which enables it to detect a possible predator on time. Although there are no big predators on Rab who would prey on mouflon and axis deer (except for man), this shows that caution in game is instinctive.

An important phenomenon detected in the hunting ground in 1998 and 1999 involves the escape of axis deer from the enclosed part of the hunting ground. It was found that axis deer swam from the enclosed part into the open part of the ground and vice versa. This corroborates the fact that mouflon game is much more aggressive, which forces axis deer to search for other habitats. Partitioning the hunting ground to suit the mouflon feeding strategy cannot be viewed any more within the theory of optimal feeding, because this deprives this game of the possibility of migrating to other, food-richer habitats in case the resources in the present hunting ground are exhausted. Axis deer does not have this problem since water does not pose any serious barrier to it. In order to increase game capacity, more attention should be paid to increasing the nutritive potentials of the habitat in the future, although they are currently still undisturbed.

CONCLUSIONS
ZAKLJUČCI

The following conclusions can be drawn from the analyses:

1. The area of cultivated grasslands amounting to 6,760 m² is sufficient to satisfy the grazing requirements of the game. However, excessive game in the nursery Topolje has seriously disturbed grassland productivity, reducing the cover to 50%.

2. To reduce the number of game in the nursery Topolje, several smaller forage areas (Jerusalem artichoke, oat, forage kale, corn and similar) should be dispersed over the hunting ground. This would reduce the number of heads in a herd and lower the costs of regenerating grass areas.

3. The game must be prevented from extracting food from feeding storages for several reasons: consuming food from the ground, the danger of damaging antlers in the process of extracting food from feeding places, and unnecessary herding in forage areas in which food storages are placed. This can be successfully prevented with enclosing the food storages.

4. Additional nutrition with bulky foods is not necessary in eu-Mediterranean conditions because there is sufficient food in the hunting ground.

5. Mouflon and axis deer use Jerusalem artichoke exclusively as forage and do not root out tubers. In the dry period (summer), Jerusalem artichoke represents an important forage plant in the hunting ground. The most intensive foraging takes place at the beginning of June, whereas before June game shows very little interest in this plant. In early June, game starts with biting off the terminal parts of the shoots, to transfer to the leaves as the drought increases.

6. The quantity of Jerusalem artichoke in the plot of 1,837 m² (10 plants/m²) was not sufficient to satisfy the nutritive requirements of 45 heads of mouflon and 22 heads of axis deer. For this reason, in the dry eu-Mediterranean period it is necessary to establish several smaller forage areas dispersed over the hunting ground, where game may satisfy their needs for fresh food. These areas should be enclosed by the beginning of summer. This procedure would reduce the pressure on the stands in the stage of regeneration, as the crops of woody species represent the only source of fresh food in dry periods.

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REZULTATI ODNOSA MUFLONA (OVIS AMMON MUSIMON PAL.) I JELENA AKSISA *(AXIS AXIS ERX.)* PREMA KULTIVIRANIM TRAVNJACIMA I NASADU ČIČOKE *(HELIANTHUS TUBEROSUS L.)* U LOVIŠTU KALIFRONT NA OTOKU RABU

SAŽETAK

Osnivanje krmnih površina kao dopune prirodne hrane za divljač u lovnom se gospodarstvu primjenjuje već desetljećima. Dok travnjačke površine u načelu služe za prehranu divljači ljeti, površine pod različitim krmnim kulturama namijenjene su ponajprije prehrani divljači u zimskim mjesecima koji su za divljač nepovoljni, i to tako da se kulture ostavljaju neubrane ili da se s njih plodovi skupe i uskladište.

U sredozemnim područjima, a napose u eumediteranskim, za razliku od kontinentalnih (srednjoeuropskih), za divljač je nepovoljni dio godine upravo ljeto jer tada pati od nedostatka sočne hrane ili čak vode. Zbog toga je glavni problem osiguranje sočne hrane kako bi se smanjio pritisak divljači na šumu koja u sredozemnim krajevima ima ponajprije zaštitnu i estetsku funkciju.

Travnjačke površine u zapadnoj i srednjoj Europi uglavnom se osnivaju za sitnu poljsku ili eventualno za smeću divljač. Zbog toga te površine u ovom lovištu dobivaju na vrijednosti za održavanje populacije običnoga zeca (*Lepus europaeus* Pall.), čija je brojnost ovdje već dulji niz godina minimalna (na cijeloj površini lovišta ima ukupno 7 repova). Takvo je stanje zečje populacije isključivo proizvod nepovoljne strukture površina jer otvorenih ima manje od 1 % (7,4 ha).

Državno lovište VIII/6 "Kalifront" prostire se na jugozapadnom dijelu otoka Raba na istoimenoj krškoj zaravni, koja je obrasla najvrjednijom šumom cijeloga otoka. Kalifront je svojevrsni poluotok, ako gledamo cjelinu otoka Raba, jer se uz Kalifront u dubinu uvlače dvije uvale: s jugoistoka Uvala svete Eufemije i sa sjeverozapada Kamporska draga.

Na temelju podataka iz akta o ustanovljenju lovišta ukupna površina lovišta iznosi 1475 ha, a odnos površina po kulturama vidljiv je iz grafikona 1. Iz njega je vidljivo da 90 % lovišta čine šume, što pogoduje prirodnom uzgoju divljih dvopapkara. Zbog maloga udjela poljoprivrednih

površina u lovištu uzgajivač će biti prisiljen praviti i održavati svijetle pruge u lovištu kako bi se divljači osigurala paša u dovoljnoj količini.

Promatrajući postotni udio poljoprivrednih površina po kulturi (grafikon 2), uočljiv je malen udio oranica, osim toga nije ih moguće iskoristiti za proizvodnju hrane za divljač jer su u privatnom vlasništvu, a stanovništvo ih obrađuje.

S obzirom na to da se radi o lovištu koje je u cijelosti smješteno na poluotoku, ono je pregrađeno u duljini 3,4 km. Međutim, pregrađivanjem se lovišta iz korijena promijenio udio zemljišta po kategorijama. Od ukupno 840 ha ograđene površine oko 825 ha (98 %) otpada na šume, a ostalih 15 ha na putove (8,8 ha), svijetle pruge (5,9 ha) i travnjačke površine – rasadnik Topolje i rasadnik "A. Petračić" (1,5 ha). Upravo je stoga bilo nužno osnovati krmne površine za prehranu divljači u lovištu jer se pretpostavljalo da divljač neće moći zadovoljiti dovoljne hranidbene potrebe isključivo na šumskim površinama.

U ograđenom dijelu lovišta tijekom uzimanja podataka za ovaj rad ukupno je bilo 45 grla muflonske divljači i 22 grla jelena aksisa. To čini gustoću populacije sve krupne divljači od 8 grla na 100 ha ukupne površine lovišta. Iz tablice 1 je vidljivo da je u godini izmjere populacija divljači bila u skladu s kapacitetima staništa. Razlika u lovnoproduktivnoj površini nastala je pregrađivanjem lovišta ogradom na dva dijela. Pregrađeni dio u kojem se istraživalo ima površinu od 840 ha, a stvarni se broj grla odnosi na prebrojavanje u tome dijelu lovišta.

Tijekom ožujka 1998. godine preorani su rasadnik Topolje te rasadnik "Andrija Petračić" i na njima zasijane djetelinsko-travne smjese. Gustoća sjetve prikazana je u tablici 6 (Šoštarić-Pisačić 1967). Stvarni normativi sjetve dobiveni su tako da se količina sjemena podijelila površinskim udjelom svake vrste koji bi zauzimala kada bi se zasijala u čistoj kulturi.

Na Topolju je zasijano1450 m^2 travnih smjesa, a u rasadniku "Andrija Petračić" je zasijano 3800 m^2 travnih smjesa te 2500 m^2 smjese bijele djeteline i lucerne. Međutim, muflonska se divljač koncentrirala na rasadnik Topolje tako da je prve godine sva trava bila popasena ili izgažena. Od travnih vrsta iznikle su na oba lokaliteta samo klupčasta oštrica i talijanski ljulj. Bijela djetelina i lucerna iznikle su i na Topolju i u rasadniku "A. Petračić". U rasadniku "A. Petračić" bijela djetelina i lucerna su već prve godine imale pokrovnost od 90 %. Prilikom prikaza pokrovnosti korištena je prividna ili projekcijska pokrovnost jer ju većina istraživača upotrebljava zato što ona jasno izražava prirodne odnose u sastojini u doba njezina najboljega razvitka.

Radi lakšega uzimanja uzorka pokrovnosti površine u rasadniku "A. Petračić" podjeljene su na tri plohe kako je prikazano na slici 3, a u rasadniku Topolje na dvije plohe (slika 4). Budući da se divljač slabo napasala u rasadniku "A. Petračić", trebalo ga je kositi. Tijekom 1999. godine iste su površine pokošene ukupno *četiri* puta, i to jednom u *svibnju*, jednom u *srpnju*, početkom *rujna* i početkom *listopada*. U rasadniku Topolje travne površine nikada nisu košene zbog toga jer nije bilo potrebno.

Tijekom svibnja 1999. godine preoran je jedan dio Topolja te je od travnih površina ostala samo ploha 1 tako da je pokrovnost trava mjerena samo na njoj.

U listopadu 1999. godine izmjerena je pokrovnost travnih površina. U to je doba godine trava dobro razvijena nakon ljetne suše. Za izmjeru pokrovnosti načinjen je drveni okvir (kvadrat) stranica 1 x 1 m (1 m^2). Radi preciznijega očitavanja pokrovnosti kvadrat je debelim

koncem podijeljen na 100 pravilnih manjih kvadrata ploštine 1 dm^2 (slika 4 i 5 – očitavanje površine). Pokrovnost je očitana za svaki kvadratni decimetar. Primjerne su plohe postavljene dijagonalno za svaku travnu plohu. Intenzitet uzorkovanja bio je 10 % za plohu na Topolju (veća varijabilnost) te 1 % za plohe u rasadniku „A. Petračić". U tablici 7 dan je prikaz distribucije ploha po pokrovnosti.

Radi određivanja kapaciteta travnjaka praćena je divljač tijekom 1999. godine iz zatvorenih osmatračnica, od kojih je svaka bila na jednom rasadniku. Divljač je praćena jedan dan ujutro, a drugi predvečer na obje osmatračnice u isto vrijeme. Motrilo se od 1. 4. 1999. do 28. 10. 1999. godine, i to svaki četvrtak. Ukupno je bilo 31 praćenje.

Kronologija pasenja čičoke nakon puštanja u lovište muflonske divljači je sljedeća:

- Ploha čičoke ostavljena je u zatečenom stanju i zauzimala je ploštinu od 1837 m^2. Nakon puštanja muflonske divljači iz karantene ona je doslovce opustošila kompletnu kulturu (slika 6). U rujnu 1998. godine ostaci stabljika čičoke bili su debljine žitne slame i odgrizeni na visini od 15 cm od tla.
- U svibnju 1999. godine polje je preorano i na polje je bačeno 25 kg umjetnoga gnojiva NPK formulacije 15-15-15. Da bi se vidjela veličina gomolja, iskopani su gomolji nekoliko biljaka, koji su bili veličine lješnjaka. Iste se godine čičoka dobro razvila (slika 7).

Kako bi se utvrdilo u kojem razdoblju divljač najviše pase čičoku, napravljene su dvije izmjere. Prva je izmjera napravljena 2. lipnja 1999. godine, a druga 31. srpnja 1999. godine. Izmjere su načinjene na primjernim plohama veličine 1 m^2. Ukupno je bilo načinjeno 7 primjernih ploha. Obje su izmjere obavljene na istim plohama. Na biljkama su prebrojeni listovi, izmjerena visina od tla do vrha biljke te biljke razvrstane na oštećene i neoštećene. Pri prebrojavanju listova brojeni su svi neoštećeni listovi.

Postotni udio travnih vrsta (po brojnosti) na površini rasadnika bio je sljedeći:

Topolje (ploha T, slika 8) – udio *Lolium multiflorum* bio je 10 %, a *Dactylis glomerata* isto 10 %, ostatak plohe su zauzimale ove biljne vrste: *Cynodon dactylon, Digitaria sanguinalis, Setaria glauca, Setaria viridis, Echinocloa crus-galli, Trifolium repens, Achillea* sp. itd.

Rasadnik "A. Petračić"

- Ploha 1 (slika 9) – oko 80 % plohe zauzimao je *Agropyron* sp., dok su oko 20 % plohe zauzimale *Trifolium repens* i *Medicago sativa*
- Ploha 2 (slika 10) – oko 20 % plohe zauzimale su *Dactylis glomerata* i *Lolium multiflorum*, a 80 % su zauzimale ostale biljne vrste (iste kao i na Topolju)
- Ploha 3 (slika 11) – oko 30 % plohe zauzimale su *Dactylis glomerata* i *Lolium multiflorum*, 10 % je zauzimala *Artemisia vulgaris*, a ostatak plohe su zauzimale ostale biljne vrste (kao i na Topolju).

Iz tablice 5 vidljivo je da najmanju pokrovnost ima travnjak u rasadniku Topolje (40 do 50 %), dok najveću pokrovnost imaju plohe 1 i 2 (80 do 90 %) u rasadniku "A. Petračić", a ploha 3 u istom rasadniku ima pokrovnost od 70 do 80 %.

Osim što postoji vidljiva razlika u pokrovnosti te je stoga nije potrebno ispitivati statističkim testovima, postoji razlika i u standardnim devijacijama pokrovnosti ploha. Ploha u rasadniku Topolje pokazuje veliku varijabilnost u pokrovnosti (s_x= 3,3), dok je na plohama rasadnika "A. Petračić" varijabilnost mnogo manja (s_x=1,9 do s_x=2,1). U prilog tomu govori i slika 12 snimljena u rasadniku Topolje na kojoj je vidljivo da je čak bilo potploha na kojima je pokrovnost bila 0 % (svrstane su u razred 1).

Na slici 13 vidi se da je pokrovnost mnogo veća. Na istim plohama zastupljeniji su bili viši razredi pokrovnosti.

Iz grafikona 3 vidljivo je da je do početka lipnja od 97 349 biljaka/ha bilo oštećeno od divljači njih 16 182/ha (17 %). Zbog velikoga pritiska divljači na čičoku u roku od dva mjeseca, odnosno tijekom lipnja i srpnja, 51 % biljaka čičoke se osušio. Zbog toga su bile zabilježene 49 573 biljke/ha, od kojih je oštećeno bilo njih 49 317/ha (99 %).

Na primjernim je plohama bilo biljaka kod kojih vegetacijski vrh nije odgrizen, ali su bili oštećeni listovi. Zbog toga je pobrojeno lišće za svaku biljku na primjernoj plohi. Iz grafikona 4 vidljivo je da je do početka lipnja svaka biljka u prosjeku imala 11 listova, dok je tijekom lipnja i srpnja broj listova na biljci smanjen na 0,5, odnosno svaka je druga biljka u uzorku imala samo jedan neoštećen list.

Promatrajući tablicu 8 vidljivo je da su biljke s oštećenim listovima (2. 6. 1999) još uvijek imale veći broj listova (=13,4) nego neoštećene biljke (10,4), a isto tako da su oštećene biljke imale u prosjeku veće visine (=38,3 cm) nego neoštećene (=42,3). U-test je pokazao (uz granicu signifikantnosti 99 %) signifikantnu razliku u prosječnom broju listova po biljci. Uzrok tomu nedvojbeno je i to što su oštećene biljke imale i veće visine (42,3 cm) od neoštećenih (38,3 cm). Isto je tako test pokazao da je divljač, do kraja mjeseca srpnja, radije konzimirala listove.

Važnost otvorenih površina nije samo u proizvodnji paše za divljač (pretpostavlja se da divljač potrebe za brstom zadovoljava u šumi), nego je ovdje riječ o sljedećim funkcijama:

- Prostor za parenje
- Prostor za koćenje (leženje) mladunčadi
- Prostor na kojem se divljač može brže osušiti nakon kiše
- Olakšavanje osmatranja i odstrela
- Zaštitna funkcija – naime osnivanjem krmnih površina u središnjim dijelovima lovišta divljač se primamljuje na njih te puno manje izlazi na obalni prostor na koji dolazi na pašu gdje najčešće postaje meta zvjerokradica i krivolovaca koji na nju pucaju iz barki, odnosno s pučine.

Prilikom osnivanja travnjaka sijane su isključivo trave i djeteline navedene u tablici 6. Međutim, za divljač je mnogo povoljnije da na travnjacima bude u smjesi i nešto zeljanica jer neke imaju bolju hranidbenu vrijednost od trava, a osim toga produljuju vegetaciju travnjaka te on dulje vrijeme stoji na raspolaganju divljači.

Radi boljega uvida u korištenje travnjaka u lovištu tijekom 1999. godine praćena je divljač iz dviju zatvorenih osmatračnica, od kojih je svaka bila smještena u jednom rasadniku (tablica 11). Pri tome se mora napomenuti da mufloni nisu izlazili u rasadnik "A. Petračić", ali su redovito izlazili u rasadnik Topolje. Jelen aksis na pašu izlazi samo navečer i drži se travnjaka

tijekom cijele noći. Mufloni obično izlaze na pašu rano ujutro. Sat izlaska na pašu tijekom godine se mijenja. Iz tablice 11 može se vidjeti da je u rasadnik Topolje prosječno izlazilo na pašu 13 grla divljači, od toga 11 grla muflonske divljači i 2 grla jelena aksisa, dok su u rasadniku "A. Petračić" pasla prosječno 4 grla jelena aksisa. S tim u svezi može se reći da je ovaj broj divljači u rasadniku Topolje u visokoj korelaciji s malom pokrovnošću jer se broj muflonskoga krda koje je paslo u rasadniku kretao od 3 do 22 grla, a kod jelena aksisa od 1 do 5 grla. Pri tome je jedan od razloga za intenzivnije korištenje rasadnika Topolje bilo spremište za kukuruz koje se nalazi u njemu. Time su se prehrambeni potencijali travnjaka znatno smanjili te se moralo pribjeći novom preoravanju travnih površina i ponovnom zasijavanju travnim smjesama. Dakle, ne može se reći da je termin prvotne sjetve bitno ugrozio rast selekcioniranih trava, djeteline i lucerne. Na njihov razvoj u prvome je redu utjecala divljač svojim djelovanjem koja se ovdje nagomilala iz više razloga:

- Blizina ograde – nakon podizanja ograde-pregrade u lovištu se još uočava da glavnina tragova divljači vodi uz samu ogradu. Vjerojatno divljač traži moguće prijelaze kojih nema.
- Odmah pored livade s druge strane glavne ceste nalazi se branjevina hrasta crnike te tako divljač (osobito jelen aksis) u njoj nalazi prvoklasan zaklon (gotovo je neprohodna za čovjeka), a na večer izlazi na pašu u rasadnik.
- Jugoistočno od rasadnika nalazi se stari kamenolom na koji se odmah smjestila muflonska divljač te odatle obično kreće na pašu.
- Trasa šume između rasadnika Topolje i ceste služi divljači kao paravan kojim je zakrita od čovjeka. Naime, ovom cestom, koja je glavna u lovištu, dosta prolaze automobili i turisti.
- Nasad čičoke privukao je divljač na ovu plohu pa se divljač hranila i na travnjacima.
- Izostanak odstrela pridonio je grupiranju muflonske divljači u veliko krdo (koje je već prve godine znalo brojiti 40 grla), koje je predvodila uvijek jedna te ista stara ovca. Naime, poznato je da u takvim slučajevima treba razbiti krdo na više manjih odstreljivanjem vođe krda. Ovdje je nužno pretpostaviti kako je veličina krda vjerojatno posljedica zajedničke dopreme, držanja u karanteni i ispuštanja u novo stanište, a ne posljedica loših hranidbenih uvjeta u lovištu.

Na biljni sastav i pokrovnost travnjaka divljač utječe na više načina:

- Pašom i gaženjem uništava biljni pokrov.
- Uriniranjem i defekacijom gnoji tlo čime se poboljšavaju uvjeti za rast biljaka.

Razbijanjem krda muflonske divljači formiranjem više travnih površina rasteretio bi se rasadnik Topolje, a time bi se smanjili troškovi uzgoja divljači jer bi travne vrste (nadosijavanje) trebale obnavljati mnogo rjeđe (svake četvrte ili pete godine). Zanimljivo je da divljač nije uzimala sijeno s hranilica i iz stogova, te nije htjela lizati sol na soliištima (izlagala se kamena sol). To pokazuje da divljač tijekom godine ima dovoljno prirodne suhe hrane te u eumediteranskim uvjetim nije potrebno predviđati prihranu kabastom hranom za muflonsku divljač i jelena aksisa. Te podatke nije bilo potrebno mjeriti jer uzimanja sijena i soli nije bilo. Isto je tako nužno zbog divljači ograditi spremišta za kukuruz iz dvaju razloga:

- Uočeno je da divljač iz njih sama vadi klipove te pri tom oštećuje lovni objekt.
- Pri vađenju klipova oni padaju na tlo te ih životinje jedu s tla, što nije dobro s gledišta patologije, odnosno zdravstvene preventive. Oko spremišta se nalaze fecesi životinja koji se doduše čiste, ali na tlu hrana dolazi u doticaj s izmetom te se prenose različite zaraze. Zbog toga se zrnata hrana mora izlagati u koritima.

Od ostalih biljnih vrsta u rasadniku Topolje divljač je konzumirala sljedeće: *Setaria viridis, Setaria glauca, Achilea* sp. (samo cvatne glavice), *Holcus lanatus, Digitaria sanguinalis, Cynodon dactylon, Echinocloa crus-galli, Erigeron canadensis, Stenactis annua, Polygonum lapathifolium, Polygonum aviculare, Solidago serotina, Rumex acetosa, Rumex acetosella, Chenopodium album* i *Hypericum veronense,* dok vrstu *Inula viscosa* divljač nije pasla. U rasadniku "A. Petračić" počela se širiti *Artemisia vulgaris*, ali divljač ju nije pasla.

Iako su se biljke čičoke do lipnja dobro razvile, o čemu svjedoči slika 8, divljač je do kraja srpnja uništila polovinu biljaka. Uzrok je tomu konzumiranje listova, nakon što je stabljika postala pretvrda za pašu. Za određivanje kapaciteta plohe čičoke može se upotrijebiti tablica 11. Čičoku nisu brstili samo mufloni (prosječno 11 grla dnevno), nego i jelen aksis (u prosjeku 2 grla dnevno). Čičoka zbog svoje sočnosti u ljetnim mjesecima pruža vrlo dorbu pašu. Zbog toga ju je preporučljivo saditi u sredozemnim lovištima, pogotovo kada se zna da muflonska divljač slabo uzima vodu s pojilišta. Nije potrebno saditi krupne gomolje jer se divljač zadovoljava i njihovom pašom, ne iskopavajući i ne jedući gomolje. Zbog toga je dovoljno saditi sitnije gomolje, ali veći broj po jedinici površine, te formirati polja čičoke isključivo za potrebe paše. Pri tome značajnu ulogu ima gnojenje. U ovom slučaju gnojenjem se (125 kg gnojiva NPK 15-15-15/ha) dobio znatan prirast. Međutim, pokazalo se da navedena površina nije bila dovoljna za prehranu divljači jer je u potpunosti opustošena već sredinom srpnja (slika 28). Vjerojatno je to jedan od razloga zašto je divljač tijekom ljeta intenzivnije brstila. Ako bi se u lovištu osnovale veće površine čičoke na više lokacija, tada bi je bilo više nego dovljno za prehranu te bi se smanjio pritisak na sastojine u fazi obnove.

Podaci dobiveni snimkom početkom lipnja upućuju na to da divljač slabije pase čičoku do početka ljeta, te ju nije potrebno ograđivati. Tek kada nastupe sušni uvjeti, a većina trava i zeljanica se osuši, divljač počinje s pašom čičoke, u prvom redu odgrizanjem vrhova, odnosno stabljika, a poslije više odgrizanjem listova, a manje odgrizanjem stabljike.

Visina odgrizanja biljaka čičoke (47 cm) približno se podudara s rezultatima koje je dobio Sajfert (2001) mjereći visinu odgrizanja runjikastoga jagušca (*Picris hieracioides* L.), a koja je iznosila 45 cm. Tijekom intenzivne paše čičoke visina odgrizanja ja pala na 35 cm, što znači da je divljač, razmjerno pogoršanjem životnih uvjeta, posegnula za jačim iskorištavanjem stabljika čičoke. Uspoređujući visine oštećenih i neoštećenih biljaka početkom lipnja, uočljiva je signifikantna razlika, odnosno biljke s obgrizenim vrhom imale su veće visine od onih neoštećenih. To bi se moglo objasniti sljedećim: visina od 47 cm optimalna je za odgrizanje jer divljač time ne samo što odgriza najkvalitetniji dio biljke nego je pri toj visini osigurano maksimalno vidno polje koje divljači omogućuje dobar pregled terena i pravodobno uočavanje predatora. Iako na Rabu nema velikih predatora koji bi se mogli hraniti muflonom i jelenom aksisom (osim čovjeka), to pokazuje da je divljač oprezna instinktivno.

Tijekom 1998. i 1999. godine u lovištu je uočeno bježanje jelena aksisa iz ograđenoga dijela

lovišta. Naime, uočeno je da jelen aksis pliva iz ograđenoga u neograđen dio lovišta i obratno. To je u skladu s činjenicom da je muflonska divljač mnogo agresivnija te da je jelen aksis prisiljen tražiti druga staništa. Pregrađivanjem lovišta na prehrambenu strategiju muflonske divljači ne može se više gledati u okvirima teorije optimalnoga hranjenja jer im je isključena mogućnost migracije u druga hranidbeno bogatija staništa, ako se resursi u sadašnjem lovištu iscrpe. Jelen aksis nema tih problema jer mu vodena površina nije značajnija prepreka. Zbog toga bi se trebala veća pozornost posvetiti podizanju hranidbenih potencijala staništa (koji doduše još nisu narušeni), ako bi se kapacitet divljači želio povećati.

Ključne riječi: muflon (*Ovis ammon musimon* Pal.), jelen aksis (*Axis axis* Erx.), čičoka (*Helianthus tuberosus* L.)

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SMALL RODENTS RESERVOIRES OF LEPTOSPIROSES IN THE FORESTS OF POSAVINA IN CROATIA

SITNI GLODAVCI KAO IZVOR LEPTOSPIROZA U POSAVSKIM ŠUMAMA U HRVATSKOJ

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Small rodents from the subfamilies *Murinae* and *Arvicolinae* are a reservoires of infectious diseases affecting humans, domestic and wild animals. The paper presents the results of research on these mammals as the reservoirs of leptospiroses. The samples were collected from April to November 2000 in the forests of Posavina in Croatia. The forests are managed by 11 forest administrations of the public enterprise "Croatian Forests", Ltd. The following species of small rodents were detected: *Apodemus agrarius, A. flavicollis, A. sylvaticus, Arvicolla terrestris, Clethrionomys glareolus, Microtus agrestis, M. arvalis* and *Mus musculus*. The dominant species in the studied plots (44) were *A. flavicollis* and *A. agrarius*. Most individuals were captured in the forests managed by forest administrations Popovača (25.86 %) and Nova Kapela (17.94 %). 83.82 % of the animals were caught in the forest communities of *Genisto elatae - Quercetum roboris caricetosum remotae, Genisto elatae - Quercetum roboris caricetosum brizoides* and *Carpino betuli - Quercetum roboris typicum*. The majority of them were captured during autumn months. A total of 379 animals were analysed with the method of renoculture were down in Korthof's liquid medium and serological reaction to microscopic agglutination with 12 serological variants of the *Leptospira*. A total of 17 *Leptospira* strains were isolated with renoculture from the individuals of three rodent species (*M. musculus, A. flavicollis* and *A. agrarius*) caught in the localities in Kutina, Velika Gorica, Popovača and Nova Kapela. The antibody titre to *Leptospira* was identified in 48 animals of the following species: *A. agrarius, A. flavicollis, M. musculus, C. glareoulus* and *A. sylvaticus*.

Key words: small rodents, forest ecosystems, leptospiroses, Posavina, Croatia

INTRODUCTION
UVOD

Forests are complex ecosystems supporting a large variety of organisms. Biodiversity, sustainable management and natural regeneration are the basic postulates of past, present and future development of forests and forestry (Gračan *et al.* 1998). In Croatia, forests cover about two million hectares. The total forest area with pedunculate oak (*Quercus robur* L.) as the dominant species accounts for 201,739 ha, which is 10 % of the overall forest area (Klepac 1996, Klepac & Fabijanić 1996).

Small rodents from the subfamilies *Murinae* (the true mice) and *Arvicolinae* (the voles) directly influence forest regeneration by damaging forest seeds, seedlings and young plants (Margaletić 1998). Damage is particularly high in the years of their overproliferation. Croatia's lowland forests are inhabited by the following species of small rodents: bank vole (*Clethrionomys glareolus* Schreib.), water vole (*Arvicola terrestris* L.), common pine vole (*Microtus subterraneus* de Sel.), common vole (*M. arvalis* Pall.), field vole (*M. agrestis* L.), Alpine pine vole (*M. multiplex* Fat.), striped field mouse (*Apodemus agrarius* Pall.), wood mouse (*A. sylvaticus* L.) and yellow-necked mouse (*A. flavicollis* Melch.) (Margaletić 1998, Glavaš & Margaletić 2001, Margaletić & Glavaš 2001). The high population densities and width of ecological valence make small rodents an important part of almost any forest ecosystem. They represent a significant group of animals which link the primary producers with higher trophic levels. These mammals have exceptionally sharp, characteristic front incisors (Delany 1974). Their breeding potential is very high (Kowalski 1976).

Small rodents are reservoires of various infectious diseases (zoonoses) of human, as well as domestic and wild animals and they play an important role in spreading zoonoses, infectious and parasitic diseases (trichinosis, leptospirosis, tick encephalitis, Lyme disease, hemorrhagic fever with kidney syndrome and others) (Bäumler 1975, Geisel *et al.* 1979, Barrow 1981, Borčić *et al.* 1982a, 1982b, 1983). This depends on the rodent population size, their distribution, mobility, feeding intensity, habitat conditions and breeding potential, as well as the number and distribution of wild and domestic animals susceptible to infectious diseases. Small rodents transmit the causes of infectious diseases actively (secretions or excretions) or passively (ectoparasites and endoparasites). The spread of diseases transmitted by mice and voles can seriously endanger the health and the number of receptive wild animal species, disturb the balance of the forest ecosystem, or inflict vast damage to organised management of good-quality hunting game. In lowland oak forests, which are the most widespread in the Posavina region of Croatia, zoonoses particularly affect people who work there or who occasionally spend some time there (foresters, gamekeepers, hunters, natural scientists, soldiers, hikers and others). As germ carriers, small rodents may occasionally or permanently secrete the causes of infectious diseases and contaminate their living environment with their secretions or excretions, turning it into intermediary and secondary sources of infectious diseases (Zaharija 1980, Cvetnić 1993).

This paper deals with leptospirosis. It is an acute septicaemic infectious disease affecting a wide range of domestic and wild animals, as well as human, which usually occurs enzootically. It is clinically manifested in icterus, sometimes in haemoglobinuriam, and in abortion in cattle

and pigs. Leptospirosis is caused by pathogenic spiral-shaped bacteria of the genus Leptospira (Noguchi 1918) which comprises several genomospecies (Ellis 1955, Brenner *et al.* 1999), 24 serogroups and more then 250 serovars (Kmety & Dikken 1993). This research gives new insights into the representation of some serological *Leptospira* strains (serovars) in the studied localities and identifies small rodents species infected with leptospiroses in the studied localities of Posavina.

The results of research of small rodents as the reservoirs of zoonoses (leptospirosis, tularaemia, rabies, hemorrhagic fever, etc.) in Croatia have been published in the following papers: Borčić et al. 1982a, 1982b, 1983, 1986, 1987, 1999, etc. These authors have recorded a natural focus of tularaemia and leptospirosis in the lowland part of northern Croatia, while hemorrhagic fever and rabies were identified in the localities of Plitvice, Dinara, Turopolje, Psunj, Papuk and Central Posavina.

Leptospiroses in micro mammals in the area of Croatia were also studied by Zaharija (1968). He studied nine rodent species, 1,431 animals, of which leptospiroses were detected in the following four species: *M. arvalis*, *Mus musculus* (L.), *Crocidura* sp. and *A. agrarius*. On six localities in Podravina and Posavina he isolated 28 leptospira strains of the following serological variants: *grippotyphosa* (21), *sejroe* (4) and *ballum* (2). Borčić *et al.* (1982a) studied small rodents in the River Sava valley. In seven localities 1,734 animals were caught, of which 15 species were identified, dominated by *M. arvalis* (38 %) and *A. agrarius* (32 %). A total of 675 animals were analysed with renoculture and 580 animals were analysed serologically. In the animals under study an infection with leptospires of the serologic variants *pomona* and *grippotyphosa* was identified with isolation and serology. Earlier papers were mostly concerned with small meadow and field rodents as sources of leptospiroses, while this paper deals with infected small rodents inhabiting forest stands, which are natural foci of these diseases.

RESEARCH AREA
PODRUČJE ISTRAŽIVANJA

The research was conducted in the forests of Posavina in Croatia. The forests included forest stands managed by 11 forest administrations of "Croatian Forests" Ltd (Figure 1). Several sample plots were set up in each locality (a total of 44). Small rodents were collected in between April and November 2000. In the majority of the localities samples of small rodents were collected twice a year, in spring and autumn. Samples were not taken from the end of July to the beginning of September.

Rodents were captured in the following forest communities: *Genisto elatae-Quercetum roboris caricetosum remotae, Genisto elatae-Quercetum roboris caricetosum brizoides, Carpino betuli-Quercetum roboris typicum, Carpino betuli-Quercetum roboris fagetosum, Carpino betuli-Quercetum roboris quercetosum cerris, Carici pilosae-Fagetum sylvaticae, Epimedio-Carpinetum betuli, Leucoio-Fraxinetum angustifoliae* and *Frangulo-Alnetum glutinosae* (Vukelić & Rauš 1998). The forest communities of *Carici pilosae-Fagetum sylvaticae, Epimedio-Carpinetum betuli, Leucoio-Fraxinetum angustifoliae* and *Frangulo-*

Alnetum glutinosae encompassed by the research, are distributed in the studied localities of state hunting grounds "Garjevica" (no. VII/4) (*Carici pilosae-Fagetum sylvaticae* and *Epimedio-Carpinetum betuli*) and "Radinje" (no. XII/16) (*Leucoio-Fraxinetum angustifoliae* and *Frangulo-Alnetum glutinosae*).

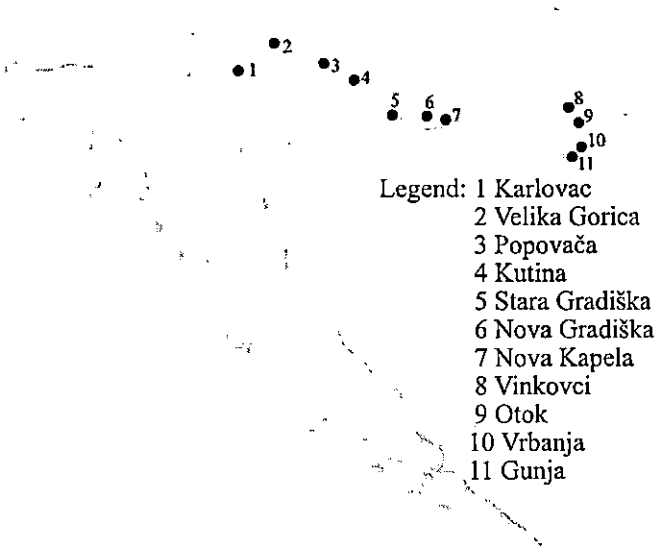

Figure 1. The localities where small rodents were collected
Slika 1. Lokaliteti uzorkovanja sitnih glodavaca

In the area managed by the Forest Administration Zagreb, research was done in the localities of the following Forest Offices: Popovača (MU „Popovačke nizinske šume", localities: „Paljevička", compartment/subcompartment 90b; "Ravnik", compartment/ subcompartment 95b and "Veliki Ravnik" compartment/subcompartment 99a), Velika Gorica (MU "Turopoljski Lug", localities: "Vratovo", compartment/subcompartment 98a; "Klenovo", compartment/ subcompartment 120a, "Rastine", compartments/subcompartments 90a and 59a, and "Jalševa Greda", compartment/subcompartment 58a) and Kutina (MU "Kutinska Garjevica", localities: "Izbjeljeno Brdo", compartment/subcompartment 102a; "Šib", compartments/subcompartments 110a and 116a, and "Poznanović Planina", compartment/subcompartment 111a).

In the area managed by the Forest Administration Karlovac, research was done in the Forest Office Karlovac, MU "Rečički Lugovi, in the localities "Stara Brajnica (compartments/ subcompartments 26a, 27b and 77a), "Prekblatnica" (compartment/subcompartment 70a) and "Mokrice" (compartment/subcompartment 33a).

In the area of the Forest Administration Nova Gradiška, research was done in the following Forest Offices: Stara Gradiška (MU "Ljeskovače", locality "Ljeskovača", compartments/subcompartments 24a, 25b, 26a, 26b, 29a and 30a), Nova Gradiška (MU "Ključevi", locality "Ključevi", compartments/subcompartments 27a, 32a and 35a) and Nova Kapela (MU "Radinje", localities: "Rastovica", compartment/subcompartment 49a; "Hajdučka Greda", compartments/subcompartments 12b and 13b; "Vlakanac", compartment/subcompartment 16d; "Ruščica", compartment/subcompartment 17a; "Vrapča", compartment/subcompartment 22a and "Lukovo", compartment/subcompartment 50a).

In the area of the Forest Administration Vinkovci, rodents were caught in the localities of the following Forest Offices: Vinkovci (MU "Kunjevci", locality "Kunjevci", compartments/subcompartments 29a and 32a), Otok (MU "Slavir", locality "Tikar", compartments/subcompartments 152a and 152b), Vrbanja (MU "Vrbanjske Šume", locality "Svenovo", compartments/subcompartments 147c, 150a, 150c and 150d) and Gunja (MU "Trizlovi-Rastovo", locality "Rađenovci", compartments/subcompartments 44a, 45a, 46a and 461).

Figure 2 shows the number of sample plots set up in the forest communities in which animal samples were taken.

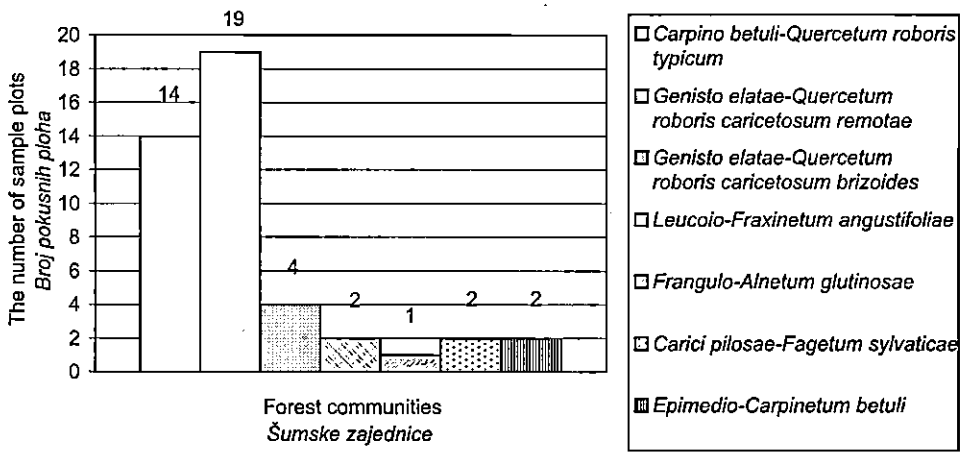

Figure 2. The number of sample plots by forest communities in which samples of small rodents were trapped

Slika 2. Broj pokusnih ploha po pojedinim šumskim zajednicama na kojima su uzorkovani sitni glodavci

METHODS
METODE

Small rodents were trapped with Sherman snap traps and live-traps. The traps were set up in transects at a distance of 5 - 7 m and were baited with apples, as well as a mixture of oatmeal and sardines in oil. The collected individuals were identified according to Niethammer & Krapp (1978, 1982) and deposited to Faculty of Forestry from University of Zagreb.

A total of 379 rodents were analysed serologically and bacteriologically in the Institute of Microbiology and Infective Diseases at the Faculty of Veterinary Science in Zagreb. A method of microscopic agglutination was used as a standard method of serologic diagnostics and leptospira classification. In case of the presence of antibodies in the basic dilution 1:100, the samples were tested in higher serum dilutions (1:500, 1:1000, etc.). The highest antibody titre to an individual leptospira antigen or serovar in the serum indicates a "possible" serovar responsible for the infection (Johnson 1976). Each blood sample was tested with the antigens *L. interrogans* sv: *icterohaemorrhagie, ballum, australis, pomona, grippotyphosa, sejroe, saxkoebing, bataviae, tarassovi, canicola, poi* and *hardjo*. To isolate leptospira, the positive individuals were treated with the renoculture weredown in Korthof's liquid medium.

A total of 17 leptospire strains isolated from *A. flavicollis, A. agrarius* and *M. musculus*, which were collected in Kutina, Popovača, Velika Gorica, Nova Kapela and Otok, were sent to Pasteur Institute (Paris, France), where the PFGE– pulsed-field gel electrophoresis was done. The PFGE analysis consists of the following: after restricting a chromosome DNA with the restriction enzymes "NotI" and "Srg AI", the restriction profiles of the tested serovars (serologic variants) are compared with the referent serovar profiles. This method may determine leptospires at the serovar level, that is, establish their physical map (Baril & Saint Girons 1990). The PFGE analysis with the restriction enzyme "NotI" isolates the serovars of "*sejroe*" and "*pomona*" serologic groups (serogroups), while the analysis with the restriction enzyme "Sgr AI" isolates the serovars of the "*australis*" serologic group.

RESULTS
REZULTATI

A total of 445 small rodents were collected in all the localities, and 379 were analysed in the laboratory (85.17 %). The remaining 66 individuals were not analysed due to predator damage or tissue decomposition caused by atmospheric occurrences (high temperature). The results of analysed individuals by species and localities are given numerically in Table 1. The animals were collected in the area of 10 different forest offices in Upper, Central and Lower Posavina. No samples of small rodents were caught in the area of the Forest Office Vinkovci, and therefore there are no results of the leptospira infection from this locality.

Table 1. Analysed small rodents by locality of collection and sex of the animal. *First row – number of analysed animals. Second row – the first number are males and the second females

*Tablica 1. Prikaz pretraženih sitnih glodavaca prema lokalitetu uzorkovanja i spolu životinje. *Prvi red – broj analiziranih životinja. Drugi red – prvi broj predstavlja muški, a drugi broj ženski spol*

Animal species *Vrsta životinje*	Kutina	Velika Gorica	Popovača	Vrbanja	Gunja	Stara Gradiška	Nova Kapela	Otok	Nova Gradiška	Karlovac	Σ	%
Apodemus agrarius	0	2 (2/0)*	33 (6/27)	9 (2/7)	1 (1/0)	12 (6/6)	33 (8/25)	5 (2/3)	8 (0/8)	5 (2/3)	108 (26/82)	28.5
Apodemus flavicollis	8 (3/5)	10 (6/4)	38 (9/29)	6 (3/3)	2 (1/1)	1 (0/1)	11 (5/6)	6 (4/2)	5 (1/4)	24 (11/13)	111 (43/68)	29.3
Apodemus sylvaticus	2 (2/0)	9 (3/6)	11 (5/6)	7 (0/3)	7 (2/5)	0	4 (1/3)	6 (2/4)	3 (1/2)	13 (3/10)	62 (23/39)	16.4
Arvicola terrestris	0	0	1 (0/1)	0	0	0	0	0	0	0	1 (0/1)	0.3
Clethrionomys glareolus	1 (0/1)	5 (4/1)	12 (0/12)	4 (2/2)	6 (1/5)	1 (1/0)	19 (9/10)	1 (0/1)	1 (0/1)	3 (0/3)	53 (17/36)	13.9
Microtus agrestis	0	2 (1/1)	2 (2/0)	0	0	0	0	0	0	2 (1/1)	6 (4/2)	1.6
Microtus arvalis	0	3 (1/2)	0	1 (0/1)	0	0	1 (1/0)	1 (0/1)	0	0	6 (2/4)	1.6
Mus musculus	30 (17/ 13)	0	1 (0/1)	0	0	1 (1/0)	0	0	0	0	32 (18/14)	8.4
Σ	41 (22/9)	31 (17/4)	98 (22/76)	27 (11/16)	16 (5/11)	15 (8/7)	68 (24/44)	19 (8/11)	17 (2/15)	47 (17/30)	379 (136/243)	100.0

The following species of small rodents were trapped: *A. agrarius, A. flavicollis, A. sylvaticus, A. terrestris, C. glareolus, M. agrestis, M. arvalis* and *M. musculus*. The dominant species were *A. flavicollis* (111 individuals) and *A. agrarius* (108 individuals), while the most numerous vole was *C. glareolus* (53 individuals) (Figure 3). The highest number of collected individuals was in Popovača (100 animals or 25.86 %). In the total of 379 analysed individuals, 136 were males and 243 females.

The majority of *M. musculus* (93.75 %) were captured in the closed facilities of the state hunting ground "Garjevica" (Forest Office Kutina).

The antibody titre to leptospires was detected in 48 animals in all the localities. The species include *A. agrarius, A. flavicollis, M. musculus, C. glareolus* and *A. sylvaticus* (Table 2). Table 3 gives detailed analysis of the presence of antibodies against serological variants of leptospires according to the highest antibody titre (quantity). The amount of 34.38 % of *M. musculus*, 14.18 % of *A. agrarius*, 10.81 % of *A. flavicollis*, 6.45 % of *A. sylvaticus*, and 9.43 % of *C. glareolus* species were found to be serologically positive. Serological variants *saxkoebing* and *hardjo* were found in *M. musculus*, while four isolates remained unidentified with the antibody titre 1:100. In *A. agrarius*, the serological variants of *grippotyphosa, sejroe, pomona, icterohaemorragiae, tarassovi* and *hardjo* were found, while the analysis of *A. flavicollis* showed the presence of antibodies against the *australis, pomona, saxkoebind* and *bataviae* serological variants. Four antibody findings remained unidentified with the antibody titre 1:100. In *A. sylvaticus*, serological variants *sejroe, pomona* and *tarassovi* were found, while the analysis of *C. glareolus*

revealed the presence of the antibodies of serological variants *sejroe, australis, saxkoebing* and *hardjo*. Five isolates remained unidentified with the antibody titre 1:100 (4) and 1:500 (1).

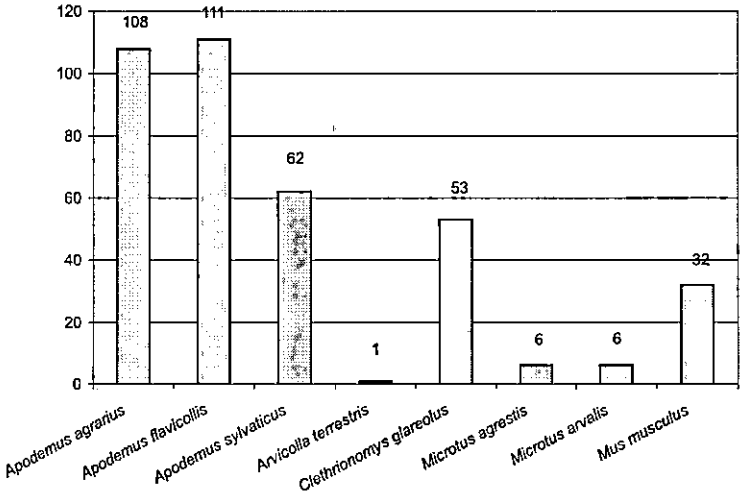

Figure 3. The number of small rodents according to species tested for leptospirosis during the year 2000.

Slika 3. Broj sitnih glodavaca po vrstama obrađenih na leptospirozu tijekom 2000. godine

Table 2. The presence of antibody titres to leptospires according to small rodent species

Tablica 2. Prisutnost titara protutijela na leptospire po vrstama sitnih glodavaca

Small rodent species *Vrsta sitnih glodavaca*	Total number captured *Ukupno ulovljeno*	Total number analysed *Ukupno pretraženo*	Antibody titre *Titar protutijela*	% infected *% inficiranih*	% analysed *% pretraženih*
Apodemus agrarius	135	108	16	14.81	80.00
Apodemus flavicollis	133	111	12	10.81	83.46
Mus musculus	36	32	11	34.38	88.89
Clethrionomys glareolus	61	53	5	9.43	86.89
Apodemus sylvaticus	62	62	4	6.45	100.00
Microtus agrestis	7	6	0	0.00	85.71
Microtus arvalis	10	6	0	0.00	60.00
Arvicola terrestris	1	1	0	0.00	100.00
Total - *Ukupno*	445	379	48	12.66	85.17

Table 3. Antibodies against leptospires in the serum of analysed animals by the highest titre

Tablica 3. Nalaz protutijela za leptospire u serumu pretraženih životinja prema najvišem titru

Animal species *Vrsta životinje*	Total number analysed *Ukupno pretraženo*	Antibody titre *Titar protutijela*	Serological leptospires variant													Total number of positive *Ukupno pozitivnih*	% serologically positive *% serološki pozitivnih*
			grippotyphosa	*sejroe*	*australis*	*pomona*	*canica*	*icterohaemorrhagiae*	*tarassovi*	*saxkoebing*	*ballum*	*bataviae*	*poi*	*hardjo*	Unidentified Neodredeno		
Mus musculus	32	1:100								3				1	4	3	34,38
		1:500								2				1		3	
		Σ								5				2	4	11	
Apodemus agrarius	108																14,81
		1:100	2	1		4		1	2					3		13	
		1:500				3										3	
		Σ	2	1		7		1	2					3		16	
Apodemus flavicollis	111																10,81
		1:100			3					1		1			4	9	
		1:500			1											1	
		1:1000				1										1	
		1:2000			1											1	
		Σ			5	1				1		1			4	12	
Apodemus sylvaticus	62																6,45
		1:100		1		1			1							3	
		1:500				1										1	
		Σ		1		2			1							4	
Clethrionomys glareolus	53																9,43
		1:100		1						1				1	1	4	
		1:500			1											1	
		Σ		1	1					1				1	1	5	
Σ	366																13,11

Table 4. Antibodies against leptospires with the microscopic agglutination reaction and leptospire isolation with renoculture in dependence on the locality and small rodent species. *First row–number of analysed animals. Second row–the first number represents antibodies against leptospires and the second leptospire isolation

*Tablica 4. Nalaz protutijela za leptospire reakcijom mikroskopske aglutinacije i izolacija leptospira renokulturom ovisno o lokalitetu i vrsti sitnih glodavaca. * Prvi red – broj pregledanih životinja. Drugi red – prvi broj predstavlja nalaz protutijela na leptospire, a drugi broj izolata leptospira*

Small rodent species *Vrste sitnih glodavaca*	Kutina	Velika Gorica	Popovača	Vrbanja	Gunja	Stara Gradiška	Nova Kapela	Otok	Nova Gradiška	Karlovac	Σ	%
Apodemus agrarius	0	2	33 (2/0)	9	1	12 (3/0)	33 (9/4)	5 (1/0)	8	5 (1/0)	108 (16/4)	28.3
Apodemus flavicollis	8	10 (4/1)*	38 (3/2)	6	2	1 (1/0)	11 (2/0)	6	5 (1/0)	24 (1/0)	111 (12/3)	29.1
Apodemus sylvaticus	2	9	11 (2/0)	7 (1/0)	7 (1/0)	0	4	6	3	13	62 (4/0)	16.3
Arvicola terrestris	0	0	1	0	0	0	0	0	0	0	1 (0/0)	0.3
Clethrionomys glareolus	1	5 (2/0)	12	4	6	1 (1/0)	19 (2/0)	1	1	3	53 (5/0)	13.9
Microtus agrestis	0	2	2	0	0	0	0	0	0	2	6 0/0	1.6
Microtus arvalis	0	3	0	1	0	0	1	1	0	0	6 (0/0)	1.6
Mus musculus	30 (11/10)	0	1	0	0	1	0	0	0	0	32 (11/10)	8.4
Σ	41 (11/10)	31 (6/1)	98 (7/2)	27 (1/0)	16 (1/0)	15 (5/0)	68 (13/4)	19 (1/0)	17 (1/0)	47 (2/0)	379 (48/17)	99.9

Table 4 gives the results of captured individuals, and antibodies against leptospires and leptospire isolation by small rodent species and locality. Leptospira antibodies were detected in 48 individuals, while leptospira isolation was positive in 17 individuals. In 108 individuals of *A. agrarius* (28.3 %), antibodies against leptospires were found in 16 animals, while in four animals the isolate was obtained. In 111 individuals of *A. flavicollis* (29.1 %), the leptospires antibodies were identified in 12 cases, and in three cases the strain was isolated. In 62 *A. sylvaticus* the microscopic agglutination reaction revealed leptospires antibodies in four animals, while no isolate was obtained. In *A. terrestris*, *M.* and *M. arvalis*, no leptospira antibodies were found, nor isolates obtained. In 53 individuals of *C. glareolus*, the leptospires antibodies were found in five, while no isolates were obtained. In 32 *M. musculus* the leptospire antibodies were identified in 11 individuals, while renoculture provided 10 leptospire isolates.

In the locality Kutina (the hunting ground "Moslavina") leptospires antibodies were found in 11 of 41 analysed animals, while isolation was in 10 individuals. All leptospires were found in succesfull *M. musculus*. No leptospires were found in *A. flavicollis, A. sylvaticus* and *C. glareolus.*

In the sample of 31 analysed rodents in Forest Office Velika Gorica, antibodies were found in six animals, and only one isolate was found. Approximately 50 % of *A. flavicollis* and *C. glareolus* were found to be infected with leptospires, while no leptospires were found in *A. agrarius, A. sylvaticus, M. agrestis* and *M. arvalis.*

A total of 98 animals from the stands in the Forest Office Popovača were analysed. The structure of the catch by species is given in Table 4. The antibodies for leptospires were found in seven animals, while leptospires were isolated in only two cases. Infection was found in a smaller part of the population of *A. agrarius, A. flavicollis* and *A. sylvaticus*, while no infection was detected in the populations of other species (*A. terrestris, C. glareolus, M. agrestis* and *M. musculus*). In Forest Office Vrbanja the antibodies to leptospires were recorded only in one *A. sylvaticus*. The same result was obtained in Forest Office Gunja.

In Forest Office Stara Gradiška the antibodies to leptospires were found in five specimens, while no leptospires were isolated. Infection was confirmed in the species *A. agrarius, A. flavicollis* and *C. glareolus*. A similar result was obtained with the animals captured in the Forest Offices Otok, Nova Gradiška and Karlovac. The antibodies were found in a small part of the population of *A. agrarius, A. flavicollis* and *A. sylvaticus*, while the leptospire isolation did not yield a positive result. No leptospira infection was recorded in other species of small rodents captured in the localities Otok, Nova Gradiška and Karlovac.

The antibodies to leptospires were recorded in 13 animals in the Forest Office Nova Kapela (the hunting ground "Radinje"), while leptospires were isolated in four animals. One part of the animal population belonging to the species *A. agrarius, A. flavicollis* and *C. glareolus* was found to be infected with leptospires, while infection in other species (*A. sylvaticus* and *M. arvalis*) was not recorded.

Testing individual small rodent species by research localities and forest communities is given in Table 5.

Table 5. Testing individual small rodent species by research localities and forest communities

Tablica 5. Uzorkovanje pojedinih vrsta sitnih glodavaca po lokalitetima istraživanja i šumskim zajednicama

Forest office *Šumarija*	Forest communities *Biljna zajednica*	*Apodemus flavicollis*	*Apodemus sylvaticus*	*Apodemus agrarius*	*Microtus agrestis*	*Microtus arvalis*	*Clethrionomys glareolus*	*Arvicolla terrestris*	*Mus musculus*	Σ
Kutina	*Carici pilose-Fagetum sylvaticae*	5	2	0	0	0	1	0	0	8
	Closed objects *Zatvoreni objekti*	0	0	0	0	0	0	0	35	35
	Epimedio-Carpinetum betuli	2	2	0	0	0	0	0	0	4
Stara Grad.	*Genisto. elatae - Quercetum roboris caricetosum remotae*	1	1	13	0	0	1	0	0	16
Velika Gorica	*Carpino betuli-Quercetum roboris typicum*	8	6	2	0	3	4	0	0	23
	Genisto elatae – Quercetum roboris caricetosum brizoides	4	3	3	3	0	3	0	0	16
Popovača	*Carpino betuli-Quercetum roboris typicum*	36	13	28	1	1	7	1	0	87
	Genisto. elatae - Quercetum roboris caricetosum remotae	4	1	5	0	0	2	0	1	13
Vinkovci	*Genisto. elatae - Quercetum roboris caricetosum remotae*	0	0	1	0	0	0	0	0	1
	Carpino betuli-Quercetum roboris typicum	0	0	0	0	0	0	0	0	0
Vrbanja	*Genisto. elatae-Quercetum roboris caricetosum remotae*	2	1	3	1	0	7	0	0	14
	Carpino betuli-Quercetum roboris typicum	7	2	2	0	1	2	0	0	14
Gunja	*Carpino betuli-Quercetum roboris typicum*	13	6	10	0	1	8	0	0	38

Forest office *Šumarija*	Forest communities *Biljna zajednica*	*Apodemus flavicollis*	*Apodemus sylvaticus*	*Apodemus agrarius*	*Microtus agrestis*	*Microtus arvalis*	*Clethrionomys glareolus*	*Arvicolla terrestris*	*Mus musculus*	Σ
Nova Kapela	*Genisto. elatae - Quercetum roboris caricetosum remotae*	6	3	35	0	1	13	0	0	58
	Leucoio-Fraxinetum angustifoliae	5	3	8	0	1	6	0	0	23
	Frangulo-Alnetum glutinosae	0	0	0	0	1	1	0	0	2
Otok	*Genisto. elatae-Quercetum roboris caricetosum remotae*	8	6	5	0	1	1	0	0	21
Nova Grad.	*Genisto. elatae - Quercetum roboris caricetosum remotae*	6	3	13	0	0	2	0	0	24
Karlovac	*Genisto. elatae - Quercetum roboris caricetosum brizoides*	16	10	6	2	0	2	0	0	36
	Carpino betuli-Quercetum roboris typicum	10	0	1	0	0	1	0	0	12
Total - *Ukupno*		133	62	135	7	10	61	1	36	445

The following number of small rodents was collected in all the localities per forest community: 147 individuals in *Genisto elatae-Quercetum roboris caricetosum remotae*, 52 individuals in *Genisto elatae-Quercetum roboris caricetosum brizoides*, 174 individuals in *Carpino betuli-Quercetum roboris typicum*, 23 individuals in *Leucoio-Fraxinetum angustipholiae,* two individuals in *Frangulo-Alnetum glutinosae*, eight individuals in *Carici pilosae-Fagetum sylvaticae*, and four individuals in *Epimedio-Carpinetum betuli.*

The renoculture method yielded 17 leptospire isolates from three rodent species: *M. musculus, A. agrarius* and *A. flavicollis* in the localities Kutina, Velika Gorica, Popovača and Nova Kapela. Serologic analyses of 16 *Leptospira* sp. isolate showed that the serovars were grouped in three serologic groups: *sejroe, pomona* and *australis* (Table 6). The serovars of 10 strains (from *M. musculus* in "Garjevica") show the highest similarity to the serovar *istrica* of the *sejroe* serological group, the genomic species *L. borgpetersenii.* Five strains (four from *A. agrarius* and one from *A. flavicollis* captured in the Forest Offices Otok, Nova Kapela and Popovača) belong to the serovar *tsaratsovo* of the *pomona* serologic group, the genomic species *L. kirsheneri.* One strain (from *A. flavicollis* captured in the Forest Office Velika Gorica) belongs to the serovar *lora* of the *australis* serologic group, the genomic species *L. interrogans.*

One isolate from *A. flavicollis* was not defined, but probably belongs to the serologic group *australis.*

Table 6. Leptospira isolation with renoculture depending on the species of analysed animals

Tablica 6. Prikaz izolacije leptospira renokulturom ovisno o vrsti pretraženih životinja

Animal species *Vrsta životinje*	Analysed renoculture *Pretraženo renokultura*	Serologic *Serološka sejroe*	Leptospira *varijanta*	Variant *leptospira*	Undefined *Nedeterminirano*	Total *Ukupno*	%
			australis	*pomona*			
Mus musculus	32	10	0	0	0	10	31.25
Apodemus flavicollis	111	0	1	1	1	3	2.7
Apodemus agrarius	108	0	0	4	0	4	3.7
Total *Ukupno*	251	10	1	5	1	17	6.77

DISCUSSION
RASPRAVA

The animals captured in the studied areas contained the majority of small rodent species that inhabit lowland forests of pedunculate oak. *M. subterraneus* and *M. multiplex* are very rare and they were not recorded. Most of analysed animals belong to of *A. agrarius* and *A. flavicollis*, while these two species were dominant in the majority of the studied areas. In terms of the number of analysed individuals from a given locality, most derive from the localities Popovača and Nova Kapela. *Mus musculus* prevail in the hunting ground "Garjevica", where the majority of animals were captured in indoor premises (roe deer shed and food storage), where they were attracted by abundant game food that they feed on. The species *A. flavicollis, A. sylvaticus* and *C. glareolus* were also captured in the stand. *A. agrarius* was not recorded there, as the stand does not suit this species. The animals were collected with traps using the methodology by Bäumler & Brunner (1988), and Margaletić (1998).

The forest communities of *Genisto elatae-Quercetum roboris caricetosum remotae, Genisto elatae-Quercetum roboris caricetosum brizoides* and *Carpino betuli-Quercetum roboris typicum* account for 83.82 % of the captured individuals. Most were captured in the autumn months, when the number of small rodent populations increases (Conley & Nichols 1978, Tapper 1979, Chudoba & Huminski 1980, Clarke 1985, Margaletić 1998, Margaletić & Glavaš 2001). The highest increase in the autumnal population was recorded in *A. agrarius*

in four localities (Popovača, Nova Kapela, Nova Gradiška and Stara Gradiška). The reason for this probably lies in the vicinity of sample plots to agricultural areas. *Apodemus agrarius* characteristically inhabits agricultural areas in the vegetation period, where it is drawn by the abundance of food, while in the autumn it migrates to the forest (Gliwicz 1980). A study of the movement of the species *A. agrarius*, made by Liro & Szacki (1987), showed that 60 % of the analysed population travelled over 100 m away from the marking place. The same authors noted that the longest distances of travelling exceeded 1000 m. In his study of the movement of *A. sylvaticus*, Watts (1970) assumed that the upper boundary for this species within its home range was 130 m. Korn (1986) proved that the home range of *A. sylvaticus* was usually less than 10000 m², which means that the diameter of the range was less than 100-150 m. Andrzejewski & Bibinska-Werka (1986) recorded much larger movement of small rodents.

The study of small rodents as a reservoir of leptospiroses yielded positive results. 17 leptospire strains were isolated from three different species of small rodents in the localities Kutina, Popovača, Nova Kapela and Velika Gorica. Of 379 analysed specimens, the leptospires antibodies were found in 48 cases. Most infections where detected in *A. agrarius, M. musculus* and *A. flavicollis*. The majority of small rodent detected leptospires antibodies (Table 4) and positive leptospira isolation were achieved in Kutina (the state hunting ground "Garjevica") and Nova Kapela (the state hunting ground "Radinje"). This fact indicates a heightened risk of infection for the game living in these localities, the consequence of which could cause heavy losses in hunting management (poorer game increment, miscarriages of fertilised females and similar) (Kovačić *et al.* 1984, Kovačić & Karlović 1984, Kovačić *et al.* 1985b, Modrić & Karlović 1977, Modrić *et al.* 1979, Modrić & Huber 1993).

The results obtained by microscopic agglutination, isolation of leptospires with renoculture and macro-restriction of chromosomal DNA show that serovar identification could be a useful method of gaining better insights into the epizootiology and epidemiology of leptospiroses in Croatia. Awareness of these facts may be of essential importance in the management of game as possible receptors of leptospiroses whose basic reservoirs are small rodents. In the area of the rivers Sava and Drava and their tributaries in north Croatia 3,543 small rodents (subfamilies *Arvicolinae* and *Murinae*) were subjected to renoculture. 2,7 % were identified as carriers of the leptospira serovariant *grippotyphosa* (95 individuals) (Borčić *et al.* 1987). Of 2,643 animals tested with microscopic agglutination, 3.9 % were found to be agglutinin carriers for an identified leptospira variant (103 animals). *Microtus arvalis* proved to be the most common carrier of this serologic variant. Leptospires of the serovariant *grippotyphosa* were found more rarely, or were not found at all in the parts of Podravinian Slavonia and in the catchment area of the left tributaries of the river Sava (the Česma, the Ilova, the Orljava) (Borčić *et al.* 1982a, b, 1983). In the present research, the same serovariant was detected in only two *A. agrarius*. Borčić *et al.* (1986) proved statistically that the infection of *A. agrarius* with the leptospira of the *pomona* serovariant, as well as its carrier status, was considerably more frequent in this species than in other species of mouse-like rodents. The incidence of carriership and the presence of leptospira antibodies of the serovariant *pomona* (in the same animals), was found to be more frequent in *A. agrarius* than in other rodent species, as well as carriership with the presence of

these antibodies (Borčić *et al.* 1986). This supports the high degree of adaptation of these two organisms, which is generally the property of basic micro-organism reservoirs in the nature. The species *A. agrarius* is a natural reservoir of leptospira of the *pomona* variant in Croatia (Borčić *et al.* 1986). The results presented in this paper show that small rodents in northern Croatia are responsible for permanent existence of leptospires in the nature, which, bearing in mind high populations of these animals, poses a realistic risk of infection for domestic and wild animals and for human. In the past studies of leptospirosis in Croatia, identifications of the isolates were done only up to the level of serologic variants. In this paper, the data on the leptospira identification for Croatia up to the specific (species) level have been given for the first time. Previous research, combined with our results, confirm the well-known fact that a wider area of Posavina represents the natural focus of leptospiroses. The forests of Posavina can be regarded as a part of this large focus, while the specific traits and the role of this biotop in the leptospira survival should be studied more extensively.

CONCLUSIONS
ZAKLJUČCI

During the year 2000, a total of 445 animals were captured, of which the following species were identified: *A. agrarius, A. flavicollis, A. sylvaticus, M. musculus, C. glareolus, M. agrestis, M. arvalis* and *A. terrestris*. 379 animals were tested for leptospires. The highest number of the tested individuals belonged to *A. flavicollis* (29.29 % of the total number of tested animals) and *A. agrarius* (28.50 % of the total number of tested individuals). 83.82 % of the tested animals were captured in the forest communities *Genisto elatae - Quercetum roboris caricetosum remotae, Genisto elatae - Quercetum roboris caricetosum brizoides* and *Carpino betuli - Quercetum roboris typicum*. The largest proportion of the catch was obtained in autumn months, when the number of small rodent populations increases.

Seventeen leptospira strains were isolated with renoculture from three small rodent species: *M. musculus, A. agrarius*, and *A. flavicollis*, captured in the localities of Kutina, Velika Gorica, Popovača and Nova Kapela. They were found to belong to the following three serologic variants: *sejroe, pomona* and *australis*. The antibody titre to leptospira was detected in 48 animals: *A. agrarius* (16), *A. flavicollis* (12), *M. musculus* (11), *C. glareolus* (5) and *A. sylvaticus* (4).

The PFGE analysis was made to identify leptospires at the level of species. The results of this research point to the need to assess the numbers of small rodent populations in the field, to test the captured individuals for the presence of some zoonoses and to apply timely protective measures to forest ecosystems. In the long run, this will result in decreased losses in hunting management and increased care for the health of people and domestic animals. The multidisciplinary nature of this research requires close cooperation of the forestry profession and other relevant institutions.

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SITNI GLODAVCI KAO IZVOR LEPTOSPIROZA U POSAVSKIM ŠUMAMA U HRVATSKOJ

SAŽETAK

Sitni su glodavci zbog brojnosti populacija i širine ekološke valencije važan dio gotovo svakoga šumskoga ekosustava. Oni su značajna skupina životinja koja povezuje primarne proizvođače s višim trofičkim razinama. To su sisavci s karakterističnim prednjim sjekutićima (glodnjaci, incisivi) koji su vrlo oštri (Delany 1974). Potencijal razmnožavanja im je vrlo visok (Kowalski 1976).

Sitni su glodavci izvor niza zaraznih bolesti čovjeka, te domaćih i divljih životinja (trihineloza, leptospiroza, krpeljni encefalitis, lyme borelioza, hemoragijska vrućica s bubrežnim sindromom i dr.) (Bäumler 1975, Geisel i dr. 1979, Barrow 1981, Borčić i dr. 1982, 1983). Kao kliconoše mogu povremeno ili trajno putem sekreta i ekskreta izlučivati uzročnike zarazne bolesti, te tako kontaminirati okoliš koji nastanjuju pretvarajući ga u intermedijarne i sekundarne izvore zarazne bolesti (Zaharija 1980, Cvetnić 1993). Od brojnih bolesti koje glodavci prenose u ovom je radu istražena leptospiroza. To je akutna septikemijska zarazna bolest različitih vrsta domaćih i divljih životinja i čovjeka koja se većinom javlja enzootski. Klinički se očituje ikterusom, ponekad hemoglobinurijom, a u goveda i svinje pobačajima. Uzročnici leptospiroze su patogene spiralne bakterije iz roda *Leptospira* (Noguchi 1918) unutar kojega je dosad otkriveno nekoliko genomskih vrsta (Ellis 1995, Brenner i dr. 1999), 24 serološke skupine i preko 250 seroloških varijanata (Kmety i Dikken 1993).

Ovim su istraživanjem dobivene nove spoznaje o zastupljenosti pojedinih seroloških varijanata (serovari) leptospira na istraživanim lokalitetima, te su determinirane određene vrste sitnih glodavaca kao izvor leptospiroza na istraživanim lokalitetima u Posavini Istraživanja su provedena u hrvatskim posavskim šumama u sastojinama kojima gospodari 11 šumarija "Hrvatske šume" d. o. o. (slika 1). Na jednom je lokalitetu bilo postavljeno po nekoliko pokusnih

ploha (ukupno 44). Ulov sitnih glodavaca obavljen je u razdoblju od travnja do studenoga 2000. godine. Na većini lokaliteta uzorkovanje je sitnih glodavaca obavljeno dva puta godišnje, u proljetnim i jesenskim mjesecima, u ovim šumskim zajednicama: *Genisto elatae-Quercetum roboris caricetosum remotae, Genisto elatae-Quercetum roboris caricetosum brizoides, Carpino betuli-Quercetum roboris typicum, Carpino betuli-Quercetum roboris fagetosum, Carpino betuli-Quercetum roboris quercetosum cerris, Carici pilosae-Fagetum sylvaticae, Epimedio-Carpinetum betuli, Leucoio-Fraxinetum angustifoliae* i *Frangulo-Alnetum glutinosae* (Vukelić & Rauš 1998). Šumske zajednice *Carici pilosae-Fagetum sylvaticae, Epimedio-Carpinetum betuli, Leucoio-Fraxinetum angustifoliae* i *Frangulo-Alnetum glutinosae*, koje su obuhvaćene u istraživanju, rasprostranjene su na istraživanim lokalitetima državnih lovišta "Garjevica" (br. VII/4) (*Carici pilosae-Fagetum sylvaticae* i *Epimedio-Carpinetum betuli*) i "Radinje" (br. XII/16) (*Leucoio-Fraxinetum angustifoliae* i *Frangulo-Alnetum glutinosae*). Na slici 2 je prikazan broj pokusnih ploha postavljenih u pojedinim šumskim zajednicama u kojima su uzorkovane životinje.

Za uzorkovanje jedinki upotrijebljene su mrtvolovke, te živolovke tipa "Sherman". Klopke su postavljane u lovne transekte na međusobnom razmaku 5–7 m. U Zavodu za mikrobiologiju i infektivne bolesti Veterinarskoga fakulteta u Zagrebu ukupno je serološki i bakteriološki obrađeno 379 glodavaca. Primijenjena je metoda mikroskopske aglutinacije kao standardni način za serološku dijagnostiku i klasifikaciju leptospira. U slučaju dokaza protutijela u osnovnom razrjeđenju 1:100 uzorci su pretraživani u daljnjim razrjeđenjima seruma (1:500, 1:1000 itd.). Nalaz najvišega titra protutijela za pojedini antigen leptospira odnosno serovar u serumu upućuje na "vjerojatni" serovar koji je uzrokovao zarazu (Johnson 1976). Svaki je uzorak krvi pretražen s antigenima *L. interrogans* sv: *icterohaemorrhagie, ballum, australis, pomona, grippotyphosa, sejroe, saxkoebing, bataviae, tarassovi, canicola, poi* i *hardjo*. Determiniranim jedinkama nacijepljeno je tkivo kore bubrega na Korthofovo hranilište radi izdvajanja leptospira.

Iz tijela sitnih glodavaca *A. flavicollis, A. agrarius* i *M. musculus*, koji su uzorkovani na lokalitetima Kutina, Popovača, Velika Gorica, Nova Kapela i Otok, izolirano je 17 izolata leptospira koji su poslani na obradu u Institut "Pasteur" (Pariz, Francuska) u kojem je analiziran gel elektroforeze u pulsirajućem polju (PFGE analiza). Ta se analiza sastoji u tome što se nakon restrikcije kromosomske DNA s restrikcijskim enzimima "NotI" i "Sgr AI" pristupa usporedbi restrikcijskih profila ispitujućih serovara (seroloških varijanata) s profilima referentnih serovara. Tom je metodom moguće odrediti leptospire na razini serovara, tj. ustanoviti njihovu fizikalnu mapu (Baril & Saint Girons 1990). PFGE analiza s restrikcijskim enzimom "NotI" razlučuje serovare seroloških grupa (serogrupa) "*sejroe*" i "*pomona*", dok analiza s restrikcijskim enzimom "Sgr AI" razlučuje serovare serološke grupe "*australis*".

Na svim lokalitetima ukupno je ulovljeno 445 jedinki, a laboratorijski ih je obrađeno 379 (85,17 %). 66 jedinki nije analizirano zbog oštećenosti uzorka izazvanoga djelovanjem predatora ili raspadanjem tkiva zbog atmosferskih utjecaja (visoka temperatura). Determinirane su ove vrste sitnih glodavaca: *A. agrarius, A. flavicollis, A. sylvaticus, A. terrestris, C. glareolus, M. agrestis, M. arvalis* i *M. musculus*. Dominantne vrste na istraživanim pokusnim plohama bile su *A. flavicollis* i *A. agrarius*. Najviše je glodavaca ulovljeno u šumama kojima gospodare šumarije Popovača (25,86 % ukupnoga ulova) i Nova Kapela (17,94 % ukupnoga ulova).

U šumskim zajednicama *Genisto elatae-Quercetum roboris caricetosum remotae*, *Genisto elatae-Quercetum roboris caricetosum brizoides* i *Carpino betuli-Quercetum roboris typicum* ulovljeno je 83,82 % uzorkovanih jedinki. Većina ih je ulovljena tijekom jesenskih mjeseci. Glavnina jedinki *M. musculus* (93,75 %) ulovljena je u zatvorenim objektima državnoga lovišta "Garjevica" (Šumarija Kutina). Rezultati obrađenih jedinki po vrstama i lokalitetima brojčano su izraženi u tablici 1.

Titar protutijela na leptospire je ustanovljen u 48 životinja sa svih lokaliteta, i to na ovim vrstama glodavaca: *A. agrarius*, *A. flavicollis*, *M. musculus*, *C. glareolus* i *A. sylvaticus* (tablica 2). Detaljna analiza prisutnosti protutijela na serološke varijante leptospira prema najvišem titru (količini) protutijela prikazana je u tablici 3. Iz nje je vidljivo da je kod vrste *M. musculus* bilo serološki pozitivno 34,38 % jedinki, kod *A. agrarius* 14,81 %, kod *A. flavicollis* 10,81 %, kod *A. sylvaticus* 6,45 %, a kod *C. glareolus* 9,43 %. Kod *M. musculus* je utvrđen nalaz seroloških varijanata *saxkoebing* i *hardjo*, dok su četiri izolata ostala neodređena uz titar protutijela 1:100. Kod vrste *A. agrarius* utvrđen je nalaz seroloških varijanata *grippotyphosa*, *sejroe*, *pomona*, *icterohaemorragiae*, *tarassovi* i *hardjo*, dok je analiza jedinki vrste *A. flavicollis* pokazala prisutnost protutijela seroloških varijanata *australis*, *pomona*, *saxkoebing* i *bataviae*, a četiri su nalaza protutijela ostala neodređena uz titar protutijela 1:100. Kod vrste *A. sylvaticus* utvrđen je nalaz seroloških varijanata *sejroe*, *pomona* i *tarassovi*, dok je analiza jedinki vrste *C. glareolus* pokazala prisutnost protutijela seroloških varijanata *sejroe*, *australis*, *saxkoebing* i *hardjo*, a pet je izolata ostalo neodređeno uz titar protutijela 1:100 i 1:500.

U tablici 4 izneseni su rezultati ulova jedinki, te nalaza protutijela za leptospire reakcijom mikroskopske aglutinacije i izolacija leptospira renokulturom po vrstama sitnih glodavaca i lokalitetu ulova. U 108 jedinki *A. agrarius* kod 16 životinja je utvrđen nalaz protutijela za leptospire, a kod četiri jedinke je dobiven izolat. U 111 jedinki *A. flavicollis* u 12 slučajeva je utvrđen nalaz protutijela za leptospire, a kod tri jedinke je dobiven izolat. U 62 jedinke *A. sylvaticus* protutijela za leptospire utvrđena su u četiri životinje, dok renokulturom nije dobiven ni jedan izolat. Kod vrsta *A. terrestris*, *M. agrestis* i *M. arvalis* nisu pronađena protutijela za leptospire, niti su dobiveni izolati leptospira. U 53 jedinke vrste *C. glareolus* u pet su utvrđena protutijela za leptospire, a ni jednom nije dobiven izolat. Kod 32 životinje *M. musculus* u 11 su utvrđena protutijela za leptospire, dok je renokulturom dobiveno 10 izolata leptospira.

Na području Kutine (državnio lovište "Garjevica") od 41 analizirane jedinke u 11 ih je utvrđen nalaz protutijela za leptospire, a u 10 jedinki je dobiven izolat. Svi su nalazi leptospira utvrđeni kod *M. musculus*, dok kod *A. flavicollis*, *A. sylvaticus* i *C. glareolus* leptospire nisu pronađene. U uzorku od 31 jedinke glodavaca iz Šumarije Velika Gorica u šest životinja su pronađena protutijela, a dobiven je samo jedan izolat. Približno 50 % populacije *A. flavicollis* i *C. glareolus* bilo je zaraženo leptospirama, dok kod *A. agrarius*, *A. sylvaticus*, *M. agrestis* i *M. arvalis* nije potvrđen njihov nalaz. U sastojinama Šumarije Popovača ulovljeno je i analizirano 98 životinja. Struktura ulova po vrstama prikazana je u tablici 4. U sedam je životinja potvrđen nalaz protutijela za leptospire, a u samo dva slučaja je dobiven izolat leptospira. Zaraženost je pronađena u manjem dijelu populacije *A. agrarius*, *A. flavicollis* i *A. sylvaticus*, a u populacijama ostalih vrsta (*A. terrestris*, *C. glareolus*, *M. agrestis* i *M. musculus*) nije zabilježena. Na području

Šumarije Vrbanja nalaz protutijela za leptospire potvrđen je samo kod *A. sylvaticus*. Isti je rezultat polučen i na jedinkama iz Šumarije Gunja.

Od 15 ulovljenih životinja u Šumariji Stara Gradiška protutijela za leptospire su pronađena u pet jedinki, dok izolati nisu dobiveni. Zaraženost je potvrđena kod *A. agrarius*, *A. flavicollis* i *C. glareolus*. Kod životinja s područja Šumarija Otok, Nova Gradiška i Karlovac također je dobiven sličan rezultat. Protutijela su pronađena u malom dijelu populacija *A. agrarius*, *A. flavicollis* i *A. sylvaticus*, a izolacija leptospira nije dala pozitivan rezultat. Kod ostalih vrsta sitnih glodavaca ulovljenih na lokalitetima Otok, Nova Gradiška i Karlovac nije zabilježena zaraženost leptospirama. U 13 životnja iz Šumarije Nova Kapela (lovište "Radinje") utvrđen je nalaz protutijela za leptospire, a u četiri je jedinke dobiven izolat. Zaraženost leptospirama utvrđena je u jednom dijelu populacije životinja koje pripadaju vrstama *A. agrarius*, *A. flavicollis* i *C. glareolus*, dok kod ostalih vrsta (*A. sylvaticus* i *M. arvalis*) nije potvrđena. Rezultati uzorkovanja sitnih glodavaca po lokalitetima istraživanja i šumskim zajednicama prikazani su u tablici 5. Ukupno je na svim lokalitetima uzorkovan ovaj broj sitnih glodavaca po pojedinim šumskim zajednicama: u *Genisto elatae-Quercetum roboris caricetosum remotae* 147 jedinki, u *Genisto elatae-Quercetum roboris caricetosum brizoides* 52 jedinke, u *Carpino betuli-Quercetum roboris typicum* 174 jedinke, u *Leucoio-Fraxinetum angustifoliae* 23 jedinke, u *Frangulo-Alnetum glutinosae* dvije jedinke, u *Carici pilosae-Fagetum sylvaticae* osam jedinki, te u *Epimedio-Carpinetum betuli* četiri jedinke.

Metodom renokulture izdvojeno je 17 izolata leptospira iz jedinki ulovljenih glodavaca na lokalitetima: Kutina, Velika Gorica, Popovača i Nova Kapela iz triju vrsta glodavaca: *M. musculus*, *A. agrarius* i *A. flavicollis*. Serološke analize 16 izolata *Leptospira* sp. pokazale su da su istraživani serovari razvrstani u tri serološke grupe: *sejroe*, *pomona* i *australis* (tablica 6). Determinirani serovari 10 izolata (izolirani iz *M. musculus* ulovljenih na području državnoga lovišta "Garjevica") pokazuju najveću sličnost serovaru *istrica* serološke grupe *sejroe*, genomne vrste *L. borgpetersenii*, pet izolata (četiri izolirana iz *A. agrarius* i jedan iz *A. flavicollis* ulovljenih u šumarijama Otok, Nova Kapela i Popovača) pripada serovaru *tsaratsovo* serološke grupe *pomona*, genomne vrste *L. kirshneri*, dok jedan izolat (izoliran iz *A. flavicollis* ulovljenoga na području Šumarije Velika Gorica) pripada serovaru *lora* serološke grupe *australis*, genomne vrste *L. interrogans*. Jedan izolat izoliran iz jedinke vrste *A. flavicollis* nije determiniran, a vjerojano pripada serološkoj grupi *australis*.

Najviše laboratorijski obrađenih životinja pripada vrstama *A. agrarius* i *A. flavicollis*, jer su one tijekom 2000. godine prevladavale na većini istraživanih lokaliteta. Najviše jedinki ulovljeno je na području Popovače i Nove Kapele. U državnom lovištu "Garjevica" najviše je analizirano jedinki vrste *Mus musculus*. Ta je vrsta ulovljena u zatvorenim objektima lovišta (staja za košute i skladište hrane) u koje se nastanila zbog obilja hrane za divljač koja joj služi u prehrani. Na istom lokalitetu u sastojini su ulovljene još i vrste *A. flavicollis, A. sylvaticus* i *C. glareolus*, dok ulov jedinki iz vrste *A. agrarius* nije zabilježen, jer sastojina u kojoj je obavljen izlov stanišno ne odgovara toj vrsti. Najveće povećanje jesenske brojnosti populacije na lokalitetima Popovača, Nova Kapela, Nova Gradiška i Stara Gradiška zabilježeno je kod vrste *A. agrarius*. Pretpostavlja se da je tomu uzrok blizina poljoprivrednih površina pokusnim plohama. Za *A. agrarius* je karakteristično da u vegetacijskom razdoblju obitava

na poljoprivrednim površinama zbog obilja hrane, a u jesen migrira u šumu (Gliwicz 1980). Istraživanja kretanja vrste *A. agrarius* koja su proveli Liro & Szacki (1987) pokazala su da je 60 % analizirane populacije prelazilo veće udaljenosti od 100 m od mjesta njihove markacije.

Zaraženost leptospirama je najviše utvrđena kod *A. agrarius*, *M. musculus* i *A. flavicollis*. Uspoređujući stanje zaraženosti sitnih glodavaca po lokalitetima ulova (tablica 4), jasno se uočava da je najviše nalaza protutijela za leptospire i pozitivnih izolacija postignuto iz populacija jedinki ulovljenih u Kutini (državno lovište "Garjevica") i Novoj Kapeli (državno lovište "Radinje"). Ta činjenica upućuje na povećanu mogućnost zaraze divljači koja obitava na spomenutim lokalitetima, a čija posljedica može biti iskazana gubitkom u lovnom gospodarenju (slabiji prirast divljači, pobačaj oplođenih ženki i sl.) (Kovačić i dr. 1984, Kovačić & Karlović 1984, Kovačić i dr. 1985b, Modrić & Karlović 1977, Modrić i dr. 1979, Modrić & Huber 1993). Mikroskopskom aglutinacijom, izolacijom leptospira renokulturom i makrorestrikcijom kromosomske DNA dobiveni su rezultati koji upućuju na to da determinacija serovara može biti koristan način za bolje upoznavanje epizoetiologije i epidemiologije leptospiroza u Hrvatskoj. Poznavanje tih činjenica bitno može pomoći u gospodarenju divljači kao mogućih primljivih vrsta leptospiroza čiji su osnovni rezervoar sitni glodavci.

Ključne riječi: sitni glodavci, šumski ekosustavi, leptospiroze, Posavina, Hrvatska

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Original scientific paper
Izvorni znanstveni članak

PLANT PREFERENCE BY MOUFLON (*OVIS AMMON MUSIMON* PAL.) AND AXIS DEER (*AXIS AXIS* ERX.) IN THE FOREST COMMUNITY OF HOLM OAK AND MANNA ASH (*FRAXINO ORNI-QUERCETUM ILICIS* H-IĆ /1956/ 1958)

PREFERABILNOST BILJNIH VRSTA ZAJEDNICE HRASTA CRNIKE I CRNOGA JASENA (*FRAXINO ORNI-QUERCETUM ILICIS* H-IĆ /1956/ 1958) U MUFLONA (*OVIS AMMON MUSIMON PAL.*) I JELENA AKSISA (*AXIS AXIS ERX.*)

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The paper presents the results of analysis of mouflon (*Ovis ammon musimon* Pal.) and axis deer (*Axis axis* Erx.) browsing in the forest community of holm oak and manna ash (*Fraxino orni-Quercetum ilicis* H-ić /1956/ 1958). In the course of 1999, three damage assessments were made in different sample plots each at the beginning of May, the beginning of July and in mid-October. At the cited density of 8 heads of big game per 100 ha in the hunting ground (mouflon and axis deer together), the game did not cause any considerable economic damage. With respect to game - forest interaction, it was found that cleaning was the main determinant for the increase in browse for game, because this treatment raises the browsing feeding capacities for the game manifoldly. The cleaning procedure may yield up to 52,000 plants of palatable species per hectare by the beginning of summer. Game was found to display seasonal preference for plant species and to favour plants from stumps over those from seeds. Similarly, the vertical growth of plants increases the probability of their being damaged by game. The summer-autumn season is the period in which forest stands are at most risk by game, because drought induces game to consume juicy shoots of woody plants.

Of woody plants, game avoided the common myrtle (*Myrtus communis*) and the mastic tree (*Pistacia lentiscus*), but also the seedlings of all woody species.

Key words: mouflon, axis deer, preference, eu-Mediterranean, damage status, preference ratio index, forest of holm oak and manna ash (*Fraxino orni-Quercetum ilicis* H-ić /1956/ 1958), carrying capacity

INTRODUCTION
UVOD

Vegetation plays a crucial role in hunting management. Not only does it act as a nutritive resource for herbivorous game, but it also provides shelter for animals. Each individual animal species has specific requirements with regard to the way of life, habitat and food. Therefore, it is important to discriminate different vegetation types or cultures in terms of their suitability for the growth of animal species. One of the main problems in assessing game habitats lies in the qualitative relation of crop fields, meadows, pastureland and forests from the standpoint of hunting management. In the case of the first three habitats, so far only the quality of artificially produced game food in the form of concentrates, silage or hay have been studied from the hunting management aspect (Grubešić 1996, cit. Manojlović 1992), leaving natural nutritive potentials for further study.

According to Grubešić (1996), the relative area importance ratio in Central Croatia, from the hunting management aspect, would be as follows: crop fields 20 %, meadows 15 %, pastureland 15 %, forests 50 %.

In the nature, game has much more food at its disposal than it really needs. This refers primarily to herbaceous vegetation, but only during vegetation periods (although grazing game also feed on dry plants in dormant vegetation stages), while outside the vegetation period, some wildlife species find food exclusively in forests. Consequently, the game-habitat interaction in Croatia and in the world has been dealt with mostly by foresters. Although many nature protectors blame foresters for the degradation of habitats of some animal species, it is important to mention that it has long been known that modern forestry improves habitats for certain animal species. Namely, progressive vegetation succession enlarges the growing area of wild herbivores both spatially and qualitatively not only in terms of food, but also shelter.

Compared to the primeval forest, the quantity and diversity of available biomass and shelter in commercial forests increase in accordance with the occurrence of the initial stage (enclosure) (Adamič 1990, cit. Mlinšek 1985). So, for example, the main reason for the increase in the moose population (*Alces alces* L.) in Northern Minnesota lies in more intensive forest exploitation and a change in felling methods. The final cut resulted in bare areas of over 100 ha, which provided the moose with optimal conditions for nutrition and shelter (Adamič 1990, cit. Peek *et al.* 1976).

The problem of forest damage should also be mentioned here. In recent times, West European countries, particularly Germany, are faced with over-numerous game populations. This problem is solved with reduction kills of excessive game. Detrimental impacts of game on

forest regeneration are seen by some authors as the main problem of Central European forestry (Adamič 1990, cit. Čop 1982). To prove that damage by game is not exclusively linked to excessive game populations and is not a new notion, Adamič (1990) cites the results of research by Mlinšek (1969), who analysed the increment cores taken from the bottom parts of adult firs (*Abies alba* Mill.) in Kočevski Rog. He found that in the period from mid-17th century to mid-19th century, the terminal buds in 75% of the analysed adult trees had been bitten off at the trees' young stage, not only once but as many as 35 times. Therefore, "damage" to forests also occurred in the past, when the number of game was low.

For this reason, it is very important to classify damage. Some authors mention *allowable damage* (Adamič 1990), according to them, allowable damage is the degree of damage which does not affect the increment of a stand. Different authors (Adamič 1990, cit. Eiberle 1965, 1985, Perko 1982, Eiberle and Reidi 1985, etc.) propose that an amount of economically allowable damage be determined for each developmental stage of a stand.

Critical damage is the degree of a stand's damage caused by excessive game numbers at which a stand is beyond regeneration. In other words, apart from young tree species, game also inflicts considerable damage on bushy and herbaceous species. In this case, critical damage is an *ecological determinant* (Adamič 1990, cit. Kotar 1987a).

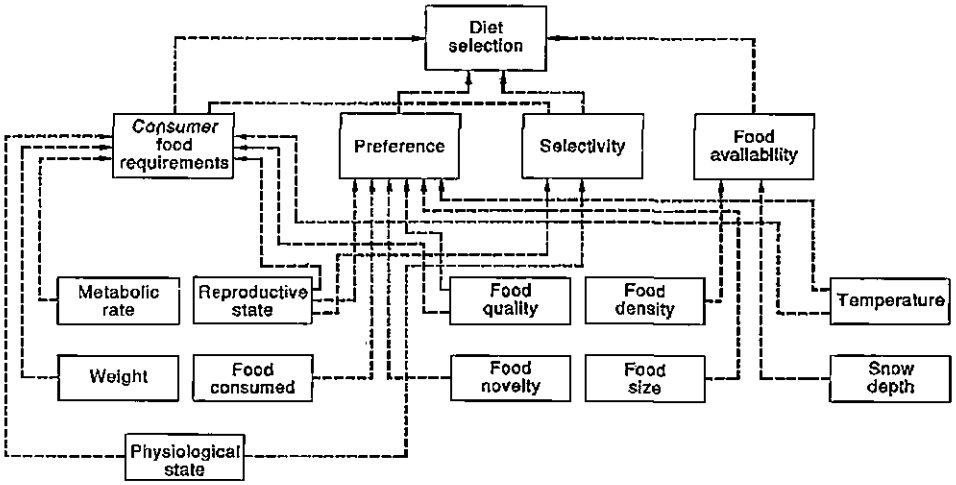
It is the lack of understanding of the role of the fauna in a forest ecosystem that causes misapprehensions of the above forestry concepts. This is directly connected to the concepts of *biotic site capacity* and *commercial site capacity* (Lovački priručnik 1976).

The present study of game nutrition deals with two completely different approaches:

- E u r o p e a n (with the exception of Scandinavia and Great Britain) - directed at adjusting and mitigating game damage and studying the importance and rationalisation of winter game feed (Adamič 1990, cit. Stenin 1969, Pheiffer & Hartfiel 1984, König 1970, Diekman 1983, etc.). This principle is a product of treating hunting as an inferior economic activity subordinated to agriculture and forestry. In connection with this, the problem of over-intensive use of space arises.
- N o r t h - A m e r i c a n - S c a n d i n a v i a n - primarily directed at studying the nutritive ecology of herbivores, competition among sympatric species and competition between wild and domestic animal species in large areas. This approach to hunting management is aimed at forming strategies for game population management in the nature respecting the biotic site capacity.

Therefore, while the second concept is aimed at respecting habitat management in the sense of increasing the site capacity based on the knowledge of game feeding patterns, the European concept focuses on decreasing game population densities in order to adjust them to commercial capacities, which in turn represent *biotic capacities reduced for the productive function of European forests and agricultural areas.*

Essentially, the value of studying the feeding behaviour lies in detecting and realising the importance of individual components within the entire nutritive spectre of a given animal species (Figure 1). Hunting operative is concerned not only with which plant species is used as food by game, but also which parts of a plant is consumed by a given game species.



Source/*Izvor:* Krebs, C.J., 1989; 405 pp.

Fig 1. Factors influencing animal feeding behaviour
Slika 1. Prikaz čimbenika koji uvjetuju hranidbeno ponašanje žvotinja

Extensive research in the interaction of herbivorous game and their nutritive base has so far been done mostly by Swedish (Danell, K., Bergoström, R., Palo, R. T. and others) and North American researchers (Risenhoover, K. L.). Thus, Risenhoover (1987) applied the preference index ratio (Pi) to find that the moose (*Alces alces* L.) showed different degrees of preferences for willow *Salix alexensis* and *Salix glauca* in different habitat types. The same author found no correlation between preference for the same willows and their number in the studied area (Denali National Park and Preserve, Alaska), but found a correlation between the preference index ratio and the chemical composition of food (e.g., the correlation coefficient between P_i and the astringent content[1] was -0.733, lignin -0.624, while between P_i and the cellulose content it was 0.570).

Danell *et al.* (1987) found a positive correlation between the intensity of silver birch (*Betula pendula* Roth.) browsing by moose and the number of plants in a site. Bergström (unpublished) analysed browsing intensity on the plants of silver birch by height classes and found that on the trees between 1.0 and 2.5 m, the most moose browsing was done on the trees in the 0.5 to 1.5 m height class.

The initial results of research (Viličić *et al.* 1998) on the influence of fallow deer on the habitat in the forest of holm oak (*Fraxino orni - Quercetum ilicis* H-ić (1956) 1958) in the hunting ground "Punta Križa" on the island of Cres showed that apart from holm oak (*Quercus ilex* L.), fallow deer also browsed on other elements of holm oak forests, such as, for example *Phillyrea* sp., manna ash (*Fraxinus ornus* L.) laurustinus (*Viburnum tinus* L.), common myrtle (*Myrtus communis* L.), Dalmatian blackberry (*Rubus dalmaticus* Tratt), evergreen rose (*Rosa sempervirens* L.) and green briar (*Smilax aspera* L.).

[1] astringent - causes contraction of body tissue, has antiinflamatory effects

MATERIAL AND METHODS
MATERIJAL I METODE

Research on the wild herbivore - habitat interaction in the Mediterranean region of Croatia began in the enclosed part of the state hunting ground VIII/6 "Kalifront", covering an area of 1351.22 ha. The hunting ground is located on the island of Rab. Of big game, the ground contains mouflon (*Ovis ammon musimon* Pall.) and axis deer (*Axis axis* Erx.). Since the whole hunting ground is located on the peninsula, the central part of the ground was divided with a partition (3.4 km long). In this way the north-western part of the ground (840 ha) and the game remained isolated from domestic cattle, which had browsed uncontrollably in the forests over the entire area of the hunting ground "Kalifront". This partition had the same effect that an enclosure around the whole ground would have, since the ground is surrounded by the sea on the three remaining sides. For this reason, the term the enclosed part of the hunting ground will be used further on in the paper. Thus, the prerequisites for the study of natural game growth were established (Table 1).

Table 1. Site class, carrying capacity and growing area (GA) for mouflon and axis deer in the hunting ground "Kalifront"

Tablica 1. Bonitet, kapacitet staništa te LPP za muflona i jelena aksisa u lovištu "Kalifront"[1]

Parameters *Parametri*	Mouflon *Muflon*		Axis deer *Jelen aksis*	
	From the working *Plan iz osnove*	Concrete situation *Stvarno stanje*	From the working *Plan iz osnove*	Concrete situation *Stvarno stanje*
ga *LPP*[1]	861 ha	840 ha	930 ha	840 ha
Site class *Bonitet*	First *Prvi*		Second *Drugi*	
Number of heads per 100 ha *Broj grla na 100 ha*	5	5	3	3
Commercial capacity *Gospodarski kapacitet*	43	45	28	22
Hunting capacity *Lovnogosp. Kapacitet*	57	51	36	28

At the time of collecting data for this paper, there were a total of 45 heads of mouflon and 22 heads of axis deer in the enclosed part of the hunting ground. Taken as a whole, this means that big game population density was 8 heads per 100 ha of the total ground area. According to Table 1, in the year of assessment, the game population corresponded to the carrying capacity. The difference in the growth area was caused by partitioning the hunting ground in two parts. The partitioned part in which research was done has an area of 840 ha, and the concrete number of heads relates to this part of the hunting ground.

[1] 01. April 1999

[2] GA=growing area/*LPP=lovnoproduktivna površina*

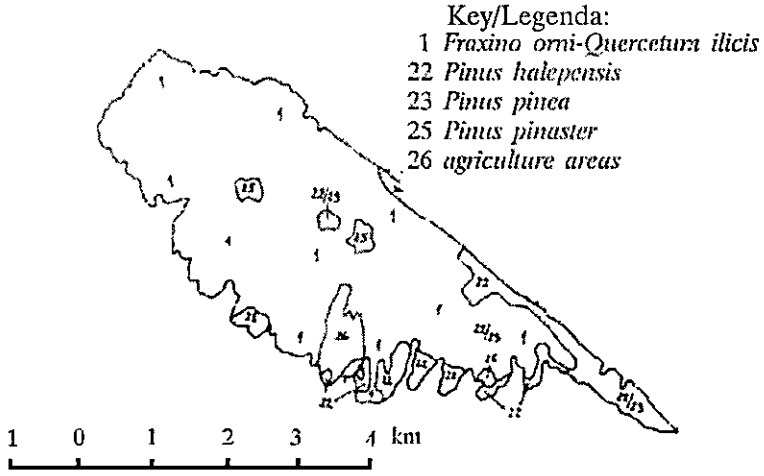
Based on the data from the Hunting Ground Establishment Act, the total ground area is 1,475 ha. The classification of the areas by cultures and land ownership ratio are given in Table 2.

Table 2. Hunting ground areas by cultures and ownership
Tablica 2. Površine lovišta po kulturama i zemljovlasničkim razmjerom

Name *Naziv*	Kind *Vrsta*	Culture *Kultura*	Ownership Zemljovlasničko razmjerje	Data from the foundation act *Podaci iz akta o ustanovljenju*	Data from the working plan *Podaci iz osnove*
Areas within the hunting ground (ha) *Zemljište unutar lovišta (ha)*	Forested *Šumsko*	Covered *Obraslo*	State/*Državno*	1287	1228.63
			Private/*Privatno*	77	90.37
			Total/*Ukupno*	1364	1319.00
		Uncovered *Neobraslo*	State/*Državno*	0	0
			Private/*Privatno*	0	0
			Total/*Ukupno*	0	0
		Overall/*Sveukupno*:		1364	1319.00
	Agricultural *Poljoprivredno*	Crop fields *Oranice*	State/*Državno*	0	0
			Private/*Privatno*	0	0.25
			Total/*Ukupno*	0	0.25
		Meadows *Livade*	State/*Državno*	0	0
			Private/*Privatno*	0	0
			Total/*Ukupno*	0	0
		Pastures *Pašnjaci*	State/*Državno*	78	14.25
			Private/*Privatno*	33	7.86
			Total/*Ukupno*	111	22.11
		Orchard and vineyards (not enclosed) *Višegodišnji nasadi (neograđeni)*	State/*Državno*	0	0.28
			Private/*Privatno*	0	1.97
			Total/*Ukupno*	0	2.25
		Other *Ostalo*	State/*Državno*	0	0.66
			Private/*Privatno*	0	7.01
			Total/*Ukupno*	0	7.67
		Overall/*Sveukupno*:		111	32.00

Name *Naziv*	Kind *Vrsta*	Culture *Kultura*	Ownership Zemljovlasničko razmjerje	Data from the foundation act *Podaci iz akta o ustanovljenju*	Data from the working plan *Podaci iz osnove*
Water within the hunting ground (ha) *Vode unutar lovišta (ha)*	Running water *Tekućice*	Natural *Prirodne*	Rivers/*Rijeke*	0	0
			Streams/*Potoci*	0	0
			Total/*Ukupno*	0	0
		Artificial *Umjetne*	Canals etc. *Kanali i dr.*	0	0
		Overall/*Sveukupno*:		0	0
	Stagnant water *Stajačice*	Natural *Prirodne*	Lakes/*Jezera*	0	0
			Swamps and ponds/ Močvare i bare	0	0
			Other/*Ostalo*	0	0
			Total/*Ukupno*	0	0
		Artificial *Umjetne*	Accummulations/ *Akumulacije*	0	0
			Retentions/ *Retencije*	0	0
			Other/*Ostalo*	0	0
			Total/*Ukupno*	0	0
		Overall/*Sveukupno*:		0	0
Overall hunting ground (ha)/*Sveukupno lovište (ha)*				1475	1351.28
Enclosed areas outside the hunting ground *Površine izvan lovišta opisane granicom (ha)*	Building land and areas up to 300 m from settlements *Građevinsko zemljište i površine do 300 m od naselja*			0	123.78
	Public areas (roads and other)/*Javne površine (ceste i dr.)*			0	0
	Specially protected matural sites/*Posebno zaštićeni objekti prirode*			0	0
	Enclosed orchard and vineyards/ *Ograđeni višegodišnji nasadi*			0	0
	Commercial fisheries/*Privredni ribnjaci*			0	0
	Other/*Ostalo*			0	0
	Total/*Ukupno*:			0	123.78

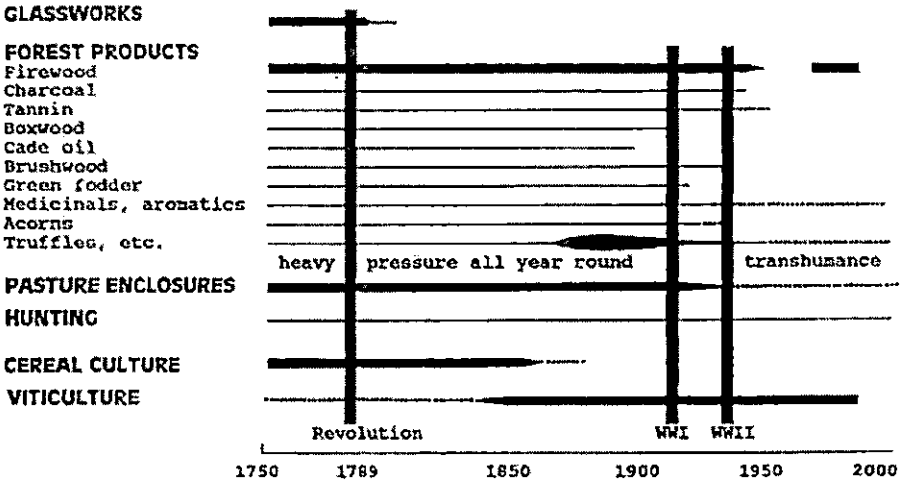
According to Table 2, the largest part of the hunting ground is taken by a forest of holm oak and manna ash (*Fraxino orni - Quercetum ilicis* H-ić1956/1958), which is exceptionally well preserved on Rab, and particularly in this hunting ground, unlike other forests of this phytocoenosis in the rest of the Croatian part of the Mediterranean, which are in different degradation stages from maquis to wasteland. In the MU Kalifront, different species of allochthonous pines are present to a lesser extent, either in the form of cultures or dispersed within natural holm oak stands. The present species include aleppo pine (*Pinus halepensis*), stone pine (*Pinus pinea*) and maritime pine (*Pinus pinaster*).



Source/Izvor: Španjol, Ž., 1995 prema Morton, F, 1915; Horvatić, S., Hodak, N., 1964; Hodak - Horvatić, 1983, Ilijanić, Lj., 1987 88p.

Figure 2. Vegetation map of the State Hunting Ground VIII/6 "Kalifront"

Slika 2. Vegetacijska karta Državnog lovišta VIII/6 "Kalifront"



Source/*Izvor:* Blondel & Aronson 1999, acc. to Bouneval 1990, Soulier 1993, 229 p.

Fig. 3. The utilisation of forest products in Mediterranean forests over the part 250 years

Slika 3. Korištenje pojedinih šumskih proizvoda sredozemnih šuma tijekom zadnjih 250 godina

METHODOLOGY OF DATA COLLECTING
METODOLOGIJA PRIKUPLJANJA PODATAKA

The choice of methods of studying the feeding behaviour should be suited to the goal of research. The following groups of methods are currently used to solve this problem matter:

1. Direct monitoring of game in the wilderness,
2. Monitoring the behaviour of domesticated wild animals in the nature:
3. Reconstructing a species' feeding activities and preference by traces in the snow,
4. Making inventories and quantifying animals' feeding choices with a list of visibly damaged plants in sample plots,
5. Observing the feeding choices of captured animals within a given offer with regard to a programmed meal content,
6. Analysing samples of the rumen content of killed or perished animals,
7. Analysing the remains of plant species collected from droppings.

Although the most reliable data on the feeding behaviour can be obtained with the methods listed under items 1 to 6, the type of methodology cited under item 4 has been used in this paper for two reasons. The first reason was that, according to field observation, game consumed different species, which would be very difficult to establish with the rumen analysis. The second reason was that it was impossible to kill a sufficient number of animals in such a small area in order to obtain a relatively satisfactory sample size.

The rumen content of common deer in the hunting grounds of Baranja has been analysed so far by Danon, Blaženčić and Bogović (1966, 1969). They found that deer fed on about 35 plant species in that site, and that in winter the dominant portion of food in the rumen came from the feeding points (meadow hay, alfalfa and corn).

A methodology of studying the impact of game on forest ecosystems in Croatia has been developed by Medvedović (1989, 1992) and Viličić (1992).

In a detailed study of the herbivore - site interaction (that is, nutritive base), research can be divided into several stages:

1. Studying the preference for individual plant species,
2. Studying the preference for individual parts of palatable plant species,
3. Measuring the biomass of palatable parts of individual plant species,
4. Determining chemical and mechanical contents of available resources.

A modified method by Viličić was used to study forest vegetation browsing. Modifications related only to a change in the intensity scale of plant damage (Adamič 1990), because it is difficult to accurately assess damage intensity on a 10%-scale in evergreen vegetation with numerous stump sprouts.

Viličić's method consists of the following: sample strips are pegged off in a forest and all the plants are listed and classified according to the following criteria:

- Plant species
- Height class - plants are divided into the following height classes:
  1. Up to 30 cm – plants of one year
  2. Plants of several years
  3. 31 – 60 cm
  4. 61 – 130 cm
  5. 131 – 150 cm
  6. 151 – 200 cm
  7. 201 – 250 cm
  8. 251 cm <
- Origin
  1. From seed
  2. From butt
  3. From stump
- Kind of damage
  1. Damaged bark
  2. Damaged lateral shoots
  3. Damaged bark and lateral shoots
  4. Damaged terminal shoot (shoots)
  5. Damaged terminal and lateral shoots
  6. Damaged bark and terminal shoot
  7. Damaged bark, terminal and lateral shoots.
- Damage intensity - the scale has been modified because in the original version it was divided into 10 degrees of 10% each (from 1 to 100%):
  1. Undamaged plants
  2. Moderately browsed plants (up to 30%)
  3. Severely browsed plants (from 31 to 50%)
  4. Critically browsed plants (from 51 to 100%).

The preference for game-damaged plants was estimated using the **preference ratio index** (P_i) given by the equation:

$$P_i = \frac{\frac{N_i}{\sum N_j}}{\frac{E_i}{\sum E_j}}$$

where:

N_i – the number of resource items i used in the sample,
ΣN_j – the total number of resource items used,
E_i – the number of resource items i in the environment,
ΣE_j – the total number of resource items in the environment.

In sample taking, the first step included defining game visitation patterns. After that, game was monitored, and when a spot of more intensive browsing was found, the plots were fenced (*Table 3*), and vegetation damage status was recorded in different seasons (spring, summer, autumn) according to the table given above. In compartments 18 and 22b, the plots were fenced in such a way that their edges bordered with the openings. This was done because it was assumed that browsing game remained close to the openings, where the browse was of better quality due to more light. It is also important to mention that this kind of browsing contributes to successful hunting because game is more easily detected on the edges than deep in the forest. The points where samples were collected are given in Map 1.

Table 3. Sample plots
Tablica 3. Podaci o primjernim plohama

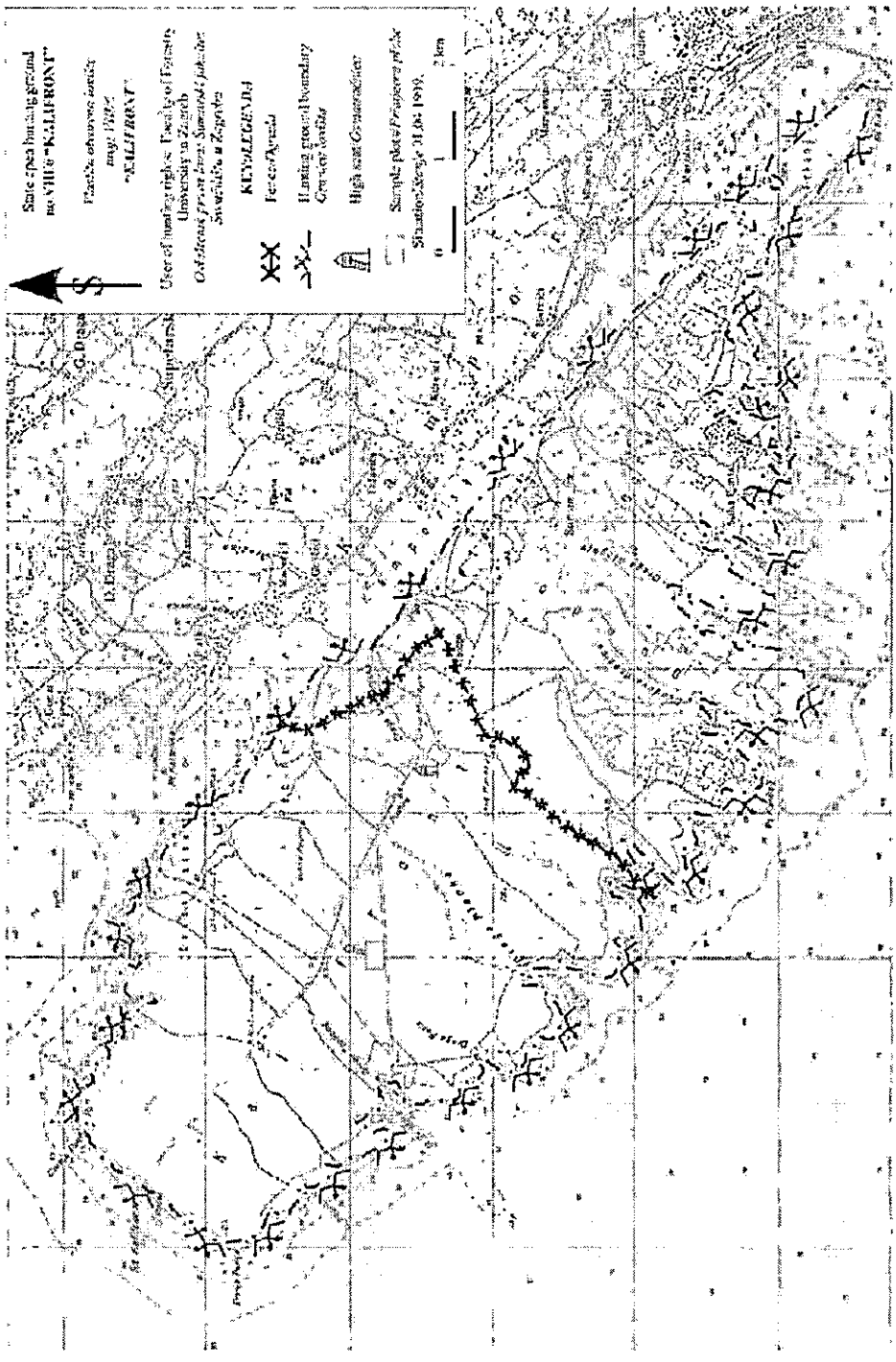
Compartment, subcompartment *Odjel odsjek*	Age (years) *Dob odjela (godine)*	Area (ha) *Površina odjela (ha)*	Size of sample plot (m²) *Veličina prim. plohe m²)*	Year of last cleaning *Godina zadnjeg čišćenja*	Date of measurement *Datum izmjere*
3	61	30.19	50	1999	06.07.1999.
4	36	19.42	600	1999	14.10.1999.
18	21	62.59	114	1996	15.05.1999.
22 b	17	34.55	86	1997	15.05.1999.

RESEARCH RESULTS
REZULTATI ISTRAŽIVANJA

Species preference cannot be studied with one recording of a given area. It has been long known that animals' feeding behaviour changes, among other things, during the year, that is, from season to season. Therefore, to study the feeding behaviour of game, more recordings should be made annually.

Forest vegetation was not browsed intensively until March 1999. It was only later, with increased stand recognisance that initial browsing in compartment 8 (managed by the NPŠO Rab) was noted, as well as in compartments 18 and 22. Compartment 8 is located immediately next to the nursery A. Petračić, while compartments 18 and 22b are located next to the nursery Topolje. Evidently, game kept close to the nurseries for browsing. Sample plots were immediately set up in compartments 18 and 22 b and the first recordings were made in mid-May (Tables 4, 5, 6, 7, 8, 9, 10, 11 and 12).

At the beginning of 1999, light strips ("snipe strips") were made in compartments 3, 4, 5 and 6 in the MU "Kalifront". A total of 4,440 m of strips averaging 4 m in width were cleared, totalling 1.78 ha. This management procedure was immediately put to use for browse recording, as it can serve as a model of monitoring the game-forest relationship when a stand is in the regeneration stage (in the case of clearcutting).



Map 1. The State Hunting Ground VIII/6 "Kalifront"
Karta 1. Državno lovište VIII/6 "Kalifront"

Table 4. Summary presentation of the number of undamaged and damaged plants per hectare by compartments, origin, height classes, damage type and intensity in the hunting ground "Kalifront"

Tablica 4. Sumarni prikaz brojnosti neoštećenih i oštećenih biljaka na jedan hektar po odjelima, načinu postanka, visinskim razredima, vrsti i intenzitetu oštećenja u lovištu "Kalifront"

Compartment, subcompartment *Odjel/Odsjek*		Only consumed species *Samo konzumirane vrste*	Origin *Način postanka*			Height classes *Visinski razredi*					Damage type *Visinski razredi*			Damage intensity *Intenzitet oštećenja*		
			From seeds *Iz sjemena*	From stumps *Iz panja*	Total *Ukupno*	1 – 30 (cm)	31 – 60 (cm)	61 – 130 (cm)	131 – 150 (cm)	151 – 200 (cm)	2	4	5	1 – 30 %	31 – 50 %	51 – 100 %
3	damaged *oštećeno*	4600	2000	2600	4600	1600	2400	600	0	0	200	1600	2800	1400	1000	2200
	undamaged *neoštećeno*	47400	68800	9200	78000	72800	4200	1000	0	0	0	0	0	0	0	0
	total *ukupno*	52000	70800	11800	82600	74400	6600	1600	0	0	200	1600	2800	1400	1000	2200
4	damaged *oštećeno*	6983	5133	1850	6983	5133	917	883	17	33	0	917	6067	617	250	6117
	undamaged *neoštećeno*	19117	18783	1117	19900	18700	467	617	100	17	0	0	0	0	0	0
	total *ukupno*	26100	23917	2967	26883	23833	1383	1500	117	50	0	917	6067	617	250	6117
18	damaged *oštećeno*	14298	4474	9825	14298	1140	6404	5439	1228	88	263	2368	11667	5877	3860	4561
	undamaged *neoštećeno*	12544	7368	7193	14561	4561	5088	4298	614	0	0	0	0	0	0	0
	total *ukupno*	26842	11842	17018	28860	5702	11491	9737	1842	88	263	2368	11667	5877	3860	4561
22b	damaged *oštećeno*	9419	3256	6163	9419	581	6163	2326	349	0	698	3953	4767	5698	1512	2209
	undamaged *neoštećeno*	2791	2093	930	3023	1512	814	581	0	116	0	0	0	0	0	0
	total *ukupno*	12210	5349	7093	12442	2093	6977	2907	349	116	698	3953	4767	5698	1512	2209

Table 5. Plant damage in the sample plot (calculated by hectare) in Compartment 18 of the Management Unit "Kalifront"

Tablica 5. Prikaz oštećenosti biljaka na primjernoj plohi (preračunato na hektar) u odjelu 18 Gospodarske jedinice "Kalifront"

No.	Area= 114 m² *Površina= 114 m²*	Compartment age: 21 YEARS *Dob odjela: 21 GOD.*								Cleaning: 1996. *Čišćenje: 1996.*		Measurement: may1999 *Izmjera: svibanj 1999.*			
	Species	Origin *Način postanka*			Height classes *Visinski razredi*					Damage type *Vrsta oštećenja*			Damage *intensity* *Intenzitet oštećenja*		
		From seeds *Iz sjemena*	From stumps *Iz panja*	Total *Ukupno*	1 – 30 (cm)	31 – 60 (cm)	61 – 130 (cm)	131 – 150 (cm)	151 – 200 (cm)	2	4	5	1 – 30 %	31 – 50 %	51 – 100 %
1	*Quercus ilex*	0	526	526	88	175	175	88	0	0	88	439	526	0	0
2	*Fraxinus ornus*	263	351	614	0	175	263	175	0	0	175	439	351	88	175
3	*Arbutus unedo*	0	175	175	0	0	88	88	0	88	88	0	175	0	0
4	*Viburnum tinus*	351	6491	6842	614	4035	2018	175	0	0	789	6053	2456	2281	2105
5	*Rubus dalmaticus*	88	0	88	0	0	88	0	0	0	0	88	0	88	0
6	*Rosa sempervirens*	0	0	0	0	0	0	0	0	0	0	0	0	0	0
7	*Clematis* sp.	88	0	88	0	0	88	0	0	0	88	0	88	0	0
8	*Pistacia lentiscus*	0	0	0	0	0	0	0	0	0	0	0	0	0	0
9	*Phillyrea latifolia*	175	2018	2193	0	526	1404	263	0	0	351	1842	702	1053	439
10	*Ruscus aculeatus*	789	0	789	0	526	263	0	0	0	0	789	0	88	702
11	*Asparagus acutifolius*	1316	0	1316	351	439	351	175	0	175	614	526	1228	88	0
12	*Erica arborea*	0	0	0	0	0	0	0	0	0	0	0	0	0	0
13	*Smilax aspera*	351	0	351	0	175	88	88	0	0	88	263	175	88	88
14	*Coronilla emeroides*	1140	0	1140	0	351	614	175	0	0	0	1140	0	88	1053
15	*Spartium junceum*	0	88	88	0	0	0	0	88	0	0	88	88	0	0
16	*Rubia peregrina*	0	88	88	88	0	0	0	0	0	88	0	88	0	0
	Total *Ukupno*	4474	9825	14298	1140	6404	5439	1228	88	263	2368	11667	5877	3860	4561

Table 6. Plant damage in the sample plot (calculated by hectare) in Compartemnt 22b of the Management Unit "Kalifront"

Tablica 6. Prikaz oštećenosti biljaka na primjernoj plohi (preračunato na hektar) u odjelu 22b Gospodarske jedinice "Kalifront"

No.	Area= 86 m² *Površina= 86 m²*	Compartment age: 17 years *Starost odjela: 17 god.*								Cleaning: 1997 *Čišćenje:* 1997.			Measurement: may 1999 *Izmjera: Svibanj 1999.*		
	Species	Origin *Način postanka*			Height classes *Visinski razredi*					Damage type *Vrsta oštećenja*			Damage *intensity* *Intenzitet oštećenja*		
		Srom seeds *Iz sjemena*	From *stumps* *Iz* panja	Total *Ukupno*	1 – 30 (cm)	31 – 60 (cm)	61 – 130 (cm)	131 – 150 (cm)	151 – 200 (cm)	2	4	5	1 – 30 %	31 – 50 %	51 – 100 %
1	*Quercus ilex*	0	349	349	0	233	116	0	0	0	349	0	349	0	0
2	*Fraxinus ornus*	0	349	349	0	0	116	233	0	116	0	233	233	116	0
3	*Arbutus unedo*	116	233	349	0	116	233	0	0	0	349	0	349	0	0
4	*Viburnum tinus*	349	5000	5349	465	3953	930	0	0	116	2326	2907	3837	465	1047
5	*Rubus dalmaticus*	1395	0	1395	0	1047	349	0	0	349	116	930	581	349	465
6	*Rosa sempervirens*	0	0	0	0	0	0	0	0	0	0	0	0	0	0
7	*Clematis* sp.	0	0	0	0	0	0	0	0	0	0	0	0	0	0
8	*Pistacia lentiscus*	0	0	0	0	0	0	0	0	0	0	0	0	0	0
9	*Phillyrea latifolia*	116	233	349	116	0	233	0	0	0	233	116	233	0	116
10	*Ruscus aculeatus*	233	0	233	0	233	0	0	0	0	233	0	0	0	233
11	*Asparagus acutifolius*	349	0	349	0	233	116	0	0	116	116	116	0	349	0
12	*Erica arborea*	0	0	0	0	0	0	0	0	0	0	0	0	0	0
13	*Smilax aspera*	698	0	698	0	349	233	116	0	0	233	465	116	233	349
	Total *Ukupno*	3256	6163	9419	581	6163	2326	349	0	698	3953	4767	5698	1512	2209

Table 7. Plant damage in the sample plot (calculated by hectare) in Compartment 3 of the Management Unit "Kalifront"
Tablica 7. Prikaz oštećenosti biljaka na primjernoj plohi (preračunato na hektar) u odjelu 3 Gospodarske jedinice "Kalifront"

No.	Area= 86 m² *Površina= 86 m²*	Compartment age: 61 years *Starost odjela: 61 god.*								Cutting: 1997. *Sječa: 1997.*			Measurement: 06.07.1999. *Izmjera: 06.07.1999.*		
	Species	Origin *Način postanka*			Height classes *Visinski razredi*					Damage type *Vrsta oštećenja*			Damage intensity *Intenzitet oštećenja*		
		From seeds *Iz sjemena*	From stumps *Iz panja*	Total *Ukupno*	1 – 30 (cm)	31 – 60 (cm)	61 – 130 (cm)	131 – 150 (cm)	151 – 200 (cm)	2	4	5	1 – 30 %	31 – 50 %	51 – 100 %
1	*Quercus ilex*	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2	*Fraxinus ornus*	0	800	800	0	600	200	0	0	0	400	400	400	0	400
3	*Arbutus unedo*	0	0	0	0	0	0	0	0	0	0	0	0	0	0
4	*Viburnum tinus*	0	800	800	400	400	0	0	0	0	600	200	200	200	400
5	*Rubus dalmaticus*	0	0	0	0	0	0	0	0	0	0	0	0	0	0
6	*Rosa sempervirens*	0	0	0	0	0	0	0	0	0	0	0	0	0	0
7	*Clematis* sp.	0	200	200	0	200	0	0	0	0	0	200	200	0	0
8	*Erica arborea*	0	1000	1000	600	400	0	0	0	0	0	1000	200	400	400
9	*Phillyrea latifolia*	0	600	600	0	400	200	0	0	0	200	400	400	200	0
10	*Ruscus aculeatus*	200	0	200	0	0	200	0	0	0	0	200	0	200	0
11	*Solanum nigrum*	0	0	0	0	0	0	0	0	0	0	0	0	0	0
12	*Picris hieracioides*	0	0	0	0	0	0	0	0	0	0	0	0	0	0
13	*Asparagus acutifolius*	200	0	200	0	200	0	0	0	0	200	0	0	0	200
14	*Smilax aspera*	600	0	600	400	200	0	0	0	200	0	400	0	0	600
15	*Stenactis annua*	200	0	200	200	0	0	0	0	0	200	0	0	0	200
16	*Tamus communis*	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	Total *Ukupno*	1200	3400	4600	1600	2400	600	0	0	200	1600	2800	1400	1000	2200

Table 8. Plant damage in the sample plot (calculated by hectare) in Compartment 4 of the Management Unit "Kalifront"
Tablica 8. Prikaz oštećenosti biljaka na primjernoj plohi (preračunato na hektar) u odjelu 4 Gospodarske jedinice "Kalifront"

No.	Area= 600 m² *Površina= 600 m²*	Compartment age: 36 years *Dob odjela: 36 god.*								Cutting: January 1999 *Sječa: Siječanj 1999.*		Measurement: 14.10.1999 *Izmjera: 14.10.1999.*			
	Species	Origin *Način postanka*			Height classes *Visinski razredi*					Damage type *Vrsta oštećenja*			Damage intensity *Intenzitet oštećenja*		
		From seeds *Iz sjemena*	From stumps *Iz panja*	Total *Ukupno*	1 – 30 (cm)	31 – 60 (cm)	61 – 130 (cm)	131 – 150 (cm)	151 – 200 (cm)	2	4	5	1 – 30 %	31 – 50 %	51 – 100 %
1	*Quercus ilex*	50	1067	1117	117	417	550	17	17	0	217	900	433	150	533
2	*Fraxinus ornus*	83	117	200	83	67	50	0	0	0	33	167	0	17	183
3	*Arbutus unedo*	0	133	133	0	0	117	0	17	0	67	67	50	17	67
4	*Viburnum tinus*	50	267	317	233	67	17	0	0	0	0	317	0	0	317
5	*Erica arborea*	0	133	133	133	0	0	0	0	0	0	133	17	17	100
6	*Phillyrea latifolia*	0	100	100	33	33	33	0	0	0	0	100	0	0	100
7	*Rubus dalmaticus*	283	0	283	200	0	83	0	0	0	17	267	117	0	167
8	*Rosa sempervirens*	333	33	367	333	17	17	0	0	0	33	333	0	33	333
9	*Solanum nigrum*	1833	0	1833	1817	17	0	0	0	0	250	1583	0	0	1833
10	*Clematis sp.*	17	0	17	17	0	0	0	0	0	0	17	0	0	17
11	*Smilax aspera*	2400	0	2400	2083	300	17	0	0	0	300	2100	0	17	2383
12	*Ruscus aculeatus*	83	0	83	83	0	0	0	0	0	0	83	0	0	83
Total *Ukupno*		5133	1850	6983	5133	917	883	17	33	0	917	6067	617	250	6117

Table 9. Undamaged plants in the sample plot in Compartment 18 of the MU "Kalifront"
Tablica 9. Prikaz neoštećenih biljaka na primjernoj plohi u odjelu 18 GJ "Kalifront"

No.	SPECIES	Origin *Način postanka*			Height classes *Visinski razredi*				
		From seeds *Iz sjemena*	From stumps *Iz panja*	Total *Ukupno*	1 – 30 (cm)	31 – 60 (cm)	61 – 130 (cm)	131 – 150 (cm)	151 – 200 (cm)
1	*Quercus ilex*	175	526	702	263	175	263	0	0
2	*Fraxinus ornus*	3158	1228	4386	1491	1491	1140	263	0
3	*Arbutus unedo*	88	789	877	88	175	351	263	0
4	*Viburnum tinus*	877	877	1754	1228	439	88	0	0
5	*Rubus dalmaticus*	1404	1140	2544	877	1491	175	0	0
6	*Rosa sempervirens*	0	0	0	0	0	0	0	0
7	*Clematis* sp.	351	0	351	263	0	88	0	0
8	*Pistacia lentiscus*	0	789	789	0	175	614	0	0
9	*Phillyrea latifolia*	263	614	877	175	439	263	0	0
10	*Ruscus aculeatus*	0	0	0	0	0	0	0	0
11	*Asparagus acutifolius*	965	0	965	88	439	439	0	0
12	*Erica arborea*	0	1228	1228	0	263	877	88	0
13	*Smilax aspera*	0	0	0	0	0	0	0	0
14	*Coronilla emeroides*	88	0	88	88	0	0	0	0
15	*Spartium junceum*	0	0	0	0	0	0	0	0
16	*Rubia peregrina*	0	0	0	0	0	0	0	0
	Total *Ukupno*	7368	7193	14561	4561	5088	4298	614	0

Table 10. Undamaged plants in the sample plot in Compartment 22b of the MU "Kalifront"
Tablica 10. Prikaz neoštećenih biljaka na primjernoj plohi u odjelu 22b GJ "Kalifront"

No.	Species	Origin *Način postanka*			Height classes *Visinski razredi*				
		From seeds *Iz sjemena*	From stumps *Iz panja*	Total *Ukupno*	1 – 30 (cm)	31 – 60 (cm)	61 – 130 (cm)	131 – 150 (cm)	151 – 200 (cm)
1	*Quercus ilex*	1512	116	1628	1395	233	0	0	0
2	*Fraxinus ornus*	0	0	0	0	0	0	0	0
3	*Arbutus unedo*	0	465	465	0	0	349	0	116
4	*Viburnum tinus*	0	233	233	0	233	0	0	0
5	*Rubus dalmaticus*	349	0	349	0	116	233	0	0
6	*Rosa sempervirens*	116	0	116	116	0	0	0	0
7	*Clematis* sp.	0	0	0	0	0	0	0	0
8	*Pistacia lentiscus*	0	0	0	0	0	0	0	0
9	*Phillyrea latifolia*	116	0	116	0	116	0	0	0
10	*Ruscus aculeatus*	0	0	0	0	0	0	0	0
11	*Asparagus acutifolius*	0	0	0	0	0	0	0	0
12	*Erica arborea*	0	116	116	0	116	0	0	0
13	*Smilax aspera*	0	0	0	0	0	0	0	0
	Total *Ukupno*	2093	930	3023	1512	813	581	0	116

Table 11. Undamaged plants in the sample plot in Compartment 3 of the MU "Kalifront"
Tablica 11. Prikaz neoštećenih biljaka na primjernoj plohi u odjelu 3 GJ "Kalifront"

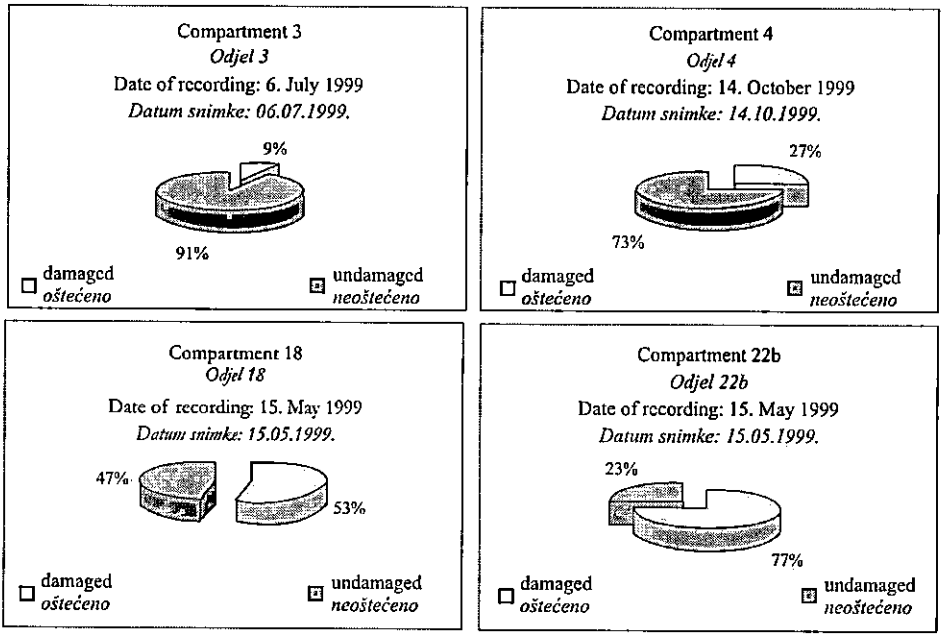
No.	Species	Origin *Način postanka*			Height classes *Visinski razredi*				
		From seeds *Iz sjemena*	From stumps *Iz panja*	Total *Ukupno*	1 – 30 (cm)	31 – 60 (cm)	61 – 130 (cm)	131 – 150 (cm)	151 – 200 (cm)
1	*Quercus ilex*	1400	4000	5400	4400	600	400	0	0
2	*Fraxinus ornus*	31600	400	32000	32000	0	0	0	0
3	*Arbutus unedo*	0	1200	1200	200	800	200	0	0
4	*Viburnum tinus*	2400	2200	4600	3800	800	0	0	0
5	*Rubus dalmaticus*	1000	0	1000	1000	0	0	0	0
6	*Rosa sempervirens*	200	0	200	200	0	0	0	0
7	*Clematis sp.*	200	0	200	200	0	0	0	0
8	*Erica arborea*	0	0	0	0	0	0	0	0
9	*Phillyrea latifolia*	2400	1400	3800	3000	600	200	0	0
10	*Ruscus aculeatus*	1800	0	1800	800	1000	0	0	0
11	*Solanum nigrum*	22000	0	22000	22000	0	0	0	0
12	*Picris hieracioides*	400	0	400	400	0	0	0	0
13	*Asparagus acutifolius*	200	0	200	200	0	0	0	0
14	*Smilax aspera*	4200	0	4200	3600	400	200	0	0
15	*Stenactis annua*	600	0	600	600	0	0	0	0
16	*Tamus communis*	400	0	400	400	0	0	0	0
	Total *Ukupno*	68800	9200	78000	72800	4200	1000	0	0

Table 12. Undamaged plants in the sample plot in Compartment 4 of the MU "Kalifront"
Tablica 12. Prikaz neoštećenih biljaka na primjernoj plohi u odjelu 4 GJ "Kalifront"

No.	Species	origin *Način postanka*			Height classes *Visinski razredi*				
		From seeds *Iz sjemena*	From stumps *Iz panja*	Total *Ukupno*	1 – 30 (cm)	31 – 60 (cm)	61 – 130 (cm)	131 – 150 (cm)	151 – 200 (cm)
1	*Quercus ilex*	1367	200	1567	1367	133	67	0	0
2	*Fraxinus ornus*	4717	83	4800	4717	50	33	0	0
3	*Arbutus unedo*	100	650	750	100	100	433	100	17
4	*Viburnum tinus*	17	0	17	17	0	0	0	0
5	*Rubus dalmatinus*	2350	50	2400	2400	0	0	0	0
6	*Rosa sempervirens*	117	17	133	133	0	0	0	0
7	*Solanum nigrum*	8483	0	8483	8483	0	0	0	0
8	*Myrtus communis*	183	117	300	150	117	33	0	0
9	*Inula viscosa*	200	0	200	100	50	50	0	0
10	*Clematis flammula*	483	0	483	483	0	0	0	0
11	*Smilax aspera*	433	0	433	417	17	0	0	0
12	*Ruscus aculeatus*	50	0	50	50	0	0	0	0
13	*Pinus pinaster*	283	0	283	283	0	0	0	0
	Total *Ukupno*	18783	1117	19900	18700	467	617	100	17

To calculate the percentage of damaged plants, only those plant species carrying browsing traces were used (consumed species). Other species were excluded from the calculation since they were not consumed by game.

During winter and early spring, game damaged a larger share of plants (53% in compartment 18 and 77% in compartment 22), in spring and early summer game damaged only 9% of the plants, while during summer and early autumn, 27% of the plants of consumed species were damaged.

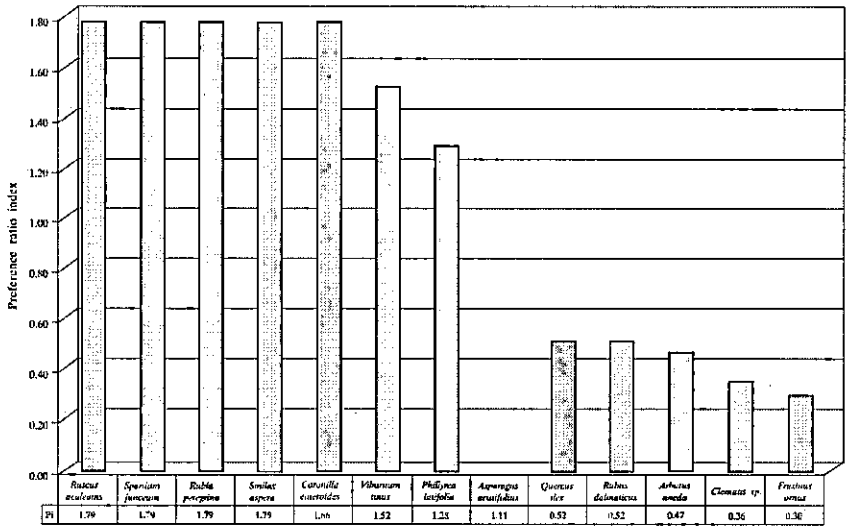


Graph 1. The share of damaged and undamaged plants in sample plots
Grafikon 1. Udio oštećenih i neoštećenih biljaka na primjernim plohama

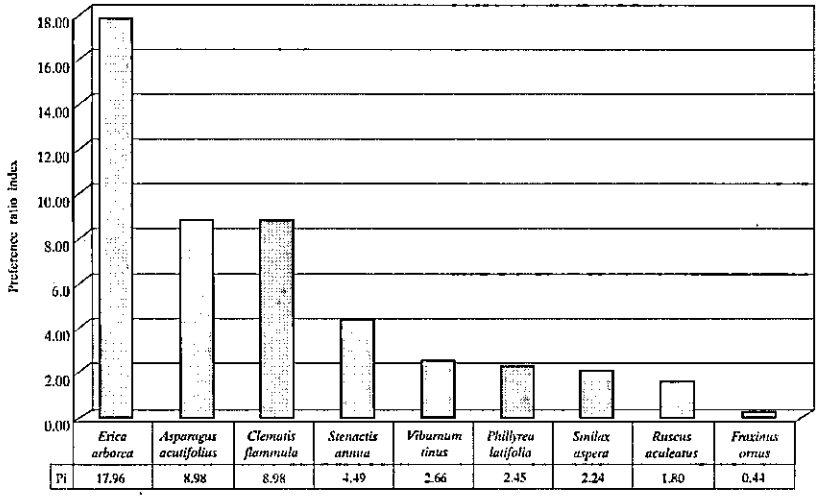
PLANT SPECIES PREFERENCE
PREFERABILNOST BILJNIH VRSTA

According to Tables 5, 6, 7, and 8, the species preference changed over seasons. During winter and spring (*Graph 2*) game preferred young tops of butcher's broom (*Ruscus aculeatus*), Spanish broom (*Spartium junceum*), wild madder (*Rubia peregrina*) and green briar (*Smilax aspera*). These four species had the same preference index of 1.79. Of a total of 16 plant species recorded in the plot, game consumed 13. Evergreen rose, mastic tree and tree heath were not browsed. It is interesting that in the recordings made during the remaining

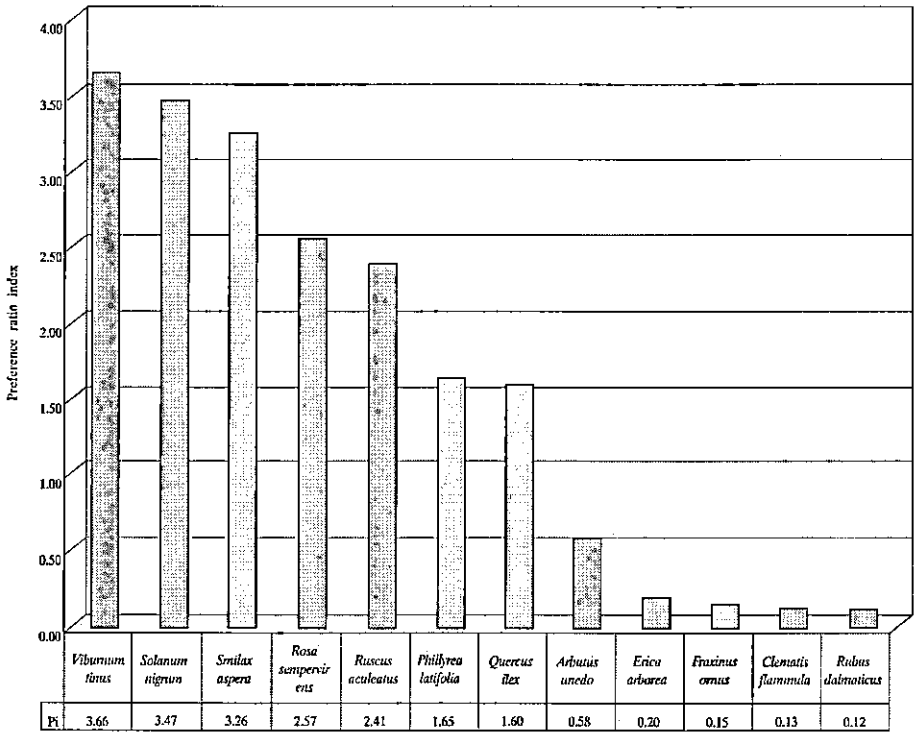
part of the year, game browsed on tree heath and evergreen rose. Spanish broom, scorpion senna and wild madder were not found in other sample plots.



Graph 2. Species preference by mouflon and axis deer for the winter-spring period
Grafikon 2. Preferabilnost vrsta u muflona i jelena aksisa za razdoblje zima-proljeće



Graph 3. Species preference by mouflon and axis deer for the spring-summer period
Grafikon 3. Preferabilnost vrsta u muflona i jelena aksisa za razdoblje proljeće-ljeto



Graph 4. Species preference by moudlon and axis deer for the summer-autumn period
Grafikon 4. Preferabilnost vrsta u muflona i jelena aksisa za razdoblje ljeto-jesen

During spring and early summer, the most preferred species was the tree heath (*Erica arborea*) - P_i=17.96 (Graph 3). Other woody species, such as laurustinus, phillyrea and manna ash achieved slightly lower preference. Of a total of 16 plant species, damage was recorded on 9. Game did not browse holm oak, strawberry tree, rose, black nightshade, hawkweed ox-tongue (*Picris hieracioides*) and black bryony (*Tamus communis*).

During summer and early autumn, the most damaged plant species was laurustinus (Pi=3.66, *Graph 4*). Black nightshade was also intensively damaged - Pi=3.46. Of a total of 14 species, game damaged 12. No damage was found on sticky fleabane (*Inula viscosa)* and maritime pine (*Pinus pinaster*). Maritime pine was represented only with seedlings up to 20 cm tall in the plot.

During spring, holm oak as a dominant species in the community took the sixth place, during summer it was not browsed by game, while browsing began only in late summer and early autumn. Field recognisance did not reveal any mastic tree (*Pistacia lentiscus*) and common myrtle (*Myrtus communis*) browsing anywhere in the hunting ground. This could support the claim that the habitat is still not over-capacitated with game, since mastic tree is damaged in Brijuni National Park, while myrtle is damaged by game (fallow deer) in the hunting ground of Punta Križa on Cres, where the habitat is over-capacitated.

In terms of seasonal changes in the preference for woody plants of the phytocoenosis *Fraxino orni-Quercetum ilicis*, no regular patterns were found, in other words, the preference changes over the season. Globally speaking, laurustinus is the most highly preferred woody species, followed by broad-leaved phillyrea, tree heath, holm oak strawberry tree and manna ash.

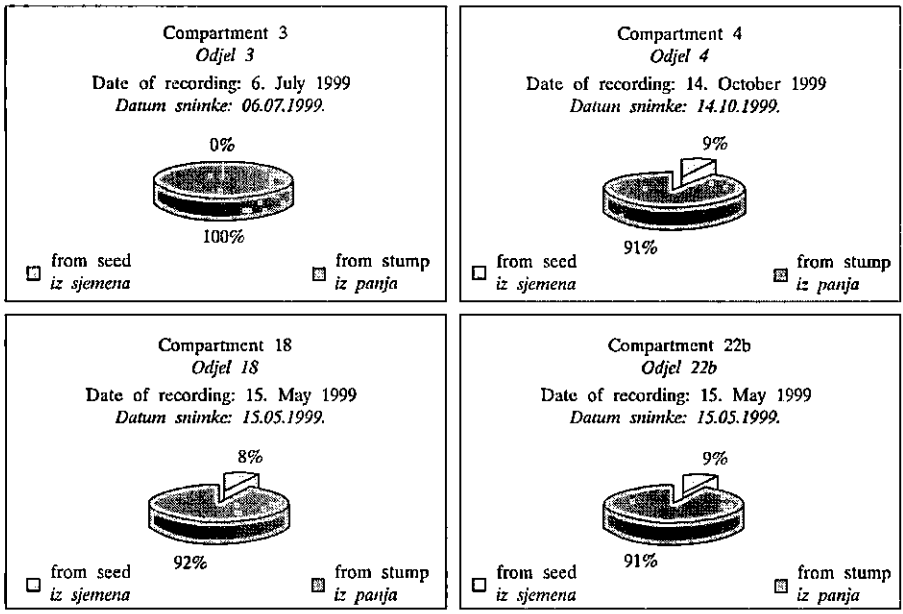
The hunting ground recognisance at the beginning of 2000 showed that Spanish broom was most game-damaged in winter. As for scorpion senna, since it grows mostly along paths, the game inflicted considerable damage in light strips.

Of 12,442 plants/ha of all species in compartment 22 b, the number of preferred species is 12,210/ha, of 28,860 plants/ha in compartment 18, the number of preferred plants is 26,842, of 82,600 plants/ha in compartment 3 there are 52,000/ha of preferred plants, and of 26,883 plants/ha in compartment 4, there are 26,100 preferred plants.

PLANT DAMAGE WITH REGARD TO ORIGIN

OŠTEĆENOST VRSTA S OBZIROM NA NAČIN POSTANKA

Since woody species of the community *Fraxino orni-Quercetum ilicis* can sprout from stumps or from seeds, the analysis of damage status was made based on the origin. The following species were encompassed by the analysis (Graph 5): holm oak, tree heath, laurustinus, phillyrea, strawberry tree and manna ash. The calculation (column "the consumed species only" in Table 4) was made for them.



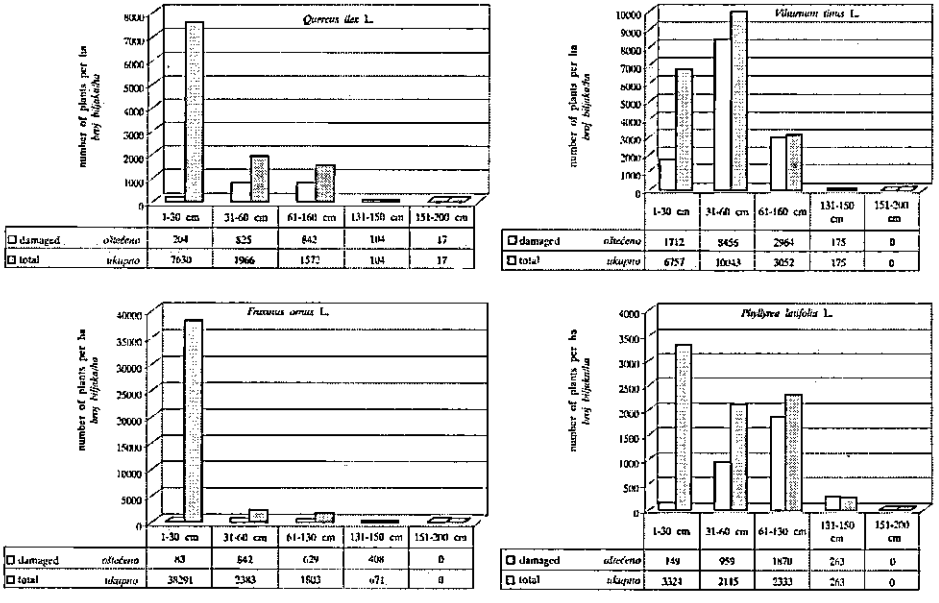
Graph 5. Distribution of damaged plants from seeds and from stumps
Grafikon 5. Distribucija oštećenih biljaka iz sjemena i iz panja

In compartment 3, all damaged plants originated from stumps. In compartment 4 there were 91% of damaged plants from stumps and 9% of plants from seeds. In compartment 18, 92% of the damaged plants sprouted from stumps and 8% from seeds. 91% of damaged plants in compartment 22 came from stumps, while 9% originated from seeds. It is evident that game prefers stump sprouts and that damage to seed sprouts is much smaller.

PLANT DAMAGE BY HEIGHT CLASSES

OŠTEĆENOST BILJNIH VRSTA S OBZIROM NA VISINSKE RAZREDE

Damage analysis by height classes was not done for tree and strawberry tree, because the former has numerous shoots and the latter lower preference. Generally, Graph 6 shows that the share of damaged plants increases with their height. In the last height class (151 to 200 cm), only plants of holm oak were registered.



Graph 6. Summary distribution of the total number of plants and damaged plants of a given plant species by height classes

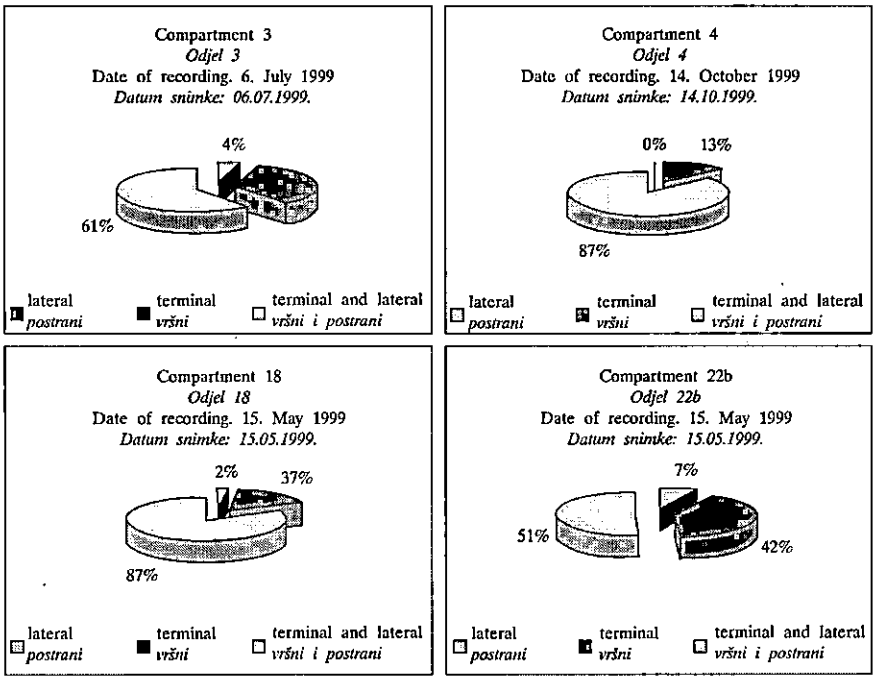
Grafikon 6. Sumarna distribucija ukupnog broja biljaka i oštećenih biljaka pojedine biljne vrste po visinskim razredima

A large quantity of plants of manna ash is the result of a high number of ash seedlings in plot 3 (31,600 plants). The major part of the seedlings later decayed so that by autumn the number had fallen considerably (4,800 plants).

PLANT DAMAGE BY DAMAGE TYPE

OŠTEĆENOST BILJAKA S OBZIROM NA NAČIN OŠTEĆENJA

The analysis of damage type was made summarily for all plants per compartments and seasons. In the majority of cases, game bites off both terminal and lateral shoots on a plant (from 51 to 87%). In the entire sample, the percentage of plants showing damage only on terminal shoots ranged from 13 to 35%, while that of the plants showing damage only on lateral shoots ranged from 0 to 7% (Graph 7).



Graph 7. Plant distribution by damage type

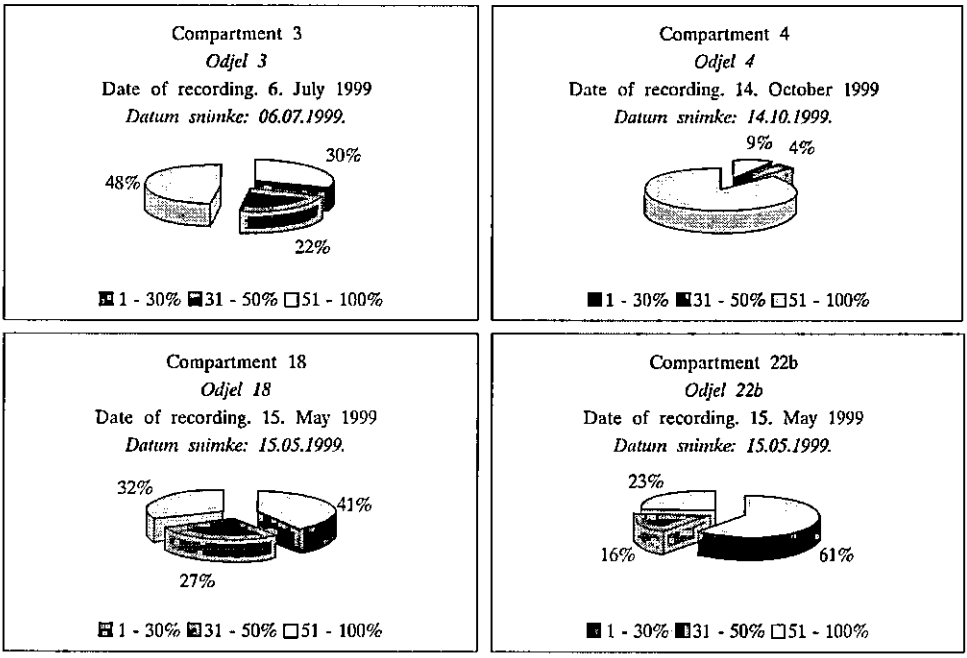
Grafikon 7. Distribucija biljaka po vrsti oštećenja

DAMAGE INTENSITY

INTENZITET OŠTEĆENJA

In winter and early spring, a larger proportion of plants (41% in compartment 18 and 61% in compartment 22b) was moderately damaged by game (from 1 to 30% of the shoots were damaged). By the beginning of summer, game inflicted critical damage to plants, so that 48% of the plants in compartment 3 were critically damaged. During summer and early autumn 87%

of the plants were critically browsed. Consequently, browsing intensity per plant increases from spring to late summer, and then decreases (Graph 8).



Graph 8. Plant distribution by damage intensity
Grafikon 8. Distribucija biljaka po intenzintetu oštećenosti

Although over 50% of the plants in compartments 18 and 22b were damaged during winter and early spring, most (41 and 61%) were moderately damaged (from 1 to 30%). In compartment 3, of the 9% of damaged plants, the majority (48%) were in the critically damaged class.

DISCUSSION
RASPRAVA

The forests in the Mediterranean region have traditionally provided the local population with a multitude of functions, unlike those in the rest of Europe. In the first place, they provided timber and food, then shelter, medicinal herbs, cork, tannin, resin, etc (Fig. 3). Intensive forest exploitation not only by felling but also by uncontrolled browsing has resulted in various degraded forms. As a result, many activities are being undertaken at present to restore and preserve these forests.

Methods of forest management on the island of Rab are characterised by a specific feature: the treatment of *cleaning*. This is a silvicultural procedure which removes subordinate species from a stand, but also reduces the number of principal woody species (primarily holm oak, followed by manna ash). The local population is thus provided with small fuelwood or browse for cattle. This procedure, since it allows a lot of light to enter a stand, is followed by a "burst" of vegetation, not only stump sprouts of felled woody species, but also climbers and ground vegetation. The vegetation biomass increases significantly under a rarefied or broken stand crown canopy and so does the concentration of raw proteins, net energy and carbohydrates, or the degree of food digestibility (Adamič 1990, cit Blair *et al,* 1983, cit Regelic *et al.* 1974). Therefore, stand tending does not lead only to an increase in the productive function of the forest, but also in the production of its other functions (integral forest management - the conversion of plant biomass into meat, trophies, etc.). In the mentioned hunting ground, game makes very good use of the cleaning results. All the plots have been established precisely in the areas that were cleaned.

According to Graphs 2, 3, and 4, game showed weaker preference for the principal woody species in the stand - the holm oak and manna ash. The most preferred woody species in these sites were scorpion senna, laurustinus and phillyrea. Tree heath was highly preferred in early summer due to the fact that young shoots sprouted from the stumps (and the plants did not exceed 60 cm in height, that is, most of the damaged plants were in the height class from 1 to 30 cm - compartments 3 and 4). Clearly, plants only had one-year-old (young) shoots, which are more digestible than older shoots, so that game did not have to invest effort into selecting more nutritious, younger shoots. It is well known that tree heath has abundant and relatively small-sized shoots compared to other species in holm oak forests. When only shoots of several years are available, which have poorer nutritive properties, game is forced to find food that will feed them faster and better. Here, there are no typical signs of woody species being browsed by ruminants as is the case on the continent, where the place of bite from the bottom looks as if cut, while the top contains the remains of bark and bast fibre. (Fig. 4) It is clear from Figure 5 that animals did not bite off the shoots in the way described above but tore them with their lips instead. In such a case, the shoot breaks at an un-lignified point, enabling the game to consume less indigestible matter, such as, for example, lignin (Fig. 5), which shows that game makes full use of browsing.

Over the year the consumed - unconsumed species ratio changes. In the winter - spring period, game consumed 13 out of 16 species, in the spring - summer period it consumed 9 out of 16 species, and in the summer - autumn period 12 out of 14 species were consumed (common myrtle, mastic tree, sticky fleabane and the seedlings of maritime pine were not consumed). Although myrtle was only recorded in compartment 4 in the sample, it should be pointed out that by reviewing the damaged plants in the entire hunting ground no damage to myrtle was found anywhere. This classifies it into the category of non-preferable plants for these two game species.

The key to a good nutritive base in the eu-Mediterranean region at the beginning of the browsing period by big game lies precisely in the production of one-year shoots of woody species. This period begins in late June and early July, when pasture elements (various grasses

and herbaceous plants) are dry and do not provide good quality forage. In this period, game primarily searches for shoots that are preferably juicy (Krapinec *et al.* 2000). Contrary to the continental part of Croatia, where unfavourable life conditions for game occur in winter, in the Mediterranean region such conditions occur in summer. It is for this reason that game in the Mediterranean migrates, as shown in Figure 6. In assessing the capacity of a hunting ground, it would be advisable to do so by taking into account the quantity of the natural nutritive base at the disposal to the game over the most unfavourable period of the year.

Since a stump plant sprouts more main shoots than a seed plant, stump plants contain higher biomass per unit than seed plants. This is undoubtedly one of the reasons why plants from stumps participated in the damage from 91 to 100%. Namely, in browsing, animals move from a plant to a plant, trying to use as little energy as possible for feeding. This is why they fed mainly on the shoots from stumps, as they had to invest much less effort and much less movement. The verity of this is testified by Graph 5, which shows that game preferred to browse higher plants, that is, plants in higher height classes.

Game was less selective with respect to terminal or lateral shoots. In most cases, it damaged both terminal and lateral shoots. Krapinec *et al.* (2000) found that an increase in the shoot diameter was directly proportionate to the shoot length, as well as the length of the bitten part of the shoot. Thus, the longer the shoot, the longer the part that the animals bite off or consume.

Game damages a larger number of plants in winter and spring, but with lower intensity. It could be concluded that in under-capacitated sites, an increase in the number of damaged plants results in a decrease in the percentage of damaged plants and vice versa. A very important fact was noted during damage assessment: game did not damage the young growth of holm oak and manna ash. The reason why the young growth of holm oak was not consumed might lie in the fact that the leaves on the young growth are thornier and tougher than those on the shoots from stumps, while the second reason has already been explained - less quantity of used energy per plant.

Terrain recognisance revealed that mouflon stripped the bark of young aleppo pines of up to 70 cm tall, which led to their subsequent death due to having been girdled (Figure 8).

It was observed during the year that mouflon formed bigger herds than axis deer. Some lone axis deer were observed, as well as groups consisting of two males up to nine heads at most, made up of bucks and does with and without calves. The size of mouflon herds ranged from four heads (an older ram with three ewes) to 27 heads. Consequently, due to a larger number of heads in a herd, mouflon poses more threat to successful forest regeneration than axis deer. Effort will have to be put into further research concerning ways of reducing the number of heads in a herd and a more balanced distribution of individuals in a hunting ground.

It is important to monitor browsing and grazing of other ("non-commercial") species in a stand in order to detect other forms of forest damage. Namely, as a result of game browsing and grazing, a situation may arise in which a characteristic set of plant species in a site changes to such a degree that the site loses the characteristics of the original community (Medvedović, 1989). In the concrete case, game might endanger butcher's broom, which is already under protection. The analysis of browsing patterns should take account of the fact that game migration in the hunting ground is not possible in the sense of seasonal movement in search for food as

is the case in some other hunting grounds where mouflon is reared. On the other hand, it is interesting that mouflon has adapted well to habitat conditions in a relatively short period, since it was re-introducted in the Mediterranean from Central Europe in 1998. The same mouflon population in the Czech Republic and Slovakia originates from the Belvedere Park near Vienna, where Eugène de Savoie brought it from Corsica in 1730. This fact testifies to the plasticity of mouflon game, because the same population, despite not having lived in the Mediterranean for over 250 years, still managed to utilize the major part of the resource for food upon its return to the original habitat.

CONCLUSIONS
ZAKLJUČCI

The following can be concluded from the analyses:

1. No economic damage was recorded in the hunting ground at a density of 8 heads of big game (mouflon and axis deer together) per 100 ha. If the principle of compensation is applied from the "Specialist groundwork ...", stating that one head of axis deer can be compensated with 1.5 head of mouflon, then the hunting ground would contain either 52 heads of axis deer (6 heads per 100 ha) or 78 heads of mouflon (9 heads per 100 ha). This would mean that the carrying capacity was exceeded by 180% in the case of mouflon, and by 200% in the case of axis deer.
2. From the aspect of hunting management, forest cleaning is the most important silvicultural procedure in these stands, since it increases the browsing nutritive capacities for the game manifoldly. The cleaning treatment may yield up to 52,000 individuals of palatable plant species per hectare by the beginning of summer.
3. The preference of browsing species changes over the season.
4. In the w i n t e r - s p r i n g period, the five best preferred species were butcher's broom (*Ruscus aculeatus*), Spanish broom (*Spartium junceum*), wild madder (*Rubia peregrina*), green briar (*Smilax aspera*) and scorpion senna (*Coronilla emeroides*).
5. In the s p r i n g - s u m m e r period, the five best preferred plant species were tree heath (*Erica arborea*), sharp-leaved asparagus (*Asparagus acutifolius*), plume clematis (*Clematis flammula*), laurustinus (*Viburnum tinus*) and crack phillyrea *(Phillyrea latifolia)*.
6. The five best preferred plant species in the s u m m e r - a u t u m n period were laurustinus (*Viburnum tinus*), black nightshade (*Solanum nigrum*), green briar (*Smilax aspera*), evergreen rose *(Rosa sempervirens)* and butcher's broom (*Ruscus aculeatus*).
7. Game prefers to browse plants from stumps than plants from seeds. Similarly, with an increase in the height of plants, the probability of their being damaged by game also rises.
8. The period in which forest stands are at most risk by game is summer - autumn. In this period, the number of damaged plants in sample plots was the highest, and so was the number of damaged plant species (86%).

9. Of woody species, game avoids common myrtle (*Myrtus communis*), mastic tree (*Pistacia lentiscus*) and young growth of all woody species.
10. The signs of biting the shoots of woody species in the eu-Mediterranean region differ from those on the continent. The place of a shoot bite is even, or in other words, game consumes non-woody shoots which are also the most digestible.
11. As a rule, in browsing, game bites both terminal and lateral shoots on one plant.
12. The reason why tree heath (*Erica arborea*) was highly preferred was that the shoots developed from winter to summer in the same year and the plants did not exceed 30 cm in height.

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PREFERABILNOST BILJNIH VRSTA ZAJEDNICE HRASTA CRNIKE I CRNOGA JASENA *(FRAXINO ORNI-QUERCETUM ILICIS H-IĆ /1956/ 1958)* U MUFLONA *(OVIS AMMON MUSIMON PAL.)* I JELENA AKSISA *(AXIS AXIS ERX.)*

SAŽETAK

Vegetacija u lovnom gospodarenju ima veliko značenje. Ona služi i za prehranu biljojedima i kao zaklon. Svaka pojedina životinjska vrsta ima specifične zahtjeve s obzirom na način života, stanište i hranu. Zbog toga je nužno lučiti različite tipove vegetacije odnosno kulture glede pogodnosti za uzgoj pojedine vrste divljači. Jedan od glavnih problema vrednovanja staništa za divljač je i dobar odnos oranica, livada, pašnjaka i šuma u lovnogospodarskom smislu. Što se tiče prvih triju kategorija s lovnogospodarskoga se gledišta do sada pokušala istražiti samo kakvoća umjetno proizvedene hrane u obliku koncentrata, silaže ili sijena za divljač tako da su prirodni hranidbeni potencijali još uvijek slabo istraženi.

U prirodnom uzgoju divljač na raspolaganju ima mnogo više hrane nego što je njezina ukupna potreba. To se u prvom redu odnosi na zeljaste biljke, i to samo tijekom vegetacije (iako pašne vrste divljači tijekom razdoblja bez vegetacije posežu i za suhim biljkama), dok izvan vegetacijskoga razdoblja određene vrste divljači hranu pronalaze uglavnom u šumi. S tom interakcijom divljač – stanište u nas, a i u svijetu uglavnom su se bavili šumari. Iako mnogi zaštitari prirode okrivljuju šumare za degradaciju staništa pojedinih životinskih vrsta, ovdje je bitno napomenuti da je već odavno dokazano kako suvremeno šumarstvo ide u prilog poboljšanju staništa za određene životinjske vrste. Naime, progresivnom sukcesijom vegetacije prostorno se i kakvoćno povećava gospodarski kapacitet divljih biljojeda, i to ne samo s prehrambenoga gledišta nego i u smislu zaklona.

U usporedbi s prašumom u gospodarskim se šumama količina i raznovrsnost dostupne biomase i zaklona povećavaju u skladu s nastajanjem inicijalne faze (branjevina). U posljednje se vrijeme u zapadnoeuropskim zemljama, pogotovo u Njemačkoj, nameće problem prekomjernoga broja divljači. Stoga se obavlja redukcijski odstrel prekobrojnih grla. Štetne učinke divljači na obnovu šuma neki autori navode kao glavni problem srednjoeuropskoga šumarstva, međutim, štete od divljači nisu isključivo u svezi s njhovom prekobrojnošću, a isto tako nisu nov pojam jer je analizom izvrtaka donjega dijela odraslih jela (*Abies alba* Mill.) iz Kočevskoga roga dobiven podatak da su u razdoblju od sredine 17. stoljeća do sredine 19. stoljeća na izraslim jelama terminalni pupovi 75 % analiziranih stabala u mladosti bili odgrizeni, i to od jednom do 35 puta. Dakle "štete" su u šumama i u prošlosti bile prisutne i pri niskom brojnom stanju divljači.

U istraživanjima prehrane divljači danas su vidljiva dva potpuno različita pristupa: europski (s izuzetkom Skandinavije i Velike Britanije), koji je usmjeren na prilagođavanje i ublažavanje šteta od divljači te proučavanje važnosti i racionalizacije zimske prehrane divljači, te sjevernoameričko-skandinavski, koji je u prvom redu usmjeren na upoznavanje prehrambene ekologije biljojeda, kompeticije među simpatičkim vrstama te kompeticije među divljim i

domaćim vrstama životinja na velikim površinama. Ovaj je pristup lovnomu gospodarstvu usmjeren na oblikovanje strategije upravljanja populacijama divljači u prirodi uz poštivanje biotskoga kapaciteta staništa.

Istraživanja interakcije divlji biljojed – stanište u sredozemnom području Hrvatske započela su u ograđenom dijelu Državnoga lovišta VIII/6 "Kalifront" površine 1351,22 ha. Navedeno lovište smješteno je na otoku Rabu. Od krupne divljači u lovištu obitavaju muflon (*Ovis ammon musimon* Pall.) i jelen aksis (*Axis axis* Erx.). S obzirom na to da se radi o lovištu koje je u biti u cijelosti smješteno na poluotoku, pregrađeno je u središnjem dijelu na duljini 3,4 km. Time je sjeverozapadni dio lovišta (840 ha) s divljači ostao izoliran od domaće stoke koja je do tada na čitavoj površini lovišta "Kalifront" nekontrolirano brstila u šumi. Učinak takve pregrade jednak je učinku potpunoga ograđivanja ovoga dijela lovišta jer su ostale tri strane okružene morem. Zbog toga će se u daljem tekstu više koristiti naziv ograđeni dio lovišta. Dakle, u potpunosti su stečeni preduvjeti za istraživanja prirodnoga uzgoja divljači.

U ograđenom dijelu lovišta tijekom uzimanja podataka za ovaj rad bilo je 45 grla muflonske divljači i 22 grla jelena aksisa. Ukupno gledano to čini gustoću populacije sve krupne divljači od 8 grla na 100 ha lovišta. Iz tablice 1 je vidljivo da je u godini izmjere populacija divljači bila u skladu s kapacitetima staništa. Razlika u lovnoproduktivnoj površini nastala je pregrađivanjem lovišta ogradom na dva dijela. Pregrađeni dio u kojem su obavljena istraživanja ima površinu od 840 ha, a stvarni se broj grla odnosi na prebrojavanje u tome dijelu lovišta.

Na temelju podataka iz akta o osnivanju lovišta ukupna površina lovišta iznosi 1475 ha. Raspored površina po kulturama i zemljovlasnički razmjer dan je u tablici 2.

Sredozemne su šume tradicionalno pružale mnogo više koristi lokalnomu pučanstvu za razliku od šuma ostaloga dijela Europe. U prvom redu služile su za drvo i hranu, a zatim za zaklon, uporabu ljekovitoga bilja, pluta, tanina, smola itd. (slika 3). Posljedica intenzivnoga iskorištavanja šuma ne samo sječom nego i nekontroliranom ispašom jesu različiti degradacijski oblici. Zbog toga se danas dosta poduzima kako bi se te šume očuvale.

Promatrajući način gospodarenja šumama na otoku Rabu, uočava se njihovo čišćenje. To je gospodarski zahvat u sastojini kojim se iz nje uklanjaju sporedne vrste, ali i smanjuje broj glavnih drvenastih vrsta (u prvom redu crnike, a manje crnoga jasena). Lokalno pučanstvo tako dobiva sitan ogrjev ili pak brst za stoku. Nakon takva zahvata u sastojini, budući da je u nju ušlo dosta svjetla, doslovce "bukne" vegetacija, ne samo izbojci iz panja posječenih drvenastih vrsta nego i penjačice te prizemno raslinje. Pri rijetkom do nepotpunom sklopu krošanja u sastojini se značajno povećava biomasa raslinja, a time raste koncentracija sirovih bjelančevina, te neto energija i ugljikohidrati, odnosno stupanj probavljivosti hrane (Adamič 1990, cit. Blair i dr. 1983, cit. Regelic i dr. 1974). Dakle, njega sastojina ne pridonosi samo povećanju proizvodne funkcije šume, nego i povećanju proizvodnosti ostalih njezinih funkcija (integralno gospodarenje šumama – konverzija biomase biljaka u meso, trofej i sl.). U navedenom lovištu divljač se jako dobro koristi posljedicama čišćenja. Sve navedene plohe smještne su upravo na površine u kojima je obavljeno čišćenje.

Promatrajući grafikone 2, 3. i 4, vidljivo je da divljač daje slabiju prednost glavnim drvenastim vrstama u sastojini, odnosno hrastu crniki i crnomu jasenu. Najpreferabilnije drvenaste vrste u ovim staništima su krunica, lemprika i zelenika. Veliki vrijes je početkom ljeta

imao veliku preferabilnost upravo zbog toga što su iz panja potjerali mladi izbojci, a biljke nisu prelazile visinu od 60 cm, odnosno veći dio oštećenih biljaka bio je u visinskom razredu od 1 do 30 cm (odjel 3 i 4). Dakle, biljke su imale samo ovogodišnje (mlade) izbojke koji imaju višu probavljivost od starijih te divljač nije morala ulagati veći napor u prebiranje hranjivijih, mladih izbojaka. Naime, poznato je da vrijes ima prilično sitne i mnogobrojne izbojke u usporedbi s ostalim vrstama crnikovih šuma te u slučaju dostupnosti isključivo višegodišnjih izbojaka, koji su slabih prehrambenih svojstava, divljač je prisiljena nalaziti hranu kojom će se brže i bolje nahraniti. Ovdje nije izraženo tipično odgrizanje drvenastih vrsta kao u kontinentnim krajevima, gdje preživači odgrizaju tako da mjesto odgriza s donje strane izgleda kao odrezano, a s gornje je ostatak kore i lika (slika 4). Na slici 11 jasno je uočljivo kako izbojci nisu odgrizani na gore opisani način, nego ih divljač kida usnama. Izbojak u tom slučaju puca na neodrvenjelom dijelu te divljač tako konzumira manje neprobavljivih tvari, npr. lignin (slika 5). To pokazuje kako divljač dobro iskorištava brst.

Tijekom godine mijenja se i odnos konzumiranih i nekonzumiranih vrsta. Tako je divljač u razdoblju zima-proljeće od 16 vrsta konzumirala njih 13, u razdoblju proljeće-ljeto od 16 vrsta konzumirala je njih 9, a u razdoblju ljeto-jesen od 14 vrsta konzumirala je 12 (nije jela mirtu, tršlju, ljepljivi oman te ponik primorskoga bora). Iako je mirta bila u uzorku snimljena samo u odjelu 4, treba reći da detaljnim pregledom oštećenih biljaka u cijelom lovištu nigdje nije ustanovljeno oštećenje biljaka mirte. To je također uvrštava u kategoriju nepreferabilnih biljnih vrsta za ove dvije vrste divljači.

Ključ dobre hranidbene podloge u eumediteranskom području na početku brsnoga razdoblja krupne divljači leži upravo u proizvodnji jednogodišnjih izbojaka drvenastih vrsta. To razdoblje nastupa krajem lipnja i početkom srpnja kada su različite trave i zeljanice suhe te su stoga loša krma. Divljač tada u prvom redu traži još neodrvenjele izbojke koji su, po mogućnosti, što sočniji (Krapinec i dr. 2000). Za razliku od kontinentalnoga dijela Hrvatske, gdje za život divljači nepovoljni uvjeti vladaju tijekom zime, u sredozemnom području takvi uvjeti vladaju tijekom ljeta. Upravo stoga divljač u Sredozemlju poduzima migracije prikazane na slici 6. Bilo bi dobro određivati kapacitet lovišta prema količini prirodne prehrambene baze divljači koja joj stoji na raspolaganju tijekom za život najnepovoljnijega dijela godine.

Budući da biljka iz panja tjera više glavnih izbojaka od biljke iz sjemena, ona ima veću biomasu nego biljka iz sjemena. Jedan od razloga zašto su biljke iz panja u udjelu oštećenosti bile zastupljene od 91 do 100 % nedvojbeno leži u toj činjenici. Naime, životinje pri brstu prelaze od biljke do biljke, a poznato je da se nastoje hraniti uz što manje trošenja energije. Zbog toga su se i hranile ponajprije izbojcima s panjača, jer su morale uložiti mnogo manje napore, odnosno što manje se kretati od biljke do biljke. Da je to točno, pokazuje i grafikon 6, iz kojega je vidljivo da je divljač radije brstila više biljke, odnosno biljke u višim visinskim razredima.

Pri izboru vršnoga ili postranoga izbojka divljač pokazuje manju selektivnost. U većini slučajeva je oštećivala i vršne i postrane izbojke. Krapinec i dr. (2000) utvrdili su da s povećanjem promjera izbojaka raste i duljina izbojka, te duljina odgrizenoga dijela izbojka. Znači, što je izbojak dulji, to je i dulji dio divljač odgrizla.

Tijekom zime i proljeća divljač ošteti veći broj biljaka, ali s manjim intenzitetom. Iz toga bi se moglo zaključiti da se u nenapučenim staništima s porastom broja oštećenih biljaka smanjuje

postotak oštećenosti biljaka, i obratno. Bitna činjenica uočena pri snimanju oštećenosti jest da divljač nije dirala ponik hrasta crnike i crnoga jasena. Razlog u nekonzumiranju ponika hrasta crnike mogao bi biti i taj što su listovi na poniku bodljikaviji i žilaviji nego na izbojcima iz panja, dok je drugi već objašnjen – manja količina potrošene energije po biljci.

Pri rekognosciranju terena utvrđeno je da je muflonska divljač gulila koru s mladih alepskih borova visine do 70 cm koji su se poslije, budući da su bili prstenovani, osušili (slika 8).

Promatranjem divljači tijekom godine moglo se uočiti da muflonska divljač formira veća krda od jelena aksisa. Kod aksisa je bilo zamijećenih samotnjaka, zatim grupe od dva mužjaka do najviše devet grla koje su činili jeleni i košute s teladi i bez teladi. Veličina krda kod muflonske divljači kretala se od četiri grla (stariji ovan s tri ovce) do 27 grla. Iz toga izlazi da je za uspješnu obnovu šuma opasnija muflonska divljač od jelenske jer ima veći broj grla u krdu. Zbog toga će trebati uložiti napore u daljnja istraživanja na koji način smanjiti broj grla u krdu te kako jedinke ravnomjerno rasporediti u lovištu.

Potreba praćenja brsta i paše na ostalim ("nekomercijalnim") vrsta-ma u sastojini bitna je zbog toga jer se šumskom štetom može smatrati i situacija u kojoj se, zbog paše i brsta divljači, promijenio karakterističan skup biljnih vrsta, i to tako da stanište prestaje biti karakteristično za prvotnu asocijaciju (Medvedović 1989). U konkretnom slučaju divljač bi mogla ugroziti bodljikavu veprinu koja je ionako već zaštićena. Pri analizi brsta treba uzeti u obzir i to da u lovištu nije moguća migracija divljači u smislu sezonskoga premještanja za hranom kao što je to slučaj u nekim drugim lovištima u kojima se gospodari muflonom. S druge je strane zanimljivo da se muflonska divljač dobro prilagodila u relativno kratkom vremenu na stanišne uvjete jer je iz srednje Europe 1998. godine dopremljena ponovo na Sredozemlje. Ista populacija muflona u Češkoj i Slovačkoj porijeklom je iz parka Belvedere kod Beča, gdje ju je Eugen Savojski dopremio s Korzike 1730. godine. Dakle, o plastičnosti muflonske divljači taj podatak puno govori jer ista populacija nije bila na Sredozemlju otprilike preko 250 godina, a ipak je uspjela pri povratku na prvobitno stanište u relativno kratkom vremenu za prehranu iskoristiti dobar dio resursa.

Ključne riječi: muflon (*Ovis ammon musimon* Pall.) i jelen aksis (*Axis axis* Erx.), šuma hrasta crnike i crnoga jasena (*Fraxino orni-Quercetum ilicis* H-ić /1956/ 1958)

UDK: 630*377:305

Original scientific paper
Izvorni znanstveni članak

PRODUCTIVITY FACTORS OF TIMBERJACK 1210 AT FORWARDING THE MAIN FELLING ROUNDWOOD IN CROATIAN LOWLAND FORESTS

ČIMBENICI PROIZVODNOSTI FORVARDERA TIMBERJACK 1210 PRI IZVOŽENJU OBLOGA DRVA GLAVNOGA PRIHODA HRVATSKIH NIZINSKIH ŠUMA

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The paper shows the influence of some factors (extraction distance, harvesting density, dimensions of processed roundwood, conditions of soil strenght, sorting of assortments during unloading) on productivity of 12-tones forwarder Timberjack 1210 which worked on extracting of roundwood from regeneration fellings in Croatian lowland forests.

Research was carried out on 5 workplaces at the period of 34 working days, when was extracted 3584 m^3 of hardwood assortments (oak and ash) in 370 forwarder cycles. The common feature of forwarder operation at all the researched felling sites was extraction of only technical roundwood processed by cut-to-lenght method with chainsaws, and free movement of the forwarder across the surface of felling units during the loading of timber. The sorting of assortments at the landing during unloading occurred in case of several types of species or quality classes of roundwood in the forwarder load. The felling sites differed by: average extraction distances (240 to 610 m), off-road soil strenght conditions in the course of the research (from mud to dry or frozen soil), harvesting density of the processed technical roundwood (85 to 132 m^3/ha) and the average quantity of the processed assortments: mid-diameter (23 to 51 cm), length (3.6 to 5.5 m), and volume (0.23 to 0.72 m^3/pcs).

The forwarder productivity was established by work and time study, and time consumptions of work components were measured by fly-back chronometry method.

The productivity level of forwarders per researched felling areas was influenced by the complex effects of off-road soil strenght conditions, dimensions of roundwood processed by cut-to-lenght method, harvesting density, and sorting of assortments at the landing during the unloading. For diversity and disparity of influenced factors encompassed at the research sites, their influence on the productivity of forwarders' operation was established indirectly,

through the time consumptions of work components, and the achieved load features. The research established the following:

– The load volume was under various influences of the key terrain factor of lowland forests – off-road soil strenght, as well as of the number of roundwood pieces of specific dimensions,

– The travel speed of unloaded and loaded forwarder depends on the type of surface on which the vehicle moves (off-road soil strenght conditions, forest road with gravel layer in the landing area),

– The time of work with crane at loading and unloading depends on the number of roundwood pieces of specific dimensions in the forwarder load,

– The time of works without crane at loading is influenced by the felling density of technical roundwood intended to primary timber transport,

–The time of works without crane at unloading depends on the need for timber sorting at the landing in case of occurrence of more types of species or quality classes of roundwood in the forwarder load,

–The allowance time depends on off-road soil strenght conditions.

Key words: forwarder productivity, influencing factors, regeneration fellings, Croatian lowland forests

INTRODUCTION
UVOD

Forestry mechinery production is not developed in the Republic of Croatia and machines required by the Croatian forestry are purchased on the foreign market. These machines and equipment are usually designed to suit the working conditions of the producer's home country. Therefore, when purchasing these machines and equipment, it is not sufficient to make decisions on the basis of factory data and data on their productivity referred to in foreign literature but they should rather be tested in our own working conditions. The reason lies in specific relief, hydrographic and climate features of the Croatian forests, as well as in diversity of tree species, condition of stands and manner of forest management.

This paper deals with the investigation of primary off-road transport of roundwood by forwarder Timberjack 1210. The purpose of this research is to give contribution to gaining knowledge of the productivity of a 12-ton forwarder Timberjack 1210 in extracting roundwood from regenerative felling in the Croatian lowland forests.

TIMBER FORWARDING
IZVOŽENJE DRVA

Forest harvesting, as the process of forest assortments production, consists of timber felling, processing and transport according to Krpan (1992). Transport of timber is broken down into

bunching, extracting and further transport. The term timber extraction, as part of timber transport, implies moving of trees or parts of trees (forest assortments) from the felling site (stump) to the landing.

When harvesting the Croatian lowland and hilly forests, timber forwarding is often used as a special form of timber extraction. In timber forwarding, the load is carried completely off the ground so that only the rolling resistance and inclination influence has to be overcome. Timber forwarding carried out by up-to-date mechanical means rely on a long-term traditional use of animal-drawn carts (Sever 1988). Today timber is forwarded by forwarders and tractors with (semi) trailer, the so called tractor equipages. The use of forwarders for extraction depends on the cut-to-length method of timber processing. Roundwood extracted by forwarders is long up to 6 (7) m. Apart from extracting, the forwarder can also be used for road hauling at shorter distances, thus excluding reloading at the roadside landing.

Tufts (1997) sets forth the following advantages of the use of the forwarder and cut-to-lenght method for timber processing: less damage to the residual stand, the ability to merchandise products in the woods, recovery of higher-valued products, reduces site damage, less visual impact on the residual stand, a smaller – more efficient workforce, and operator safety and comfort.

The forwarder productivity level is seriously affected by the following factors: timber extraction distance, tree species and dimensions of processed roundwood, felling density, terrain slope, surface obstacles, soil strength conditions, snow thickness, the openness of felling sites through a secondary network of forest roads, possible preliminary preparation of load by another means of work, need to sort the assortments at the roadside landing, skill of the operators as well as the technical and technological characteristics of the vehicle and loader (Richardson & Makkonen 1994, Poršinsky 1996, Krpan & Poršinsky 1997, Poršinsky 2000, Poršinsky 2001)

FORWARDER TIMBERJACK 1210

FORVARDER TIMBERJACK 1210

Forwarder Timberjack 1210 is a six-wheel drive vehicle, with bogie on the rear axle (Fig. 1). It is designed for off-road transport of roundwood as well as for the transport on constructed roads with the possibility of self-loading and unloading.

Timberjack 1210 belongs to the group of the latest development stage of traditional forwarders without the latest achievements of independent wheels with the device for leveling the whole vehicle or only the cabin. The entire forwarder control – control of driving, engine, gearbox, hydraulic crane, is carried out by the so-called proportional technique by use of joysticks in the handholds of the driver's seat. Along with electro-hydraulic distributors used by forwarders before, hydrostatic-mechanical transmission is one of the latest components to provide it.

Figure 1. Forwarder Timberjack 1210
Slika 1. Forvarder Timberjack 1210

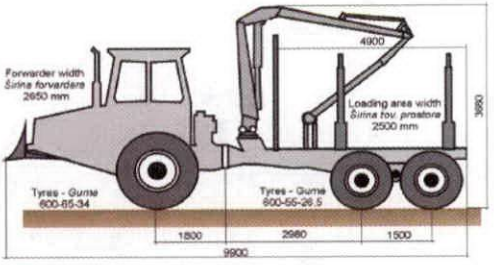

Figure 2. Basic dimensions
Slika 2. Osnovne dimenzije

The basic characteristics of the forwarder Timberjack 1210 are as follows:

- Perkins 1006-6TW engine is a water-cooled, 6-cyliner, diesel engine with turbo charger, which generates a power output of 114 kW at 2200 min^{-1} and 511 Nm of torque at 1590 min^{-1},
- Steering is articulated with maximum angle of ±40° and the turning radius 8.7 m,
- Forwarder dimensions are shown schematically in Figure 2. The mass of unloaded forwarder is the same as its permited load rating – 12,000 kg,
- Hydraulic loader is a Loglift F 70 L 71 model used for loading and unloading timber assortments. The crane has a lifting moment of 70 kNm (66.2 kNm is an average) and a maximum 7.1 m reach. By checking the lifting moment of the loader based on measurements (Horvat & Sever 1995), the following deviations from manufacturer's specifications have been determined: the crane also has the fourth (extension) arm so that its highest reach is 9.25 m and the mean lifting moment of the loader is by 35 % lower than specified and it is 42.7 kNm.

SCOPE OF RESEARCH
CILJ ISTRAŽIVANJA

The scope of research is to establish the factors affecting the work productivity of the forwarder Timberjack 1210 engaged in extracting roundwood from regeneration felling in the Croatian lowland forests.

Timber extraction by forwarders has the characteristics of cyclic work. Each forwarder cycle consists of four basic groups of cyclic working components (unloaded travel from landing to first loading point, felling site works – loading, loaded travel from felling site to landing, landing works – unloading) and work breaks (delay times) i.e. time consumption of random character. This means that by reducing the consumption of total cycle time and by increasing the load volume better forwarder productivity is achieved. Forwarder productivity, i.e. total cycle time and load volume, is affected by a large number of factors, among which this research will cover the following: extraction distance, felling density, dimensions of processed roundwood, soil strength conditions and sorting of assortments in unloading.

In addition to establishing these factors, the way and extent of their impact on the productivity of roundwood extraction will also be determined. By use of computer processing involving suitable statistical methods, interrelationship between the achieved productivities and the influencing factors will be determined.

The obtained results of research should be the base for the assessment of the use of the tested vehicle for timber extraction in set operating conditions.

METHOD OF RESEARCH AND DATA ANALYSIS
METODA ISTRAŽIVANJA I OBRADA PODATAKA

Forwarder performance was investigated by time and work study method. The time used for timber extraction was divided into work components (Fig. 3) with pre-selected fixed points, which were in accordance with the set scope of research. Time consumptions of the duration of working components were researched by snap-back chronometry method and records were taken throughout the whole working day.

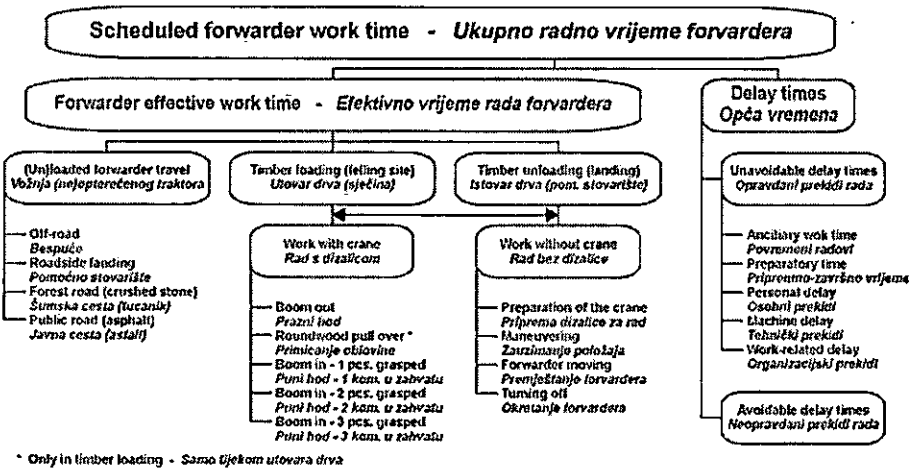

Figure 3. Working components
Slika 3. Radne sastavnice

Distances of unloaded and loaded travel were measured by the measuring tape and load related data were collected by measuring the mid diameter and length of each piece of roundwood. Soil strength (soil condition) on which the forwarder was moving during research was not measured with adequate measuring equipment. It was described instead (frozen soil, partly frozen, dry, moist, wet, muddy, waterlogged) with the aim of breaking it down subsequently into two classes of soil strength: good soil strength and limited soil strength.

Due to the variety and complexness of factors affecting the productivity of forwarder performance, the analysis will determine their impact on forwarder productivity indirectly through researched time consumptions and load characteristics (Samset 1988, Thompson

1992). This would be the way to connect the impact of one factor (or group of factors) with time consumption of specific working components and load characteristics, respectively. The basic unit of analysis would be the forwarder cycle.

The measurement data were entered into computer files from the field record sheets so as to make them available for data processing. Data processing covered the control and selection of data, classification of recorded times and calculation of the achieved work productivity.

With independent variables, different measures of the central dispersion tendency of measurement data were studied and median and arithmetical mean value were chosen as the

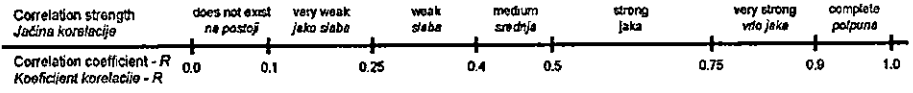

Figure 4. Roemer-Orphals scale
Slika 4. Roemer-Orphalova raspodjela

The selection of the regression curves was carried out on the bases of the following parameters: coefficient of correlation (R), standard deviation of the dependence variable around the regression line as well as t-variable and the probability of first grade error of regression coefficients (Kachigan 1991). Roemer-Orphal's scale was used for establishing the connecting force between the independent and dependent variables (Fig. 4).

RESEARCH SITES
MJESTA ISTRAŽIVANJA

Research of productivity of timber extraction by forwarder Timberjack 1210 was carried out at five different felling sites: Otok, Gradiška, Gorica 1, Čazma, Gorica 2 (Fig. 5).

Figure 5. Research sites
Slika 5. Mjesta istraživanja

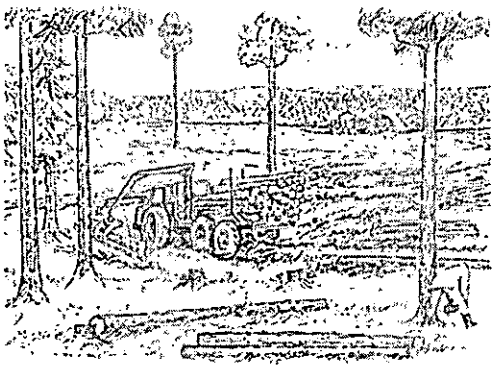

Figure 6. Applied technology (Malmberg 1990)
Slika 6. Primijenjena tehnologija (Malmberg 1990)

Different stand and harvesting conditions were found at each researched felling site and they are summarized and shown comparatively in Table 1.

Table 1. Exploatation stand features
Tablica 1. Eksploatacijske značajke sastojina

Felling sites - Sječina	Otok	Gradiška	Gorica 1	Čazma	Gorica 2
Forest office - *Šumarija*	Otok	Nova Gradiška	Velika Gorica	Čazma	Velika Gorica
Management unit - *Gospodarska jedinica*	Slavir	Gradiška brda	Šilj. dubrava II	Čaz. nizin. šume	Šilj. dubrava II
Subcompartment - *Odsjek*	57a	23c	46b	11d	139a
Age, years - *Starost, godine*	132	75	145	111	135
Rotation, years - *Ophodnja, godine*	120	80	120	120	140
Area - *Površina*, ha	56.07	19.8	15.32	12.63	20.29
Extraction distance - Udaljenost privlačenja, m	400	950	240	280	240
Growing stock - *Drvna zaliha*, m³/ha	484	268	249	384	346
Basal area - *Temeljnica*, m²/ha	26.6	23.0	16.9	25.2	23.7
Trees per ha - *Stabala po ha*	143	474	46	253	180
Management class - Uređajni razred	oak from seed*	coppice of oak**	oak from seed*	oak from seed*	oak from seed*
	lužnjak iz sjemena	panjača kitnjaka	*lužnjak iz sjemena*	*lužnjak iz sjemena*	*lužnjak iz sjemena*
Silvicurtural type - *Uzgojni oblik*	high - *visoki*	low - *niski*	high - *visoki*	high - *visoki*	high - *visoki*
Felling type - *Vrsta sijeka*	Seeding - *Naplodni*	Seeding - *Naplodni*	Final - *Dovršni*	Final - *Dovršni*	Final - *Dovršni*
Harvesting density - Sječna gustoća, m³/ha	186	186	227	236	206
Mean cutting tree - Srednje sječno stablo, m³	4.3	0.6	5.4	5.1	4.2
Soil conditions - *Stanje tla*	frosen - *smrznuto*	moist - *vlažno*	woterlogged - *blatno*	dry - *suho*	woterlogged - *blatno*

* *Quercus robur* L. , ** *Quercus petrea* (Matt.) Liebl. & *Quercus cerris* L.

Common features for all researched felling sites are as follows:

- each researched felling sites was in the period of natural regeneration by shelterwood system,
- motor-manual felling of trees and cut-to-length method for processing assortments by chain saws and processed roundwood extracted by use of forwarders (Fig. 6),
- researched felling sites make part of lowland forests without the impact of slopes,
- forest soils of the researched felling sites make part of the group of hydromorfic, alluvial coherent soils (different types of gley), whose characteristic is their changeable bearing capacity depending on the current soil moisture content,
- extraction only of technical roundwood (veneer bolts, sawlogs and small-sized technical roundwood) from felling units, while cordwood (fuelwood) was to be processed by local inhabitants. Due to such approach, the parameter affecting the forwarder productivity is the felling density of

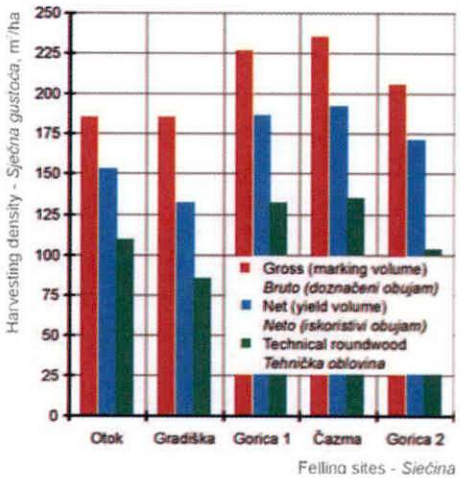

Figure 7. Harvesting density
Slika 7. Sječna gustoća

technical roundwood (Fig. 7),
- when working in the felling units (loading the tractor and unloaded and loaded travel of the tractor) the forwarder could move freely within the area of the felling site as there was no network of secondary forest roads and no bunching of processed assortments was carried out,
- in the event of several species and quality classes of timber in the forwarder loading area, sorting of roundwood in separate piles was carried out at roadside landing.

METHOD OF FORWARDER OPERATION
NAČIN RADA FORVARDERA

At the beginning of the working day, drivers would prepare the vehicle for the work. At the end of unloaded travel on the landing the forwarder would cross over the forest road drainage canal and continue its off-road travel on the felling site to the place of first loading. After loading the logs within the reach of the loader, the forwarder would go on with its travel on the felling site (maneuvering, positioning) to the place of its next loading. In this way, the driver would repeat the operations until the optimum load was loaded depending on soil strength conditions. After having completed the loading operation, the forwarder would start its loaded travel toward the roadside landing. At this landing, situated by the forest road, passing on the boundary of the sub-compartment, during unloading, the logs would be sorted by tree species and quality classes. After finishing the operations at the roadside landing, a new cycle would begin. At the end of the working day, the drivers would check the tractor to eliminate possible faults and they would clean and lubricate it.

RESULTS OF RESEARCH
REZULTATI ISTRAŽIVANJA

Research of timber extraction by forwarder Timberjack 1210 at the workplaces is shown through achieved results such as: load parameters, structure of total and effective time, structure of delay times and allowance time, forwarder travel speed and work time consumptions at the felling site and roadside landing. In the same way, possible productivities are shown depending on timber extraction distance and other factors affecting timber extraction.

REALISED PRODUCTIVITY AND STRUCTURE OF TOTAL AND EFFECTIVE TIME
OSTVARENI UČINAK TE STRUKTURA UKUPNO UTROŠENOGA I EFEKTIVNOGA VREMENA

Forwarder performance was being observed at all five workplaces for 34 working days. During that time 3,584 m^3 of timber was extracted in 370 recorded cycles. The survey of total time consumption by working components, realized average productivities and total and effective time consumptions per m^3 for all felling sites is given in Table 2. The variety of factors affecting research at felling sites caused considerable differences between realized average

productivities. The lowest realized productivity was recorded at the felling site Gradiška (6.6 m³/h), followed by Čazma (11.2 m³/h), Gorica 1 (13.1 m³/h), Gorica 2 (18.8 m³/h) and finally Otok (19.2 m³/h). Similarly to the realized average productivities, considerable differences were observed between researched felling sites with regard to total time consumptions (from 3.13 min/m³ to 9.07 min/m³) and effective time consumptions (from 2.21 min/m³ to 7.25 min/m³) per unit of extracted timber.

The difference of 290 % between the minimum and maximum realized average productivity lies in the difference between working conditions at various workplaces. The average distance of timber extraction ranged between 135 m and 610 m, the average load volume was from 7.3 m³ to 12.2 m³, the average volume of processed roundwood was from 0.23 m³ to 0.72 m³, felling density of technical roundwood was from 85 m³/ha to 135 m³/ha and soil strength conditions ranged from muddy to frozen (dry) soil.

Table 2. Structure of total time consumption and some realised average values
Tablica 2. Struktura ukupno utrošenih vremena i neke ostvarene prosječne vrijednosti

Work components – *Radne sastavnice*	Felling sites – Sječine				
	Otok	Gradiška	Gorica 1	Čazma	Gorica 2
	Time consumptions – *Utrošci vremena*, min				
Unloaded forwarder travel – Vožnja neopterećenoga traktora	344.53	684.33	479.66	498.62	286.05
Off-road – Bespuće	293.42	455.83	282.58	426.27	164.49
Roadside landing – Pomoćno stovarište	46.13	19.09	25.22	72.35	36.45
Forest road – *Šumska cesta*	4.98	166.45	–	–	68.36
Public road (asphalt) – *Javna cesta (asfalt)*	–	42.96	171.86	–	16.75
Timber loading (felling site) – Utovar drva (sječina)	1022.29	876.00	642.56	652.68	657.76
Work with crane – *Rad s dizalicom*	690.79	600.94	410.76	417.83	420.65
Work without crane – *Rad bez dizalice*	331.50	275.06	231.80	234.85	237.11
Loaded forwarder travel – Vožnja opterećenog traktora	432.59	686.96	404.57	736.36	339.81
Off-road - Bespuće	387.38	586.19	374.24	659.49	290.29
Roadside landing – Pomoćno stovarište	45.21	22.5	30.33	76.87	43.37
Forest road – *Šumska cesta*	–	65.91	–	–	6.15
Public road (asphalt) – *Javna cesta (asfalt)*	–	12.36	–	–	–
Timber unloading (roadside landing) – Istovar drva (pomoćno stovarište)	694.86	344.27	369.65	374.80	383.24
Work with crane – *Rad s dizalicom*	563.86	263.53	316.5	332.22	322.70
Work without crane – *Rad bez dizalice*	131.00	80.74	53.15	42.58	60.54
Effective time – *Efektivno vrijeme*	2494.27	2591.56	1896.44	2262.46	1666.86
Delay time – Opća vremena	1043.02	651.89	1663.78	998.03	602.87
Total time – *Ukupno utrošeno vrijeme*	3537.29	3243.45	3560.22	3260.49	2269.73
Ratio Delay time / Effective time – Odnos općega i efektivnoga vremena	0.42	0.25	0.88	0.44	0.36
Effective time per unit – *Efektivno vrijeme po jedinici*, min/m³	2.21	7.25	2.44	3.73	2.34
Total time per unit – *Ukupno vrijeme po jedinici*, min/m³	3.13	9.07	4.57	5.38	3.19
Realised productivity – *Ostvarena proizvodnost*, m³/h	19.2	6.6	13.1	11.2	18.8
Average extraction distance – Prosječna udaljenost privlačenja, m	310	505	135	610	190
Average volume of load, m³/cycle – Prosječni obujam tovara, m³/tura	12.2	9.2	7.3	9.6	10.5
Average volume of roundwood, m³/pcs – Prosječni obujam oblovine, m³/kom.	0.60	0.23	0.72	0.67	0.60
Days of observation – *Broj dana snimanja*	7	8	10	5	4
Number of cycles – *Snimljeno turnusa*	93	39	107	63	68
Total forwarded volume – *Ukupno izvezeno drvo*, m³	1130.6	357.6	778.5	606.1	711.2
Forwarded pieces of roundwood – *Izvezeno komada oblovine*	1855	1547	1079	912	1191

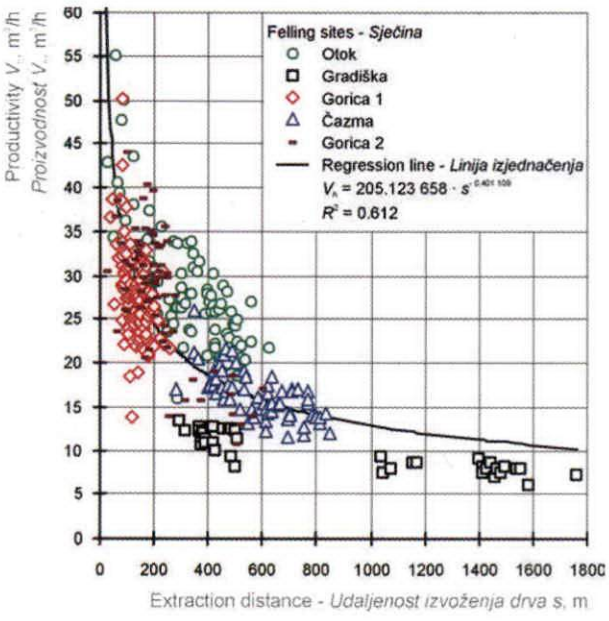

Figure 8. Productivity vs. extraction distance
Slika 8. Ovisnost proizvodnosti o udaljenosti privlačenja

Effective time accounts for 53.3 % (Gorica 1) to 79.9 % (Gradiška) of total time. The reason for such a large range of share of the effective time in total time, lies in different levels of quality of work organization at different research sites as well as in difficulties met during research in timber extraction depending on terrain conditions at different workplaces. During research, delay times accounted for 20.1 % (Gradiška) to 46.7 % (Gorica 1) of total time consumption.

By excluding recorded delay times (with different shares at each researched felling site) a clearer picture can be seen of the variability of forwarder productivity depending on factors affecting specific felling sites during research. The productivity per effective hour of work (Fig. 8) was calculated out of data related to effective time consumptions and load volumes of each recorded cycle at all researched felling sites.

STRUCTURE OF DELAY TIMES AND ALLOWANCE TIME
STRUKTURA OPĆIH VREMENA I DODATNO VRIJEME

Delay times (work breaks) consist of unavoidable and avoidable work breaks and efforts are made to minimize them to the necessary level by technological and organizational measures. By excluding the avoidable breaks from delay times, allowance time is determined as an absolute value. Allowance time is calculated based on effective time to which it is added in the form of percentage or factor of allowance (Samset 1988, Krpan and Ivanović 1994).

Shares of avoidable or unavoidable delay times within the achieved delay times are shown in Figure 9 and Table 3 shows the structure of allowance time that ranged between 18 % and 24 % of effective time at researched felling sites. Analyzing the shares of allowance time component groups related to soil

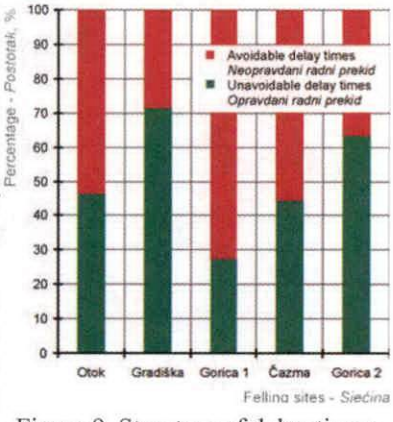

Figure 9. Structure of delay times
Slika 9. Struktura općih vremena

condition, considerable increase of share of ancillary works can be noticed in case of limited soil strength while the deviations with other components are not significant.

Table 3. Structure of allowance time
Tablica 3. Struktura dodatnoga vremena

Unavoidable delay times *Opravdani prekidi rada*	Good soil strenght conditions *Tlo dobre nosivosti*			Limited soil strenght conditions *Tlo ograničene nosivosti*		Average soil strenght conditions *Prosječno uvjeti nosivosti tla*	
	Gradiška	Otok	Čazma	Gorica 1	Gorica 2	good - *dobri*	limited - ograničeni
	% of effective time - *% od efektivnog vremena*						
Ancillary work time *Povremeni radovi*	3.30	4.57	4.00	8.47	8.05	3.96	8.47
Preparatory time *Pripremno-završno vrijeme*	3.58	3.98	4.16	4.24	4.38	4.07	4.07
Personal delay *Osobni prekidi*	9.55	9.82	9.77	10.12	9.66	9.78	9.78
Machine delay *Tehnički prekidi*	0.52	1.03	0.90	1.21	0.24	0.78	0.78
Work related delay *Organizacijski prekidi*	1.04	0.00	0.74	0.00	0.60	0.48	0.48
Allowance time *Dodatno vrijeme*	18.0	19.4	19.6	24.0	22.9	19.1	23.6

The allowance time is, therefore, modeled on the basis of soil strength conditions. The average share was taken for the component groups: preparatory times, personal delays, delays related to means of work and work organization, regardless of soil strength conditions and for ancillary works the average share was taken with respect to soil strength conditions. The modeled allowance time for good soil strength is 19.1 % of effective time and with soil of limited strength it is by 4.5 % higher.

FEATURES OF LOAD
ZNAČAJKE TOVARA

Load volume is the parameter that affects directly the forwarder productivity level. Maximum load rating for forwarder Timberjack 1210 is 12,000 kg, which is approximately 11 m^3 of roundwood made of hardwood timber in raw condition (density ~ 1.1 t/m^3). Table 4 shows the data on realized load volumes, number of roundwood pieces in the load and dimensions of extracted roundwood by researched felling site. Figure 11 shows these values depending on soil strength conditions and dimensions of roundwood.

In general the most suitable soil for extraction timber by forwarders is the frozen or dry soil condition, where forest off-road mobility of the forwarder becomes prominent (Sever and Slabak 1988). By increase of water content (moisture), especially in gley soils, they come into a limited strength condition and then forwarder mobility becomes limited or even doubtful (Horvat and Poršinsky 2000). These restrictions are shown in wheel slipping, reduction of load volume and travel speed, disturbed vehicle stability and also serious damage to soil (Krpan et al. 1993, Horvat 1995, Martinić 2000).

Figure 10. Forwarder load
Slika 10. Tovar forvardera

In general the most suitable soil for extraction timber by forwarders is the frozen or dry soil condition, where forest off-road mobility of the forwarder becomes prominent (Sever and Slabak 1988). By increase of water content (moisture), especially in gley soils, they come into a limited strength condition and then forwarder mobility becomes limited or even doubtful (Horvat and Poršinsky 2000). These restrictions are shown in wheel slipping, reduction of load volume and travel speed, disturbed vehicle stability and also serious damage to soil (Krpan *et al.* 1993, Horvat 1995, Martinić 2000).

On soils of good strength (frozen, dry to partly moist soil condition) the load volume averaged 10.7 ± 1.8 m^3/cycle, and it ranged between 7.1 m^3 and 14.1 m^3, and on soils of limited strength (moist to muddy soil condition) the average realized load volume was 8.5 ± 1.9 m^3/cycle, ranging between 3.3 m^3 and 13.9 m^3. The wide range of realized values is the result of the drivers efforts to extract the largest possible load volume per cycle at the price of travel speed and tractor's stability as well as extreme damage to the soil. As a result, drivers very often used to overload the vehicle (load volumes exceeding 11 m^3/cycle).

Table 4. Load parameters
Tablica 4 Značajke tovara

Felling sites *Sječina*	Load volume *Obujam tovara*	No. of pcs. in the load *Komada u tovaru*	Quantity of roundwood - Veličina oblovine		
			diameter - *promjer*	length - *duljina*	volume - *obujam*
	m^3/cycle - m^3/tura	pcs/cycle – kom./tura	cm	m	m^3/pcs – m^3/kom.
Otok	12.2 ± 1.1 (9.9 – 14.1)*	20 ± 3.5 (12 - 29)*	43 ± 9 (25 - 89)*	4.0 ± 1.0 (2.0 - 7.9)*	0.60 ± 0.31 (0.15 - 2.55)*
Gradiška	9.2 ± 0.8 (7.6 - 11.3)*	40 ± 4.3 (30 - 48)*	23 ± 5 (12 - 45)*	5.5 ± 1.0 (2.0 - 9.0)*	0.23 ± 0.09 (0.06 - 0.55)*
Gorica 1	7.3 ± 1.1 (3.3 - 9.9)*	10 ± 2.2 (5 - 18)*	51 ± 10 (25 - 80)*	3.4 ± 0.8 (2.0 - 6.5)*	0.72 ± 0.31 (0.17 - 1.86)*
Čazma	9.6 ± 1.3 (7.1 - 12.4)*	14 ± 2.2 (8 - 19)*	44 ± 10 (25 - 76)*	4.2 ± 1.2 (2.0 - 8.4)*	0.67 ± 0.34 (0.12 - 2.11)*
Gorica 2	10.5 ± 1.2 (8.0 - 13.9)*	18 ± 2.9 (12 - 23)*	45 ± 9 (26 - 79)*	3.6 ± 0.8 (2.0 - 6.1)*	0.60 ± 0.29 (0.13 - 2.04)*

* Minimums and maximums - *Najmanja i najveća izmjera*

On soils of good strength (frozen, dry to partly moist soil condition) the load volume averaged 10.7 ± 1.8 m^3/cycle, and it ranged between 7.1 m^3 and 14.1 m^3, and on soils of limited strength (moist to muddy soil condition) the average realized load volume was 8.5 ± 1.9 m^3/

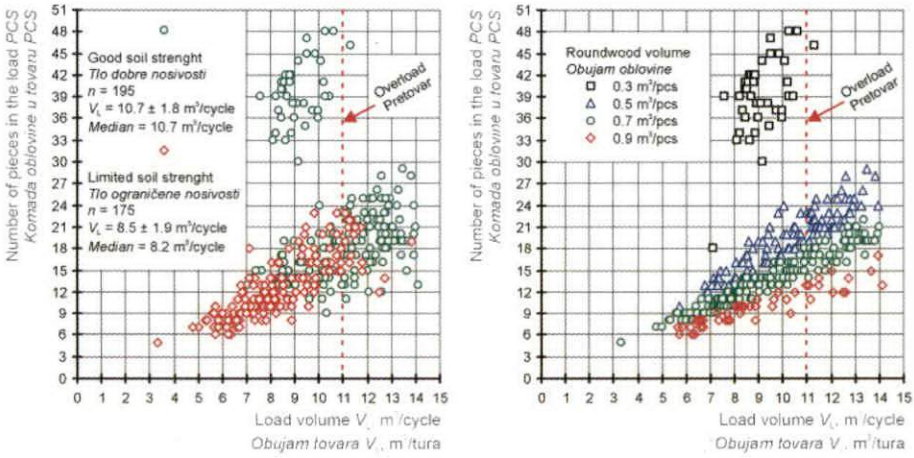

Figure 11. Load volume vs. soil conditions and roundwood volume

Slika 11. Ovisnost obujma tovara o nosivosti tla i obujmu oblovine

cycle, ranging between 3.3 m^3 and 13.9 m^3. The wide range of realized values is the result of the drivers efforts to extract the largest possible load volume per cycle at the price of travel speed and tractor's stability as well as extreme damage to the soil. As a result, drivers very often used to overload the vehicle (load volumes exceeding 11 m^3/cycle).

Apart from the impact of terrain factors (Mellgren 1980, Berg 1992), which mostly reduce the forwarder load volume, it also depends on the number of roundwood pieces of specific dimensions. Mid diameters of assortments range between 12 cm and 89 cm, length 2 m to 9 m and volume 0.06 m^3 to 2.55 m^3. Such a wide range of dimensions of individual pieces of processed roundwood at researched felling sites is the result of cut-to-length metod in timber processing as well as of different dimensions of marked and felled trees at felling sites involved by regeneration felling.

Due to different dimensions (mid diameter and length) between assortments transported within the forwarder load, the average piece volume is used further on as the parameter representing the mean assortment in the vehicle load area (Conway 1984).

The data of load features (number and average piece volume), within the limit values of 95 % probability of arithmetic mean interval estimate of load volume depending on soil

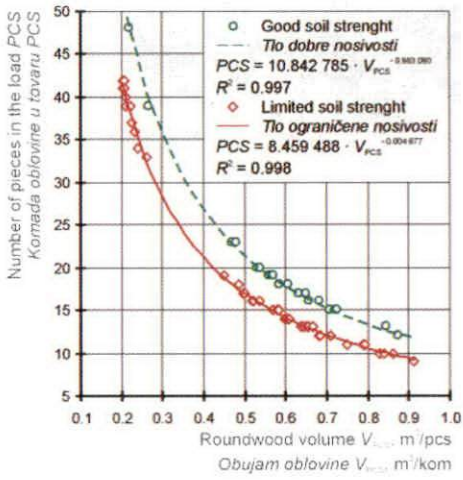

Figure 12. Load volume vs. no. and volume of roundwood

Slika 12. Ovisnost obujma tovara o broju komada i obujmu oblovine

strength conditions, are regressed by exponential equation with complete correlation of variables (Fig. 12). In this way the dependence of the number of pieces and volume of roundwood in the load was calculated depending on soil strength conditions, which will be necessary for modeling algorithms of crane time consumptions in (un)loading timber.

FORWARDER TRAVEL TIMES
VREMENA KRETANJA FORVARDERA

Travel time consumptions of unloaded and loaded forwarder depending on travel distance will be investigated by regression analysis in view of whether the vehicle travels on forest off-road terrain or on constructed roads (forest road with crushed stone cover, public road with asphalt cover). Travel times of loaded vehicles will be investigated versus load volume.

TIME CONSUMPTIONS AND TRAVEL SPEEDS OF FORWARDER ON OFF-ROAD
UTROŠCI VREMENA I BRZINE KRETANJA FORVARDERA PO ŠUMSKOM BESPUĆU

At researched felling sites, soil strenght condition (Fig. 13 and 14) is the only terrain factor affecting forwarder mobility on forest off-road terrain. Loaded tractor travel is also affected by the volume of the load extracted by forwarder.

Figure 13. Limited soil strenght
Slika 13. Tlo ograničene nosivosti

Figure 14. Good soil strenght
Slika 14. Tlo dobre nosivosti

The impact of soil strength condition on travel time consumption of unloaded forwarder is shown in Figure 15 and Figure 16 shows the travel of loaded forwarder.

The data on travel time consumption of (un)loaded forwarder depending on travel distance are regressed with straight line from origin for both soil strength conditions.

For unloaded forwarder travel on limited soil strength a very strong correlation was obtained ($R = 0.825$), while for unloaded forwarder travel on good soil strength a complete correlation was obtained ($R = 0.973$). The average travel speed of unloaded forwarder on good soil strength is 4.6 km/h and on limited soil strength it is by 24 % lower (3.5 km/h).

By regressing the data on travel time consumption of loaded forwarder (Fig. 16) a complete correlation was obtained for both classes of soil strenght condition. The average travel speed of

loaded forwarder on good soil strength is 3.2 km/h and on limited soil strength by 25 % lower (2.4 km/h).

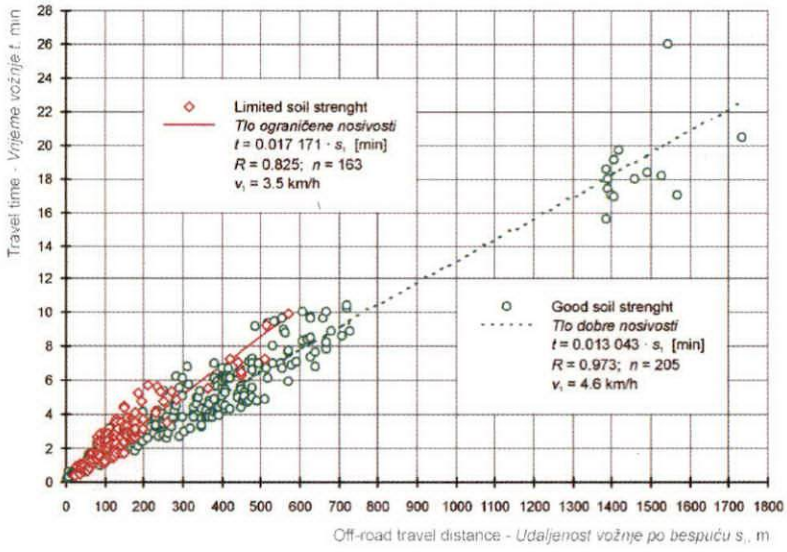

Figure 15. Unloaded forwarder (soil strenght conditions)
Slika 15. Neopterećeni forvarder (uvjeti nosivosti tla)

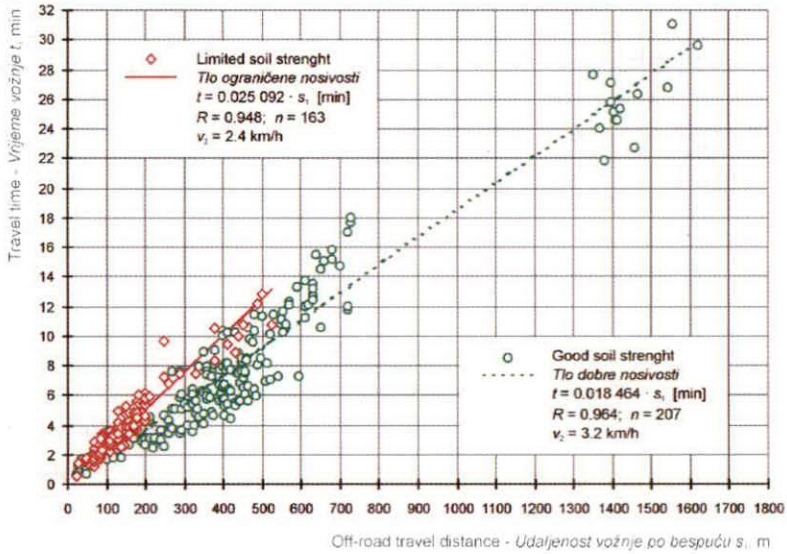

Figure 16. Loaded forwarder (soil strenght conditions)
Slika 16. Opterećeni forvarder (uvjeti nosivosti tla)

The impact of load volume on travel time consumption of loaded forwarder is shown in Figure 17, by classes of load volume (6 m³/cycle, 8 m³/cycle, 10 m³/cycle and 12 m³/cycle). Due to mixing of data on travel time consumption of different classes of load volume within a huge number of data, it can be concluded that the load volume has no impact on travel time consumption of the loaded forwarder Timberjack 1210, probably because of its technical characteristics.

On good strength soils the average travel speed of a loaded forwarder is by 30 % lower than the average speed of unloaded tractor and on limited strength soil it is lower by 31 %.

It can be concluded, that time consumption and average travel speeds of (un)loaded forwarder Timberjack 1210 on forest off-road terrain are only affected by soil conditions, while the impact of load volume on loaded tractor travel is reduced by technical characteristics of forwarder itself.

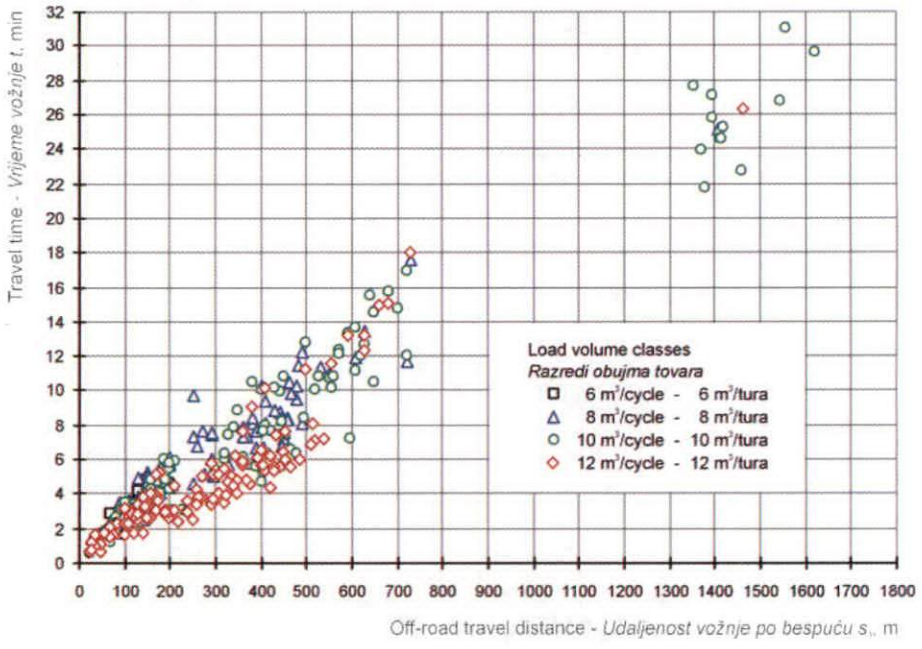

Figure 17. Loaded forwarder (load volume classess)
Slika 17. Opterećeni forvarder (razredi obujma tovara)

TIME CONSUMPTIONS AND TRAVEL SPEEDS OF FORWARDER ON THE CONSTRUCTED ROADS

UTROŠCI VREMENA I BRZINE KRETANJA FORVARDERA PO IZGRAĐENIM PUTOVIMA

With regard to the type of the upper layer of constructed roads, forwarder travel is separated into travel on forest road with crushed stone cover and travel on public road with asphalt cover.

Forwarder travel on forest road with crushed stone cover is additionally separated into vehicle travel in the area of roadside landing and outside of it (Fig. 18).

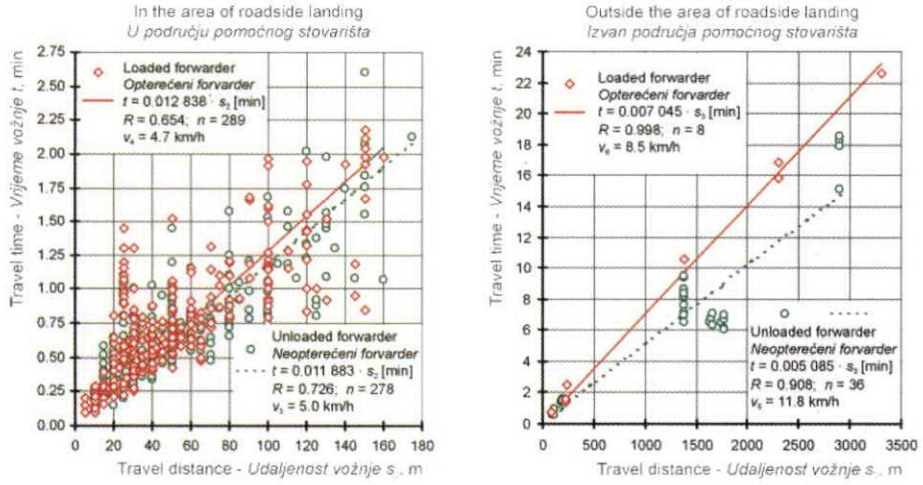

Figure 18. Forest road (crushed stone)
Slika 18. Šumska cesta (tucanički zastor)

The reason for this separation lies in a series of roadside landing characteristics (the road gets narrower due to piles of timber on both sides of forest road and to the presence of other means of work of primary and secondary timber transport with occasional occurence of a series of other forestry activities related to roadside landings), which affect forwarder traficability in their area, as well as in the necessity of this working component in each tractor cycle, while all other forwarder moving on constructed forest roads occurred exclusively within the vehicle arrival on and departure from the workplace. The above characteristics of roadside landings caused high dispersions and mixing of measured travel time consumptions of (un)loaded forwarder depending on travel distance. The average travel speed of unloaded forwarder in the area of roadside landing is 5 km/h and with loaded forwarder it is by 6 % lower (4.7 km/h).

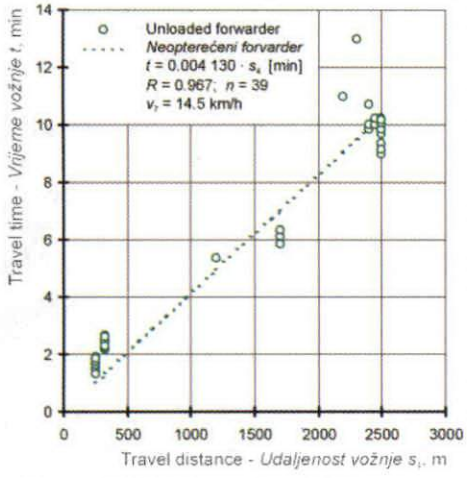

Figure 19. Public road (asphalt)
Slika 19. Javna cesta (asfalt)

Higher travel speeds were achieved when the forwarder travelled on forest road outside the area of roadside landing and they were as follows: 11.8 km/h for unloaded vehicle and 8.5 km/h for the loaded one.

During research, forwarder travel on public road with asphalt cover was only realized for unloaded vehicle at the distance of up to 2500 m with the average speed of 14.5 km/h (Fig. 19).

TIME CONSUMPTIONS OF TIMBER (UN)LOADING
UTROŠCI VREMENA UTOVARA I ISTOVARA DRVA

At researched felling sites, time consumptions of forwarder work at the felling site and roadside landing ranged widely between 9.46 min/cycle and 31.29 min/cycle or from 1.30 min/m^3 to 3.40 min/m^3 per unit of extracted timber. In loading and unloading timber, the drivers most frequently used to grasp one (rarely two) pieces of roundwood by the hydraulic crane, except at Gradiška felling site, where the driver used to grasp two and even three pieces by the crane graple at one boom in during at unloading.

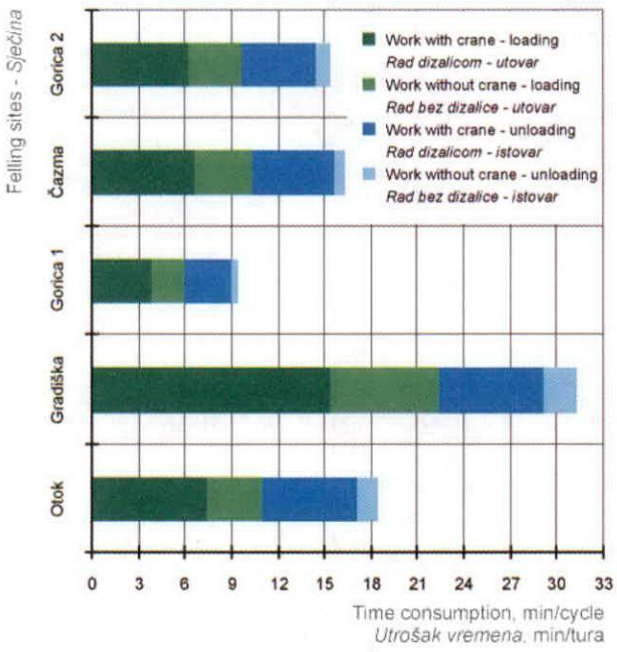

Figure 20. Time consumptions of timber (un)loading
Slika 20. Utrošci vremena utovara i istovara drva

In order to provide cross reference with some other influencing factors, time consumptions of forwarder work at the felling site and roadside landing were separated into four groups of working components (Table 5).

The base for this separation is the workplace (felling site and roadside landing) and the type of work carried out by the vehicle (work with the crane or without the crane – vehicle moving).

Table 5. Analysis of time consumptions of loading and unloading
Tablica 5. Analiza utrošaka vremena utovara i istovara drva

Work components *Radne sastavnice*	Felling sites - Sječina				
	Otok	Gradiška	Gorica 1	Čazma	Gorica 2
	Time consumption - *Utrošak vremena*, min				
Timber loading (feling site) Utovar drva (sječina)	10.99 ± 2.05 (6.61 - 16.64)*	22.46 ± 3.40 (16.16 - 31.34)*	6.01 ± 1.40 (3.53 - 10.16)*	10.36 ± 2.52 (5.88 - 20.74)*	9.67 ± 1.78 (6.50 - 16.37)*
Work with crane *Rad s dizalicom*	7.43 ± 1.40 (4.81 - 11.68)*	15.41 ± 2.23 (10.78 - 21.19)*	3.84 ± 0.77 (2.03 - 5.46)*	6.63 ± 1.25 (3.92 - 9.86)*	6.19 ± 0.83 (4.70 - 8.01)*
Work without crane *Rad bez dizalice*	3.56 ± 1.15 (1.07 - 7.17)*	7.05 ± 2.10 (3.6 - 12.07)*	2.17 ± 1.07 (0.44 - 6.54)*	3.73 ± 1.86 (0.82 - 12.58)*	3.49 ± 1.35 (1.55 - 10.16)*

Work components *Radne sastavnice*	Felling sites - Sječina				
	Otok	Gradiška	Gorica 1	Čazma	Gorica 2
Time consumption - *Utrošak vremena*, min					
Timber unloading (landing) *Istovar drva (stovarište)*	(4.71 - 10.60)*	(5.88 - 14.50)*	(1.89 - 5.65)*	(3.46 - 8.35)*	(3.72 - 7.77)*
Work with crane *Rad s dizalicom*	6.06 ± 1.13 (3.25 - 8.62)*	6.76 ± 1.58 (3.34 - 10.87)*	2.96 ± 0.60 (1.50 - 4.57)*	5.27 ± 0.89 (3.21 - 7.75)*	4.75 ± 0.69 (3.00 - 6.18)*
Work without crane *Rad bez dizalice*	1.41 ± 0.64 (0.18 - 3.17)*	2.07 ± 1.11 (0.60 - 7.39)*	0.50 ± 0.35 (0.11 - 2.48)*	0.68 ± 0.27 (0.21 - 1.42)*	0.89 ± 0.46 (0.14 - 2.61)*

* Minimums and maximums - *Najmanja i najveća izmjera*

It should be noted that at all researched felling sites forwarder drivers had problems with loader due to its insufficient lifting moment in loading and unloading larger assortments (2 m^3/pcs to 2.5 m^3/pcs). Processed assortments of higher volumes that could not be loaded by forwarder, were later on extracted to roadside landing by cable skidders.

TIMBER LOADING
UTOVAR DRVA

Boom out, boom in and pull over of assortments by hydraulic crane make the working components of crane work time (Fig. 21). Cycle time consumption of this group of working components is affected by: number of roundwood pieces in the forwarder loading area, roundwood dimensions and hence the load volume (Tufts 1997).

Due to different dimensions of processed roundwood within the felling units, and hence also within the forwarder load, the average piece volume is taken as the parameter presenting the mean assortment in the vehicle loading area. Considering the above mentioned dependence in Fig. 22, it can be concluded time consumption of crane work is exclusively affected by the number of roundwood pieces in the load.

Forwarder moving during loading, maneuvering, preparation of the crane for work and transport and forwarder turning off make the working components of time consumption of timber loading without crane. Time consumption of this group of working components is affected by density and size of processed technical roundwood per unit of cut block (Bulley 1999). This means that time consumption of this group of working components depends on distance and number of moving (i.e. the place of loading from which the forwarder driver loads the assortments within the reach of hydraulic crane) required to carry out optimum loading in respect of terrain factors.

Figure 21. Loading
Slika 21. Utovar

Due to high variability of time consumption of work without crane in loading within specific researched felling sites, arithmetic means were taken for the regression analysis (Fig. 23). The dependence was regressed by exponential equation with strong correlation ($R^2 = 0.65$).

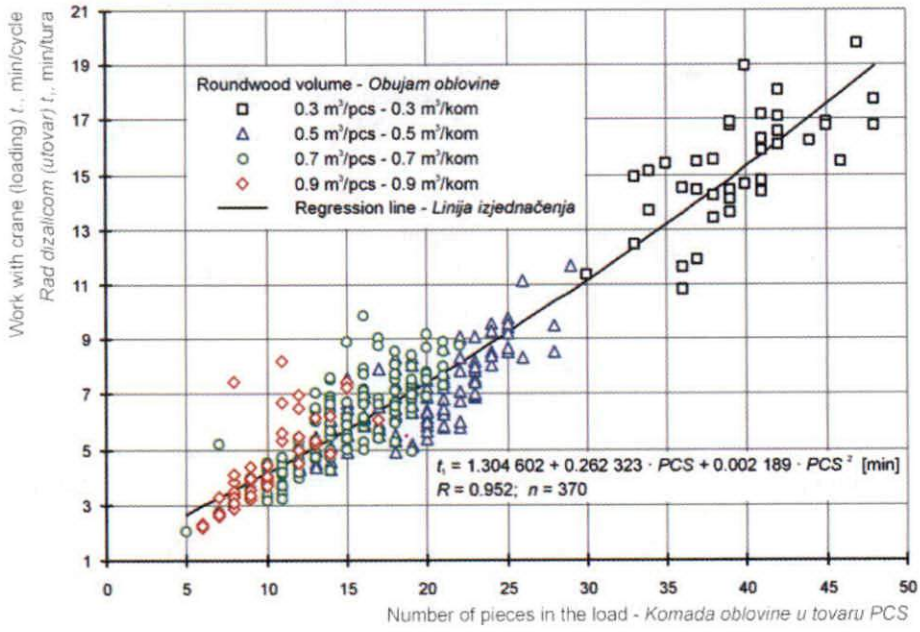

Figure 22. Work with crane vs. no. and roundwood volume
Slika 22. Ovisnost rada dizalicom o broju komada i obujmu oblovine

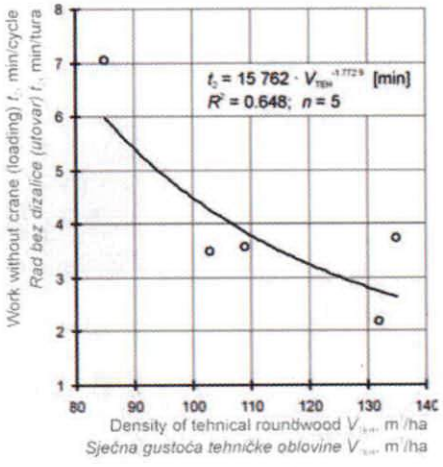

Figure 23. Work without crane
Slika 23. Rad bez dizalice

TIMBER UNLOADING
ISTOVAR DRVA

Time consumptions of work with crane in unloading is affected by the same factors as with loading. Figure 24 shows the impact of the roundwood volume on time consumptions of work with crane depending on number of pieces of loaded timber for classes of average piece volume (≤ 0.3 m^3, 0.5 m^3, 0.7 m^3 and ≥ 0.9 m^3). Two areas of data grouping can be seen from dependence:

- the group of average piece volume ≥ 0.5 m^3/pcs, where mostly one piece of roundwood was grasped in unloading with boom in hydraulic crane. Tipically for this group with the increase of number of pieces (ranging between 5 and 29 pieces) of roundwood in the loading area of the forwarder, time consumption of unloading with crane increased, too;
- the group of average piece volume ≤ 0.3 m^3/pcs, where mostly several (2 to 3) thinner pieces of roundwood (ranging betwen 30 and 48 pieces in the load) were grasped in unloading with boom in hydraulic crane, there is no express dependence of time consumptions on work with crane in unloading, as the result of unloading several pieces of roundwood in one grasp of boom in hydraulic crane. The arithmetic mean was, therefore, taken as the average time consumption for this group of data on time consumption of unloading with crane.

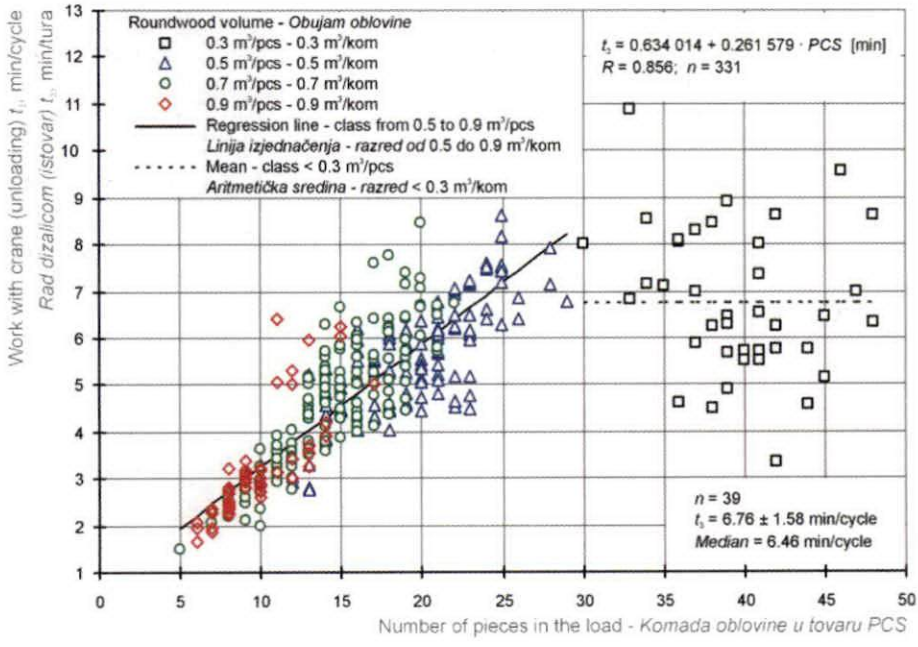

Figure 24. Work with crane vs. no. and roundwood volume
Slika 24. Ovisnost rada dizalicom o broju komada i obujmu oblovine

Figure 25. Unloading
Slika 25. Istovar

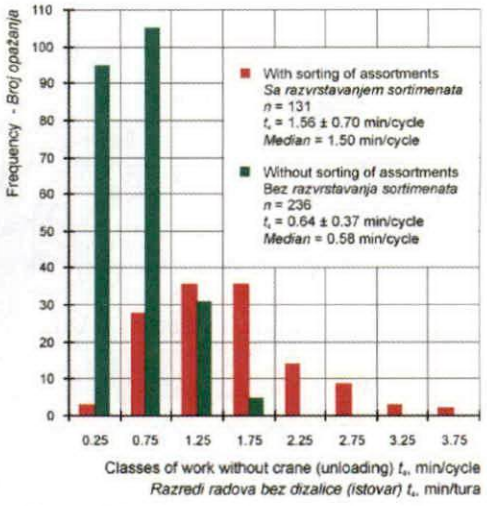

Figure 26. Work without crane (unloading)
Slika 26. Rad bez dizalice (istovar)

Time consumption of work without crane at timber unloading is affected by the need to sort timber at unloading into piles within the roadside landing, in case of different species of wood and quality classes in forwarder load, which brings to the increase of number and distance of forwarder maneuvering in unloading and hence also to the increase of time consumption of this group of working components (Gingras 1996, Gingras and Godin 1997). Krpan (1991) outlines that the arranged landings, where sorting of timber is carried out by forwarders, have impact on reducing the time of timber loading by trucks, which is especially important in case of simultaneous occurring of primary and secondary transport of timber.

Figure 26 shows the distribution of observation frequency of time consumption classes of work without crane in unloading, depending on whether sorting of assortments occurs or not. At researched felling sites, where there is no sorting of assortments at the roadside landing, time consumption of work without crane at unloading averages 0.64 ± 0.37 min/cycle, and when there is sorting of assortments, time consumption of this group of working components is 1.56 ± 0.70 min/cycle.

FORWARDER PRODUCTIVITY MODEL
OBLIKOVANJE PROIZVODNOSTI FORVARDERA

By bringing together the partial analysis of factors affecting the load volume and time consumptions of specific forwarder working components the model was developed for calculating forwarder productivity.

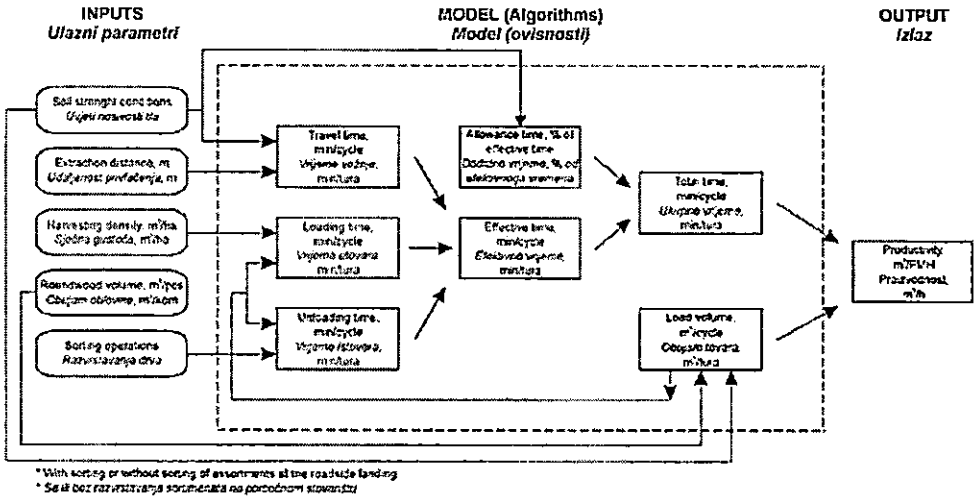

Figure 27. Forwarder productivity model

Slika 27. Model proizvodnosti forvardera

The model shown in Figure 27 calculates the forwarder productivity in accordance with the following formula:

$$V_h = \frac{60}{k_{ALL} \cdot \left\{ \left[s_1 \cdot \left(\frac{60}{v_1} + \frac{60}{v_2} \right) \right] + \left[s_2 \cdot \left(\frac{60}{v_3} + \frac{60}{v_4} \right) \right] + t_1 + t_2 + t_3 + t_4 \right\}} \cdot V_L \quad \left[\frac{m^3}{h} \right]$$

Symbol key -*Tumač simbola*

Symbol *Simbol*	Measuring item *Mjerna veličina*	Measuring unit *Mjerna jedinica*
V_h	Forwarder productivity *Proizvodnost forvardera*	m³/PMH m³/h
V_L	Load volume *Obujam tovara*	m³/cycle m³/tura
k_{ALL}	Factor of allowance time *Faktor dodatnoga vremena*	- -
s_1	Off-road forwarding distance *Udaljenost privlačenja drva po bespuću*	km km
v_1	Off-road travel speed of unloaded forwarder *Brzina kretanja neopterećenoga forvardera po bespuću*	km/h km/h
v_2	Off-road travel speed of loaded forwarder *Brzina kretanja opterećenoga forvardera po bespuću*	km/h km/h
Symbol *Simbol*	Measuring item *Mjerna veličina*	Measuring unit *Mjerna jedinica*

Symbol *Simbol*	Measuring item *Mjerna veličina*	Measuring unit *Mjerna jedinica*
s_2	Roadside landing forwarding distance *Udaljenost privlačenja drva po pomoćnom stovarištu*	km km
v_3	Travel speed of unloaded forwarder on roadside landing *Brzina kretanja neopterećenoga forvardera po stovarištu*	km/h *km/h*
v_4	Travel speed of loaded forwarder on roadside landing *Brzina kretanja opterećenoga forvardera po stovarištu*	km/h km/h
t_1	Time consumption of work with crane (felling site) *Utrošak vremena rada dizalicom (sječina)*	min/cycle min/tura
t_2	Time consumption of work without crane (felling site) *Utrošak vremena rada bez dizalice (sječina)*	min/cycle min/tura
t_3	Time consumption of work with crane (roadside landing) *Utrošak vremena rada dizalicom (stovarište)*	min/cycle min/tura
t_4	Time consumption of work without crane (roadside landing) *Utrošak vremena rada bez dizalice (stovarište)*	min/cycle min/tura

Due to partial determining of time consumption of individual groups of working components depending on the impact of the established influencing factor, the test was carried out of differences between realized productivity and modeled productivity. The results of testing confirmed that there were no significant differences between the results of realized productivity and modeled productivity.

CONCLUSIONS – DEPENDENCE OF FORWARDER PRODUCTIVITY VS. THE INFLUENCING FACTORS
ZAKLJUČCI – OVISNOST PROIZVODNOSTI FORVARDERA O UTJECAJNIM ČIMBENICIMA

The impact of the factors on the productivity of timber extraction by forwarder Timberjack 1210 was calculated on the basis of modeling the productivity in respect of specific influencing factors. The factors involved are as follows: soil strength conditions, distance of timber extraction, dimensions of processed timber, felling density of technical roundwood and sorting of assortments at roadside landing.

Due to frequently complex impact of many influencing factors on forwarder productivity, which cause a large number of possible work variants, only some of them are shown in this paper, while the others can be calculated by given time consumption models.

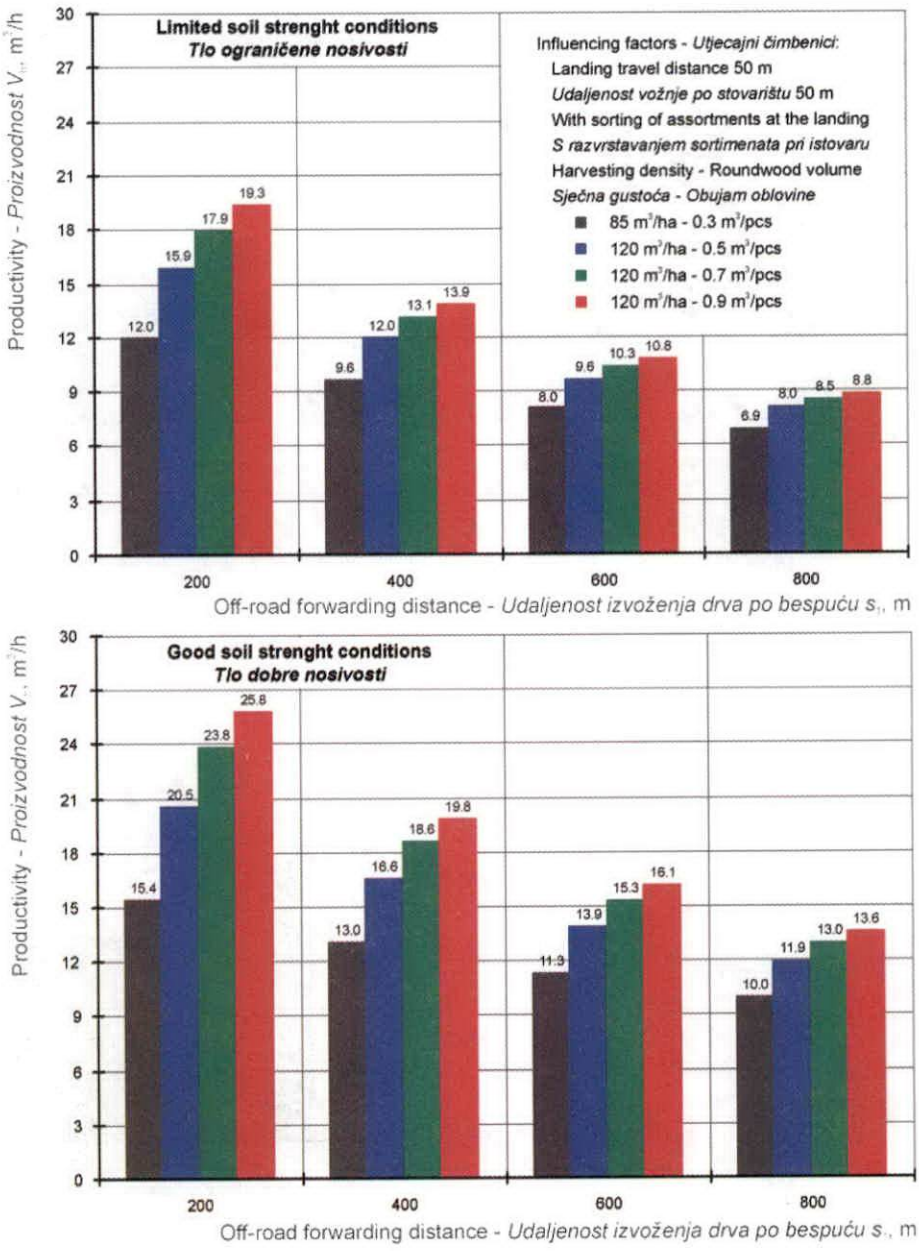

Figure 28. Productivity vs. soil conditions
Slika 28. Ovisnost proizvodnosti forvardera o uvjetima nosivosti tla

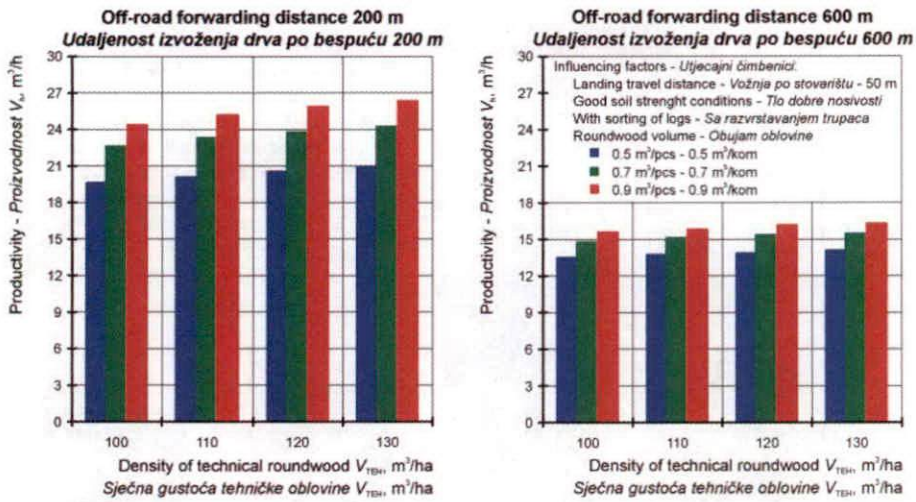

Figure 29. Productivity vs. density of tehnical roundwood

Slika 29. Ovisnost proizvodnosti forvardera o sječnoj gustoći tehničke oblovine

Figure 28 shows the impact of soil strength conditions and volume of roundwood on forwarder productivity within the extraction distance ranging between 200 m and 800 m. From the obtained results, it can generally be concluded that:

- —reduction of productivity of forwarder timber extraction is seriously affected by limiting soil strength conditions and average roundwood volume in the load as well as by the increase of extraction distance,
- —by increase of the roundwood volume in the load at a constant distance of timber extraction and under the same soil strength conditions, the forwarder productivity increases. However, with the increase of the distance of timber extraction, the differences between the productivity with classes of average piece volume in the load are reduced due to higher share of the vehicle travel time in total time of the modeled cycle,
- —at shorter distances of timber extraction, forwarder productivity is highly affected by the roundwood volume in the load and with the increase of the forwarding distance its significance is lowered.

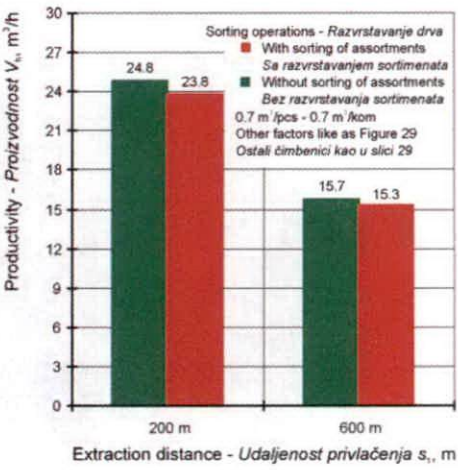

Figure 30. Productivity vs. landing operations

Slika 30. Utjecaj razvrstavanja sortimenata na proizvodnost forvardera

The increase of felling density of processed technical roundwood in the presented range, at a constant forwarding distance, affects only slightly the forwarder productivity. Its impact should be considered together with the roundwood dimensions of the processed assortment when it becomes significant (Fig. 29).

Sorting of assortments on roadside landing, affected slightly the decrease of forwarder productivity compared to the productivity achieved when the vehicle made no sorting of roundwood in unloading (Fig. 30). The increase of forwarding distance reduces the adverse effect caused by sorting of assortments on productivity of timber forwarding, due to higher share of travel in total cycle time.

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ČIMBENICI PROIZVODNOSTI FORVARDERA TIMBERJACK 1210 PRI IZVOŽENJU OBLOGA DRVA GLAVNOGA PRIHODA HRVATSKIH NIZINSKIH ŠUMA

SAŽETAK

Rad prikazuje utjecaj nekih čimbenika (udaljenost privlačenja drva, sječna gustoća, dimenzije izrađene oblovine, uvjeti stanja šumskoga tla te razvrstavanje sortimenata tijekom istovara) na proizvodnost izvoženja obloga drva glavnoga prihoda nizinskih šuma Hrvatske 12-tonskim forvarderom Timberjack 1210.

Istraživanja su provedena na pet sječina, u trajanju od 34 radna dana, za koje je vrijeme u 370 traktorskih turnusa privučeno 3 584 m^3 tvrdih listača (hrast i jasen). Zajedničko je obilježje rada forvardera na svim istraživanim sječinama izvoženje isključivo tehničke oblovine izrađene sortimentnom metodom motornim pilama te slobodno kretanje forvardera po površini sječnih jedinica pri skupljanju i utovaru drva. Razvrstavanje se sortimenata na pomoćnom stovarištu pri istovaru pojavljivalo u slučaju više vrsta ili klasa kakvoće obloga drva u tovaru forvardera. Sječine su se međusobno razlikovale prema: srednjim udaljenostima privlačenja drva (od 240 m do 610 m), stanju tla šumskoga bespuća tijekom istraživanja (od blatnoga do suhoga ili smrznutoga tla), sječnoj gustoći izrađene tehničke oblovine (od 85 m^3/ha do 132 m^3/ha) te prosječnim dimenzijama izrađenih sortimenata: srednjem promjeru oblovine (od 23 cm do 51 cm), duljini oblovine (od 3,6 m do 5,5 m) te njezinu obujmu (od 0,23 m^3/kom. do 0,72 m^3/kom.).

Proizvodnost traktora utvrđena je metodom tijeka rada i vremena, a utrošci su vremena pojedinih radnih sastavnica mjereni povratnom metodom kronometrije.

Na proizvodnost je forvardera u istraživanim sječinama utjecalo složeno djelovanje uvjeta stanja (nosivosti) tla, dimenzija sortimentnom metodom izrađene oblovine, sječne gustoće te razvrstavanja sortimenata na pomoćnom stovarištu pri istovaru. Zbog raznovrsnosti i raznorodnosti čimbenika koji su obuhvaćeni na objektima istraživanja, njihov je utjecaj na učinkovitost rada forvardera utvrđen posredno preko utrošaka snimljenih vremena te ostvarenih značajki tovara. Istraživanjem je utvrđeno:

- —Obujam je tovara pod izrazitim utjecajem ključnoga terenskoga čimbenika nizinskih šuma – nosivosti tla. Također na obujam tovara djeluje i broj komada oblovine određenih dimenzija.
- —Brzine kretanja neopterećenoga i opterećenoga forvardera ovise o vrsti podloge po kojoj se vozilo kreće (bespuće sa stanjima nosivosti šumskoga tla, šumska cesta s tucaničkim zastorom u području pomoćnoga stovarišta).
- —Vremena rada dizalicom pri utovaru i istovaru ovise o broju komada oblovine određenih dimenzija u tovaru forvardera.
- —Vremena radova bez dizalice pri utovaru pod utjecajem su sječne gustoće tehničke oblovine namijenjene primarnom transportu drva.
- —Vremena radova bez dizalice pri istovaru ovise o potrebi za razvrstavanjem drva na

pomoćnom stovarištu u slučaju pojave više vrsta i klasa kakvoće obloga drva u tovaru forvardera.

—Dodatno je vrijeme ovisno o uvjetima nosivosti tla šumskoga bespuća.

Utjecaj čimbenika na učinkovitost izvoženja drva forvarderom Timberjack 1210 izračunat je na osnovi oblikovanja učinaka s obzirom na pojedini utjecajni čimbenik. Obuhvaćeni čimbenici su: uvjeti nosivosti tla, udaljenost izvoženja drva, dimenzije i veličina izrađene oblovine, sječna gustoća tehničke oblovine i razvrstavanje sortimenata na pomoćnom stovarištu.

Zbog čestoga složenoga djelovanja više utjecajnih čimbenika na učinak forvardera, koji uzrokuju velik broj mogućih inačica, prikazane su u radu samo neke, dok je ostale moguće izračunati pomoću danih modela utrošaka vremena.

Za dobivene rezultate može se općenito zaključiti da:

—Na smanjenje učinkovitosti izvoženja drva forvarderom izrazito utječu ograničavajući uvjeti nosivosti tla i prosječnoga obujma komada u tovaru te povećanje udaljenosti privlačenja.

—Povećanjem prosječnoga obujma komada u tovaru pri stalnoj udaljenosti izvoženja drva i uvjetima nosivosti tla učinkovitost forvardera raste, međutim, s povećanjem udaljenosti izvoženja drva razlike između učinkovitosti kod razreda prosječnoga obujma komada u tovaru smanjuju se zbog povećanja udjela vremena kretanja vozila u ukupnom vremenu oblikovanoga turnusa.

—Na kraćim udaljenostima privlačenja drva na učinkovitost forvardera izrazito utječe prosječan obujam komada u tovaru, dok povećanjem udaljenosti privlačenja njegovo značenje opada.

—Povećanje sječne gustoće izrađene oblovine pri stalnoj udaljenosti privlačenja neznatno utječe na učinkovitost forvardera, međutim njezin utjecaj treba promatrati zajedno s prosječnim obujmom izrađene oblovine kad ona dobiva na značenju.

—Razvrstavanje sortimenata na pomoćnom stovarištu neznatno je utjecalo na smanjenjenje učinkovitosti forvardera u odnosu na učinkovitost kad vozilo ne razvrstava oblovinu prilikom istovara. Povećanjem udaljenosti privlačenja smanjuje se negativno djelovanje razvrstavanja sortimenata na proizvodnost privlačenja drva zbog porasta udjela kretanja vozila u ukupnom vremenu turnusa.

Ključne riječi: proizvodnost forvardera, utjecajni čimbenici, oplodne sječe, nizinske šume u Hrvatskoj

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Original scientific paper
Izvorni znanstveni članak

THE OPTIMIZATION IN FOREST INVENTORY ON REGIONAL LEVEL IN BOSNIA AND HERZEGOVINA

OPTIMIZACIJA U INVENTURI ŠUMA NA REGIONALNOJ RAZINI U BOSNI I HERCEGOVINI

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The present study is made to determine optimal sampling plan for growing stock estimation in forest inventory on regional level. The method is based on anticipated variance with lack of fit (Mandallaz 2001). For research object is chosen one forest economic management unit in Bosnia and Herzegovina. On database of most recent forest inventory is applied tree selection plan optimization and sample size optimization. Alternate optimal sample plans are developed and compared.

Key words: forest inventory, optimization, optimal sampling plan, growing stock, regional level

INTRODUCTION
UVOD

Forest inventory presents a basis of information on natural resources of forested areas. Recently there are certain efforts to optimize all activities that are done within the forest inventory (Stahl 1998). Also, there are two especially important, and comparatively researched approaches in sampling theory for forest inventory in large areas: standard (classical) approach and model based approach. In the standard approach the key is probabilistic nature of sampling plan (Gregoire 1998). Besides, extensive researches quoted the possibility to make conclusions on population parameters based on the population model (Arvanitis & O'Regan 1967, Särndal 1978, Mackisack & Wood 1990, Penttinen *et al.* 1992, Kangas 1994, Schröder & Williams 1995, Eriksson 1995, Rao 1997, Gregoire 1998, Mandallaz 1991, 1995, 1997, Mandallaz & Ye 1999).

In the last decade new technologies and development of scientific approaches in sampling theory have certainly lead to the improvement of previously used sampling plans for forest inventories. Special attention is paid to the sampling plans for taxation recording that would provide the required information with necessary precision. In order to make a decision on the sampling plan for the next forest inventory, it is necessary to analyze the existing plan and prepare alternate plans. At the forest inventory in large areas, the selection of alternate plans should be based on a number of factors. The factors of primary importance are a precision of the estimated most important taxation elements and cost efficiency. In other words, interesting items are the alternatives that provide desired precision of estimate with minimal costs, or vice versa, minimal costs for desired precision of estimate. These solutions can be reached by making optimal sampling plans, i.e. determination of optimal size of alternate samples. Besides of sample size optimization, models of general optimization of sampling plans have been developed in the last few years (Lanz 2001, Mandallaz 2001). Kuliesis & Kasperavicius (1998) made the optimization of the sampling plan parameters for national forest inventory in Lithuania. Reich & Arvanitis (1992) analyzed the relations between the size of sample plot and sample variance, depending on the regional distribution of trees, volume and basal area of trees. Jonsson, et al. (1992) and Hočevar (1989) investigated alternate plans for forest inventory. Köhl & Scott (1993) presented a method for comparison of alternate sampling plans for extensive inventories. Stamellos & Blioumis (1997) have proposed the optimization of growing stock estimate with plot-double sampling plan.

Sampling plan for forest inventory on regional level in Bosnia and Herzegovina is based on research done by Matić (1964, 1971, 1977). Also Stojanović & Drinić (1974) investigated elements for efficient sampling. Koprivica (1984) suggested regression models for sample plan parameters.

Now, using database of previous forest inventory it is possible to improve existed sampling plan according to new developed method of general optimization.

FORMULATION OF THE RESEARCH AIM
FORMULACIJA ISTRAŽIVAČKOGA CILJA

To discuss possibilities for planning an sample for terrestrial measurements in the next forest inventory on the regional level (forest economic management unit), in this paper were established next aims of research:

I. To develop alternate optimal sample plans:
   1. To optimize tree selection plan according to PPS for tree volume;
   2. To determine optimal sample size using criteria:
      — Minimize variance of estimator for fixed costs, or conversely
      — Minimize costs for given precision;
   3. To determine alternate optimal plan parameters;

II. To compare developed alternate optimal sample plans mutually and with previous sample plan.

This research may provide an alternative to the current sampling plan in forest inventory. The results of this study could be useful to open the possibility to develop multivariate sampling plan (the growing stock, the growth, the volume of marked trees, the regeneration). Additionally, the study may serve as a basis for the development of improved and statistically complex sampling plans (multi-stage multi-phase).

METHODS AND MATERIALS
METODE I MATERIJALI

FOREST ECONOMIC MANAGEMENT REGIONS
ŠUMSKOGOSPODARSKA PODRUČJA

In the Federation of Bosnia and Herzegovina, forested area is 1135931 ha, with 56,3% high forests with natural regeneration. The area of 895104 ha of state owned forests is managed by thirty-two forestry enterprises. Average forested area of forestry enterprises is about 39000 ha. Average volume of the growing stock in high forests with natural regeneration is 251 m^3/ha (Golob 2001). Analyzing the available information, it was concluded that for this research the most complete documentation could be provided by JP Šume Tuzlanskoga Kantona Tuzla ŠG Konjuh Kladanj.

FOREST ECONOMIC MANAGEMENT UNIT KONJUH KLADANJ
ŠUMSKOGOSPODARSKO PODRUČJE "KONJUH" KLADANJ

The area of study is forestry economic management unit (FEMU) Konjuh Kladanj with forested area of about 26000 ha.

The last forest inventory was done between 1989-1990. The objectives of this forest inventory were multiple. Here will be considering the estimate of the volume of the growing stock in high forest with natural regeneration as a main objective.

The pedological and typological mapping for the FEMU Konjuh Kladanj was done in 1980. Based on this classification, forest stratification was done and the whole area was divided into thirty-four basic classification units (management classes) considered as strata. Assuming that there was no significant changes in the boundaries of forestry area, nor in the structure of the forest recently, data and information gained in the previous inventory were considered as reliable for making conclusions on the current state of the forest.

APPLIED SAMPLING PLAN
PRIMIJENJENI PLAN UZORKA

The sampling scheme used in recent forest inventory in forestry area FEMU Konjuh Kladanj can be signed as two-phase one-stage sampling with stratification.

The first phase of sample was related to the separation of the strata and to the allocation of sample plots to each of divided strata (allocation of sample plots into management classes).

Terrestrial measurements conducted on these sample plots were marked as second phase of sample.

Taxation recording were done in concentric circles in high forests with natural regeneration, systematically distributed in square network 100x100 m (Stojanović & Drinić 1974). Tree selection plan was the system of concentric circles with joint centre and different radiuses, depending on the diameter at breast height of trees and nature of gathered data (Table 1).

Table 1. Tree selection plan (Stojanović & Drinić 1974)
Tablica 1. Plan selekcije stabala (Stojanović & Drinić 1974)

Threshold (cm)	5–10	10–15	15–20	20–30	30–50	50–80	>80.0
Radius (m)	2.2	3.5	4.5	5.5	9.0	15.0	25.0

The following taxation elements were recorded in the sample plots: canopy, tree species, tree diameter at breast height and tree height on every fourth sample plot.

Volumes of individual trees were determined using volume tables for individual (or similar) species: "Tables of taxation elements of high and coppice forests" (Drinić et al. 1980). Input variables in these tables are: tree species, site quality, and diameters at breast height with bark included. For determination of site quality, heights of sample trees were measured in the smaller part of sample (on ¼ of all sample plots). Recorded heights, therefore, did not participate in the determination of volume of individual trees numerically. As determination of the volumes of individual trees is based numerically only on the values of diameter at breast height, estimation of timber volume per area unit is considered to be one-stage.

Taxation recording was done in the total of 19269 circular sample plots within the taxation recording in high forests with natural regeneration of 19269 ha. That sample plots were used to collect the data on diameter at breast height for 134467 trees.

In the same forest category, data of height were recorded for 30533 trees in 5735 detailed sample plots.

Data gained during the taxation measuring done within recent forest inventory were registered by RC Šipad Sarajevo.

APPLIED STATISTICAL ESTIMATION PROCEDURE
PRIMIJENJENA STATISTIČKA PROCEDURA PROCJENE

Considering the fact that the stratification of forest area into management classes was previously completed, and that the allocation of sample plots in management classes was known, statistics were determined using formulas for simple random and stratified sampling.

COSTS
TROŠKOVI

In the forest inventory costs of taxation recording include financial means or time required for the planned taxation recording.It is more practical to express the costs as time. As the

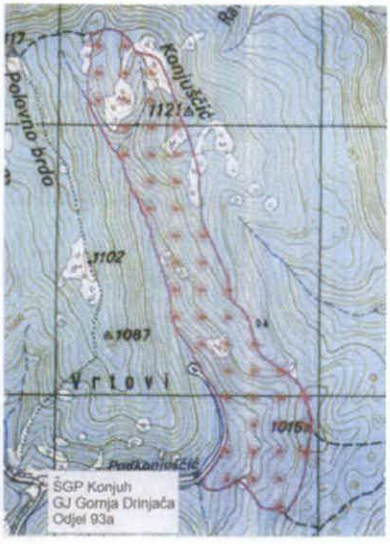
information for evaluation of the cost function were not noticed at the taxation recording, it was necessary to do this, according to method used for the previous inventory.

Two forest compartments were selected randomly. Compartment 17, of 52.0 ha was selected in Management unit Gostelja (Figure 2(A)). Compartment 93a, of 34.2 ha was selected in Management unit Gornja Drinjača (Figure 2(B)).

In the field were determined:

- travelling between sample plots (travelling time),
- Time for the installation of sample plots (marking of the centre of sample plot in the field, registration of the sample plot in the manual, and canopy estimate), and
- Time for measuring of diameter at breast height (testing of the distance of the tree from the centre of the sample plot, and two cross-measuring of diameter at breast height).

A



B

Figure 2. MU Gornja Drinjača Forest compartment 93a (A) and MU Gostelja Forest compartment 17 (B)

Slika 2. GJ Gornja Drinjača, odjel 93a (A), i GJ Gostelja, odjel 17 (B)

METHOD
METODA

Here were applied optimization techniques within the linear programming framework. The optimization problem is presented in the following form: to minimize or to maximize the objective function for anticipated constrains (Beale 1997).

Given the fact that it was intended to use the general optimization of the sampling plan, it was necessary to analyze the methods of trees selection plan optimization and the sample size optimization. In this research the Mandallaz method was used (2001). Discrete approximation for PPS is applied for optimal threshold optimization (Mandalay 2001). The optimization model based on the concept of anticipated variance within local Poisson's model for spatial distribution of trees is used.

OPTIMIZATION - MINIMAL ANTICIPATED VARIANCE FOR GIVEN COST
OPTIMIZACIJA – MINIMALNE PREDVIDLJIVE VARIJANCE ZA DANE TROŠKOVE

Mandallaz (2001) presented the optimization as classical problem of the linear optimization:

1. minimize the anticipated variance for the given costs, or
2. minimize the costs for corresponding anticipated variance.

The objective function (the anticipated variance) expresses timber volume per unit area variability. It depends on sample size (n), forested area $\lambda(F)$, tree volume (Y_i), inclusion probability (π_i) and lack of fit (Δ).

The constrain function is expressed as cost function deepening on travelling cost $\phi(n)$, installation cost (c_1), unit cost per tree (c_2) and inclusion probability .

The anticipated variance $(\mathrm{AV}(\overline{Y}))$ defined by:

$$AV(\overline{Y}) = \frac{1}{n\lambda^2(F)} \sum \frac{Y_i^2}{\pi_i} + \frac{1}{n}\Delta^2$$

Should be minimized within the constrain:

$$\phi(n) + nc_1 + nc_2 \sum_{i=1}^{N} \pi_i \le C$$

It is important to define the sample size for the lowest limit of the anticipated variance $(\mathrm{MAV}(\overline{Y}))$, with the given sample size:

$$MAV(\overline{Y}) = \frac{\left(\overline{Y}\left(\sqrt{c_{2i}}\gamma_g\right)\right)^2}{C - nc_2 - \phi(n_2)} + \frac{\Delta^2}{n}$$

The lowest limit of the anticipated variance $(\mathrm{MAV}(\overline{Y}))$ is function of average timber volume per unit area $(\overline{Y})$, corrected unit cost per tree (c_{2i}), PPS factor (γ), cost function, lack of fit and sample size.

OPTIMAL SAMPLE SIZE
OPTIMALNE VELIČINE UZORKA

The optimal sample size $(n_{u,opt})$ is depending on average timber volume per unit area, relative lack of fit (υ), travelling cost (c_2) and PPS factor. It could be reached through

differentiation of the lowest limit of the anticipated variance by value of the sample size:

$$n_{opt} = \frac{\tilde{C}\Delta}{\sqrt{c_2}\left(\gamma\sqrt{c_{21}} + \upsilon\sqrt{c_2}\right)}$$

For the optimal sample size, the absolute lowest limit of the anticipated variance could be evaluated by:

$$\min_n MAV(\bar{Y}) = \frac{\left(\bar{Y}\left(\gamma\sqrt{c_{21}} + \upsilon\sqrt{c_2}\right)\right)^2}{\tilde{C}}$$

Evaluated anticipated variances could be used as the foundation for the analysis of the alternate sampling plans deducted by the optimization technique. The optimization evaluated using alternate criteria – to minimize costs for given precision – leads to the same solution for optimal sample size (Mandallaz 2001).

Minimal cost for given precision is:

$$C_{\min} = \frac{\left(\bar{Y}\left(\gamma\sqrt{c_{21}} + \upsilon\sqrt{c_2}\right)\right)^2}{W}$$

RELATIVE EFFICIENCY ALTERNATE SAMPLING PLANS
RELATIVNA UČINKOVITOST ALTERNATIVNIH PLANOVA UZORAKA

Relative efficiency could be used in the decision-making between the two alternate plans. Relative efficiency (precision) of the alternate plans is determined as a relative relation of previous (VarB) and planed variances of the estimates (VarA) (Cochran 1977):

$$\mathrm{RE} = \frac{\mathrm{VarA}}{\mathrm{VarB}}$$

If the relative efficiency is between 0.95 and 1.05, it is considered that the optimal plans of approximate efficiency are completed and the choice for one of the two plans should be based on other essential criteria.

COST EFFICIENCY ALTERNATE SAMPLING PLANS
UČINKOVITOST TROŠKOVA ALTERNATIVNIH PLANOVA UZORAKA

According to the method used, minimization of costs for given (desired) precision, result in the same optimal sample size. For determined cost of alternate optimal plans, the cost efficiency (EC) can be expressed as percentage differences between the costs of the alternate sampling plans.

OPTIMAL SAMPLE PLAN PARAMETERS
PARAMETRI OPTIMALNOGA PLANA UZORKA

Sampling plans remain on the measures of the sample parameters as: number of units (sample plots) in a sample, their spatial distribution, shape and size.

Previous research and practice showed that the square distribution of sample plot centres was the most acceptable in the forest inventory. Keeping the square distribution of sample plot centres, the distance from one centre to another (R_u) is determined by:

$$R_u = \sqrt{\frac{\lambda(F)}{n_{u,opt}}}$$

The surface size of the concentric circles ($S_{u,p}$) are evaluated as (Mandallaz 2001):

$$S_{u,p} = \frac{C - n_1 c_1 - \phi(n_2)\, g(Y)}{\bar{Y} c_{21} \gamma \quad n_2}$$

RESULTS AND DISCUSSION
REZULTATI I DISKUSIJA

THE TREE SELECTION PLAN OPTIMIZATION
OPTIMIZACIJA PLANA SELEKCIJE STABALA

Using the method discrete approximation for PPS, optimal threshold values for tree volume classes for one, two and three optimal concentric circles were determined (Čabaravdić 2002). Also, here was determined PPS factor for previous sampling plan (6*). The determination was done on Chair for forest inventory and planning ETH Zurich. Table 2 summarizes the results on PPS factors, optimal thresholds, improved volume expectations in diameter classes and their variability.

Table 2. Optimal diameter threshold and γ_u factor for tree volume

Tablica 2. Optimalni debljinski intervali i faktori za volumen stabala

u	$N_{u,p}$	γ_u	p	$d_{u,p}$	$g^v_{u,p}$	$sd_{u,p}$	$V^-_{u,p}$	$V^+_{u,p}$
1	95	2.4595	I	>5	0.4067	0.0882	0.0072	10.8449
2	27	1.3689	I	5 - 30	0.2408	0.0339	0.0072	0.7827
	68		II	>31	2.6665	0.0746	0.8462	10.8449
3	17	1.1692	I	5 – 20	0.1103	0.0165	0.0072	0.2953

3	23		II	21 – 44	0.8613	0.0406	0.3322	1.8211
	55		III	> 45	4.0433	0.0571	1.9201	10.8449
6	1	1.1288	I	5 – 10	0.0186	0.0000	0.0186	0.0186
	2		II	11 – 20	0.1157	0.0272	0.0679	0.1608
	2		III	21 – 30	0.4237	0.0443	0.3113	0.5329
	4		IV	31 – 50	1.4119	0.0985	0.8289	2.1593
	6		V	51 – 80	3.8432	0.0803	2.7541	6.7189
	4		VI	> 80	8.2342	0.7470	7.4074	10.844

Legend: u – diameter classes number, $N_{u,p}$ – count, γ_p – PPS factor, p – diameter class rang, $d_{u,p}$ – optimal threshold, $V_{u,p}$ – volume expectation, $g^{v}_{u,p}$ –improved volume expectation, $sd_{u,p}$ – standard deviation, $V^{-}_{u,p}$ – minimal value, $V^{+}_{u,p}$ – maximal value

Legenda: u – *broj debljinskih intervala,* $N_{u,p}$ – *broj vrijednosti,* γ_p – *PPS faktor, p – rang debljinskoga intervala* $d_{u,p}$ – *optimalni prag,* $V_{u,p}$ – *volumno očekivanje,* $g^{v}_{u,p}$ – *korigirano volumno očekivanje,* $sd_{u,p}$ – *standardna devijacija,* $V^{-}_{u,p}$ – *minimalna vrijednost,* $V^{+}_{u,p}$ – *maximalna vrijednost*

OPTIMIZATION
OPTIMIZACIJA

OPTIMIZATION PARAMETERS
PARAMETRI OPTIMIZACIJE

It is necessary to know some parameter population to carry out the optimization. Here it is necessary to have: number of trees of previous sample, diameter distribution of sample, previous sample size, estimated values of the volume of the growing stock for every sample plot, number strata and allocation sample plots in that strata.

First, it is necessary to express the volume of the growing stock variability in local Poisson forest. Basic database of previous inventory was consisted of values for estimated local densities for 19269 sample plots under the forested area distributed in eighteen management units (strata) in high forest with natural regeneration. On the base allocation of sample plots into management units, in order to determine necessary optimization parameters, it was carried out analyses of variance for working-strata (Table 3).

Table 3. ANOVA for working strata

Tablica 3. ANOVA za radne stratume

Sources	df	Sum square	Expected values
Model	17	57883091	3003.949
Residual	19252	451510510	23431.96
Total	19269	509393601	26435.91

Here was found low determination (0.1136) what pointed out that applied stratification criteria had not reached result what was possible when a volume of the growing stock estimation was in a consideration (Table 4).

Mostly, stratification achieves minimal coefficient of determination about 0.20. But, in management praxis, stratification criteria are complex, so, here found such a value of determination was accepted for further analyses, although it stayed a question about stratification criteria related to more precise the growing stock estimation.

Table 4. Population parameters
Tablica 4. Parametri populacije

$\overline{Y}$ (m³/ha)	R^2(%)	ε^2	Δ	υ(%)
241.62	0.1136	12268.03	105.65	0.4372

Legend: $\overline{Y}$ – volume of growing stock in m³/ha, R^2 – determination in %, ε^2 – pure error, Δ – lack of fit, υ – relative lack of fit

Legenda: $\overline{Y}$ – *drvna zaliha u (m³/ha)*, R^2 – *determinacija u %*, ε^2 – *čista greška*, Δ – *nedostatak izravnanja*, υ – *relativni nedostatak izravnanja*

Using previous tree selection plan, here is determined value of puree error and evaluated lack of fit . Puree error value showed on high variability for the volume of the growing stock in strata.

It was left to express overall costs in local Poisson forest and means of particular costs. Table 5 summarizes values for cost coefficients.

Table 5. Costs coefficients
Tablica 5. Koeficijenti troškova

Costs	Mean	Standard error	Confidence interval (95%)	Sample size
c_0	3.5581	0.1198	0.2383	84
c_1	1.0504	0.0656	0.1304	86
c_2	0.4982	0.0401	0.0797	86
c_2^h	0.6794	0.0921	0.2006	13

Legend: c_0 – travelling time in min/plot/crew member, c_1 – installation time in min/plot/crew member, c_2 – unit cost per tree diameter in min/tree, c_2^h – unit cost per tree height in min/tree

Legenda: c_0 – *vrijeme prelaza u min/premjernoj površini/članu sekcije*, c_1 – *vrijeme instalacije u min/premjernoj površini/članu sekcije*, c_2 – *vrijeme mjerenja prsnoga promjera u min/stablu*, c_2^h – *vrijeme mjerenja visine min/tree*

Figure 3 shows percentage structure of particular activities in terrestrial measurement.

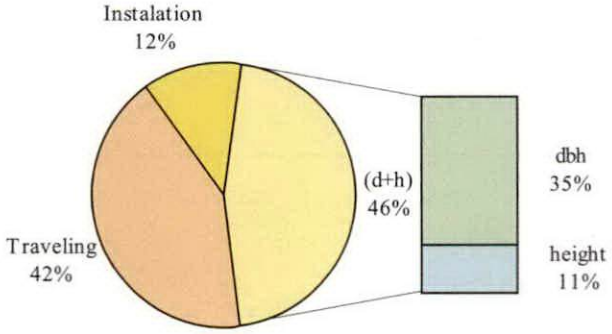
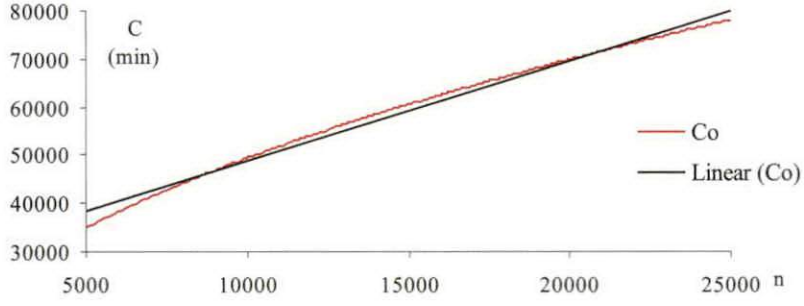


Figure 3. Cost structure in %
Slika 3. Struktura troškova u %

Empirical experience showed that travelling costs follow square root function (Figure 4). In optimization purpose it was determined travelling cost model as a linear function:

$$\phi(n) = 27797 + 9.44n$$



Legend: Co: travelling cost in *min, Linear (Co)*: linearized travelling cost in *min*, n number of terrestrial plots

Legenda: Co: *troškovi prijelaza u min, Linear (Co): linearizirani troškovi prijelaza u min, n broj premjenih površina*

Figure 4. Travelling costs
Slika 4. Troškovi prijelaza

Finally, overall costs for growing stock estimation for 19269 sample plots was 445091 minutes (Table 6).

Table 6. Average and total costs
Tablica 6. Prosječni i totalni troškovi

Intercept a	Slope b (min)	c_{2i} (min)	C (min)	$\tilde{C}$ (min)
27797	9.44	1.9574	445091	417294

Legend: a – intercept for travelling cost, b – slope for travelling cost, c_{2i} – unit cost per tree, C – total cost, $\tilde{C}$ – variable cost

Legenda: a – *koeficijent funkcije troškova prijelaza,* b – *korak funkcije troškova prijelaza,* c_{2i} – *trošak mjerenja po stablu,* C – *ukupni troškovi,* $\tilde{C}$ – *varijabilni troškovi*

OPTIMIZATION – OPTIMAL SAMPLING PLAN FOR GIVEN COST
OPTIMIZACIJA – OPTIMALNI PLAN UZORKA ZA DANE TROŠKOVE

First, it was optimized sample size for given cost. It meant, anticipated variance was minimized for different number concentric circles for tree selection, for given budget of variable cost in previous forest inventory. Using a criteria to minimize anticipated variance for given cost, here were determined optimal sample size and minimal anticipated variance using optimal one, two, three and six concentric circles (Table 7).

Table 7. Minimal anticipated variances
Tablica 7. Minimalne predvidljive varijance

u	$(n_{u,opt})$	(MAV_u)	$2RE_{u,opt}$ (%)
1	12525	3.1462	1.4684
2	18231	1.4849	1.0088
3	19934	1.2420	0.9226
6	20323	1.1950	0.9050
6*	19269	1.2180	0.9136

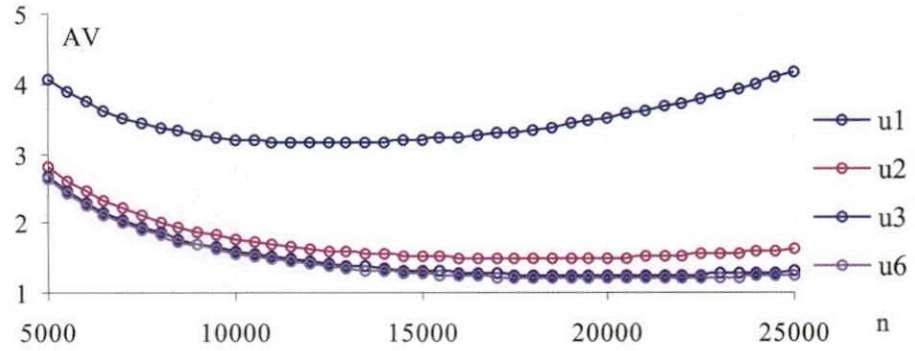
Legend: u – concentric circle number for tree selection, $(n_{u,opt})$ – optimal sample size, (MAV_u) – minimal anticipated variance, $2RE_{u,opt}$ (%) – double relative error

Legenda: u – *broj koncentričnih krugova za selekciju stabala,* $(n_{u,opt})$ – *optimalna veličina uzorka,* (MAV_u) – *minimalna predvidljiva varijanca,* $2RE_{u,opt}$ *(%) – dvostruka relativna greška*

When concentric circle number for tree selection increase, optimal sample size also increase. That cause anticipated variance decrease. It could be seen that precision expressed by double relative error also decrease. Optimal sample plan with tree selection in one circle,

for fixed cost, overestimates desired precision (double relative error of 1%). Also, optimal sample plan with tree selection in two concentric circles, for fixed cost, overestimates desired double relative error slightly. Results show that optimal sample plan with tree selection in tree and six concentric circles, for fixed cost, could provide desired precision.

Minimizing anticipated variance in range from 5000 to 25000 sample plots, it could be seen that optimal sample sizes correspond with minimal anticipated variances (Figure 5). Also it could be noticed that values of anticipated variances differ slightly in the wide interval around minimal anticipated variance (optimal sample size).



Legend: AV – anticipated variance, *u* – concentric circle number for tree selection, γ_u – *n* – sample size

Legenda: AV – *predvidljiva varijanca,* u – *broj koncentričnih krugova za selekciju stabala,* γ_u – n – *veličina uzorka*

Figure 5. Anticipated variance, C const

Slika 5. Predvidljiva varijanca, C konstatno

In narrow interval, values of anticipated variance are almost equal, so it is possible to consider sample size freely. There are wide range sample size where could be chosen other sample parameters without large deviation from expected precision.

It means it could be chosen small number of larger circles or inversely, without significant influence on precision.

Also, it is possible to notice that minimal anticipated variance for optimal tree and six concentric circles overlap almost. Here could be achieved very small difference in expected precision. Even sampling in two optimal concentric circles achieves good result.

RELATIVE EFFICIENCY ALTERNATE OPTIMAL SAMPLING PLANS
RELATIVNA UČINKOVITOST ALTERNATIVNIH PLANOVA UZORAKA

Table 8 shows relative efficiency for developed optimal alternate sampling plans with different number of concentric circles for tree selection.

Table 8. Relative efficiency alternate sampling plans

Tablica 8. Relativna učinkovitost alternativnih planova uzoraka

u \REf	(u|2)	(u|3)	(u|6)	(u|6*)
1	0.69	0.63	0.62	0.62
2		0.91	0.90	0.91
3			0.98	0.99
6				1.01

Legend: u: concentric circle number for tree selection, *REf*: relative efficiency
Legenda: u: broj koncentričnih krugova za selekciju stabala, REf: relativna učinkovitost

As referent sample plan it is signed previous sampling plan with six concentric circles. Relative efficiencies for alternate plans with one and two concentric circles are less then 0.91. They could be considered as enough efficient. Relative efficiency between alternate plan with tree and six concentric circles (0.98 and 0.99) pointed out close precision. Also, there is not significant precision difference between optimal plan with six concentric circles and previous sample plan (1.01).

OPTIMAL PLAN PARAMETERS
PARAMETRI OPTIMALNIH PLANOVA

Table 9 summarizes parameters of optimal plans with tree selection in three and six concentric circles. Optimal plan with three concentric circles is related to tree selection on concentric circles with radii of 3.86 m (dbh > 5 cm), 10.66 (dbh > 22 cm) and 23.10 m (dbh > 45 cm).

Table 9. Optimal sampling scheme with three and six concentric circles

Tablica 9. Optimalni plan uzorka s tri i šest koncentričnih krugova

u	$(n_{u,opt})$	R_u	p	$d_{u,p}$	$S_{u,p}$	$P_{u,p}$
		(m)		(cm)	(m²)	(m)
3	19934	98.32	I	5 – 20	23.5	2.7
			II	21 – 44	179.0	7.5
			III	> 45	840.2	16.4
6	20323	97.37	I	5 – 10	4.1	1.1
			II	11 – 20	25.9	2.9
			III	21 – 30	95.6	5.5
			IV	31 – 50	286.4	9.5
			V	51 – 80	801.4	16.0
			VI	> 80	1753.6	23.6

Legend: u – concentric circle number for tree selection, R_u – distance between terrestrial plots, p – diameter class, $d_{u,p}$ – optimal threshold, $S_{u,p}$ – surface areas of optimal circles, $P_{u,p}$ – optimal radii of concentric circles

Legenda: u – *broj koncentričnih krugova za selekciju stabala,* R_u – *rastojanje između premjernih površina,* p – *debljinski interval,* $d_{u,p}$ – *optimalni intervali prsnih promjera,* $S_{u,p}$ – *optimalne površine koncentričnih krugova,* $P_{u,p}$ – *optimalni radijusi koncentričnih krugova*

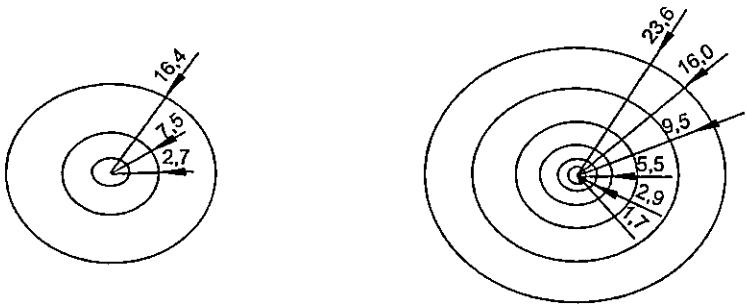


Figure 6. Optimal inclusion surfaces

Slika 6. Površine optimalnih koncentričnih krugova

On Figure 6 are presented surface areas of concentric circles according to tree diameter and volume, using optimal tree (A) and six circles (B).

OPTIMIZATION FOR GIVEN PRECISION
OPTIMIZACIJA ZA DANU PRECIZNOST

Application the second criteria, minimizing costs for given precision, gave optimal sample sizes and relative efficiency corresponding to optimal sample sizes and relative efficiency determined using criteria minimizing anticipated variances.

Table 10. Minimal costs for given precision

Tablica 10. Minimalni troškovi za danu preciznost

u	1	2	3	6	6*
Min C (min)	1078796	509249	425959	409828	417294

Legend: u: concentric circle number for tree selection

Legenda: u: *broj koncentričnih krugova za selekciju stabala*

For given precision, optimal sample plans with one, two and three concentric circles are more expensive then previous sample plan (Table 10). But, optimal sample plan with six concentric circles for tree selection is not. It means that the same precision could be achieved using mentioned optimal plan providing cost reduction.

OPTIMIZATION FOR DESIRED PRECISION
OPTIMIZACIJA ZA ŽELJENU PRECIZNOST

Beside the optimization for given costs, it was found that it was important to evaluate optimal sample sizes for desired precision. Desired precision is expressed by variance W derived from empirical double relative error for investigated forest category of 1%. The value of such determined variance was 1.4595.

It was applied criteria minimizing costs for desired precision to develop optimal sampling plans. Table 11 summarizes optimal sample sizes and minimal costs of determined alternative optimal plans.

Table 11. Optimal sample size (W=1%)
Tablica 11. Optimalna veličina uzorka (W=1%)

u	$n^{W}_{u,opt}$	$C^{W}_{u,MIN}$ (min)
1	27031	900215
2	18572	424949
3	16985	355447
6	16661	341986

Legend: u – concentric circle number for tree selection, γ_u – PPS factor, $n^{W}_{u,opt}$ – optimal sample size, $C^{W}_{u,MIN}$ – minimal cost

Legend: u – *broj koncentričnih krugova za selekciju stabala,* γ_u *– PPS faktor,* $n^{W}_{u,opt}$ *– optimalna veličina uzorka,* $C^{W}_{u,MIN}$ *– minimalni troškovi*

For desired precision, optimal sample plan with one circle for tree selection should have 27031 sample plots. If concentric circle number for tree selection increase, optimal sample size decrease as minimal cost too.

Cost efficiency alternative optimal plans are presented in Table 12.

Table 12. Cost efficiency
Tablica 12. Učinkovitost troškova

$u\backslash EC$	(u|2)	(u|3)	(u|6)	(u|6*)
1	111.84	153.26	163.23	115.73
2		19.55	24.26	1.83
3			3.94	-14.82
6				-18.05

Legend: u – concentric circle number for tree selection, EC – cost efficiency
Legend: u – *broj koncentričnih krugova za selekciju stabala,* EC – *učinkovitost troškova*

It could be noticed that optimal sample plan with two concentric circle for tree selection excel referent cost slightly (1.83 %). Cost reduction could be assured using optimal plans with tree and six concentric circles. Optimal sample plan with tree concentric circles could provide 14.82 % cost reduction. Also, optimal sample plan with six concentric circles could provide 18.05 % cost reduction.

COMPARISON TO RESULTS OF OTHER AUTHORS
POREDBA S REZULTATIMA DRUGIH AUTORA

TREE SELECTION PLAN
PLAN SELEKCIJE STABALA

Determined radii for tree selection in six concentric circles (A) are in the same range as radii of current tree selection plan (B) (Table 13). The first and the second concentric circles could be smaller due to huge number of trees with diameter of breast height less then 20 cm. Following radii are larger with last one of 25 m.

Table 13. Concentric circles radii (m)
Tablica 13. Radijusi koncentričnih krugova u m

u	$(n_{u,opt})$	R_u (m)	p	$d_{u,p}$ (cm)	$P_{u,p}$(A) (m)	$P_{u,p}$(B) (m)	$P_{u,p}$(C) (m)
6*	19269	100.00	I	5 – 10	1.0	2.5	2.2
			II	11 – 20	3.0	4.5	4.6
			III	21 – 30	6.0	5.5	6.0
			IV	31 – 50	10.0	9.0	7.0
			V	51 – 80	17.0	15.0	14.0
			VI	> 80	25.0	25.0	20.0

Compared with Matić tree selection plan (C), plan (A) has larger tree selection radii. We found plan (A) more appropriate for concrete investigated forest area.

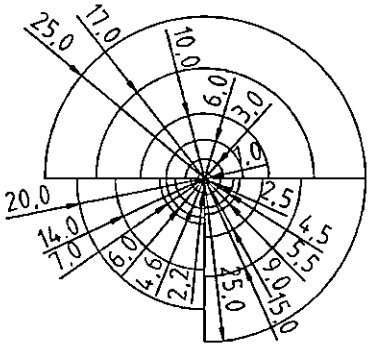
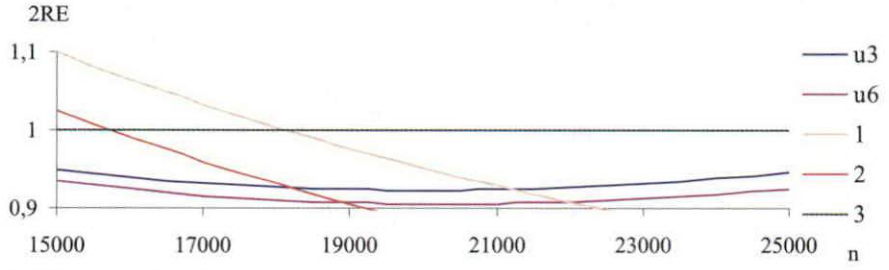


Figure 7. Concentric circles radii (m)
Slika 7. Radijusi koncentričnih krugova u m

SAMPLE SIZE
VELIČINA UZORKA

Figure 8 shows double relative error depending on sample size. Results achieved using sample random sampling (1), regression model (2) developed by Koprivica (1984) conformed that it could be chosen sample size on the optimization base (u3, u6) which could provide desired precision (3) in a range up to 18000 sample plots.



Legend: *2RE* – double relative error in %, u – concentric circle number for tree selection, *1* – sample random sampling, *2* – regression model (Koprivica 1984), *3* – double relative error of 1%, *n* – sample size.

Legend: 2RE – *dvostruka relativna greška u %*, u – *broj koncentričnih krugova za selekciju stabala*, 1 – *slučajni izbor*, 2 – *regresijski model (Koprivica 1984)*, 3 – *dvostruka relativna greška od 1%*, n – *veličina uzorka.*

Figure 8. Precision depending on sample size

Slika 8. Preciznost u zavisnosti od veličine uzorka

CONCLUSIONS
ZAKLJUČCI

1. Related to tree selection plan, it could be concluded that tree selection in one circle deviates form exact PPS significantly.
2. Optimal threshold for two concentric circles are 5 cm and 31 cm. Here is noticed tree volume precision increase.
3. Optimal threshold for tree concentric circles are 5 cm, 21 cm and 45 cm.
4. PPS factor for six concentric circles points out tree selection the closest to exact PPS.
5. Relative difference between PPS factor for tree and six concentric circles could be considered as negligible.
6. Considering the optimization for fixed cost, developed alternate optimal plans show differences in sample sizes. There is wide range of sample size around optimal sample size without significant changes in precision. Then, relative efficiency of alternate optimal plans point out close precision for sample plans with tree selection in three and

six circles.

7. Optimal sample plan with three concentric circles has 19934 sample plots with radii for tree selection of 2.7 m, 7.5 m and 16.4 m.
8. Optimal sample plan with six concentric circles has 20323 sample plots with radii for tree selection of 1.1 m, 2.9 m, 5.5 m, 9.5 m, 16.0 m and 23.6 m.
9. For desired precision, the optimization showed that optimal sample plan with tree selection in three optimal concentric circles could provide cost reduction of 14.82 % having 16985 samples plots. Optimal sample plan with six concentric circles could provide cost reduction of 18.05 % with 16661 sample plots.

The evaluated optimization results are related to investigate forest area only, due to model, which was developed here, used characteristic of concrete forest on investigated area. For optimal sampling plans for other economic forest management units it is necessary to know characteristics of their forests. Particular cost expressed in time are not usually registered in forest inventory measurement in forest inventories recently. If forests and stands characteristics of two forests economic regions are similar, it is possible to use similarity law travelling cost to develop cost model.

Using this optimization model, it was found that there is significant cost reduction. Also, cost reduction could be achieved introducing new stratification criteria, new instruments for forest inventory measurements or with two-member crew.

Further improvement in planning is development advanced sampling plans (two-phase two-stage) what uses all available auxiliary information (maps, air-photos, previous databases, GPS, GIS) and technological improvement (new instruments).

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OPTIMIZACIJA U INVENTURI ŠUMA NA REGIONALNOJ RAZINI U BOSNI I HERCEGOVINI

SAŽETAK

Cilj je rada primjena nove metode planiranja uzorka za taksacijska snimanja (procjenu drvne zalihe) u inventuri šuma na regionalnoj razini.

Metoda se temelji na predvidljivoj varijanci uz nedostatak izravnanja (Mandallaz 2001).

Za objekt istraživanja odabrano je jedno šumskogospodarsko područje u Bosni Hercegovini.

Plan opće optimizacije proveden je uz upotrebu baze podataka prethodne inventure šuma. Pri tome je provedena optimizacija plana selekcije stabala i optimizacija veličine uzorka. Izvedeni su alternativni planovi uzoraka i međusobno uspoređeni.

Optimizacija plana selekcije stabala upućuje na mogućnost redukcije broja koncentričnih krugova za selekciju stabala sa šest na tri koncentrična kruga uz zanemarljiv gubitak na preciznosti procjene. Optimalni planovi uzoraka sa selekcijom stabala u tri i šest koncentričnih krugova, za dane troškove, pokazuju približnu relativnu učinkovitost (0,98). Planiranje optimalnih uzoraka za željenu preciznost izraženu dvostrukom relativnom greškom od 1 % pokazuje da bi se optimalnim planovima sa selekcijom stabala u tri i šest koncentričnih krugova mogla ostvariti redukcija troškova od 15 % i 18 % u odnosu na prethodni plan uzorka.

Plan uzorka mogao bi se dalje unaprijediti analizom stratifikacije, primjenom složenijih planova uzoraka, te uvođenjem novih tehnologija.

Ključne riječi: inventura šuma, optimizacija, optimalni plan, drvna zaliha, regionalna razina

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Knjiga

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