RADOVI
Šumarskog fakulteta Univerziteta u Sarajevu

WORKS
of the Faculty of Forestry University of Sarajevo

Volume 48 Issue 2

Sarajevo, 2018

The first issue was published in 1952 by the Faculty of Forestry and the Institute for Forestry in Sarajevo. These two Institutions have published Journal for 26 years. After the restructuring of the scientific and research activities in Bosnia and Herzegovina, on 1 April 1974 the Journal changed its name to "Works of the Faculty of Forestry University of Sarajevo", and the publisher is the Faculty of Forestry in Sarajevo.

Print
"ŠTAMPARIJA FOJNICA" - Fojnica

Works of the Faculty of Forestry
University of Sarajevo
No. 2, 2018 (1-16)

UDK 630*23:582.475(234.422 Bjelašnica)

REGENERATION OF FIR IN DIFFERENTLY STRUCTURED STANDS OF BEECH AND FIR FORESTS (WITH SPRUCE) ON BJELAŠNICA

Podmlađivanje jele u različito strukturiranim sastojinama šuma bukve i jele (sa smrčom) na Bjelašnici

Sead Ivojević[1], Osman Mujezinović[1], Damir Prljača[1], Kenan Zahirović[2]

Abstract

This document includes research in regeneration of fir in differently structured stands of beech and fir forests (with spruce) on mountain Bjelašnica near Sarajevo. Analysis of fir regeneration in differently structured stands was done by comparison of numbers of units of young fir, per growth category, and by total number of young fir at canopy density degree of 0.7 (0.60 – 0.79) and 0.9 (0.80 – 1.00), and by mixture ratio – share of fir (spruce) 0.7 (60 – 79 %) and 0.9 (80 – 100 %). Comparisons were done between virgin forest stands of beech and fir (with spruce) on 'Ravna vala', than, two-storied stand where we recorded transition of tree species (beech is dominant in upper growth, while fir is mainly dominant in young growth) on location 'Medvjeđa lokva' and stands of typical uneven aged production forest of beech and fir (with spruce) in direct vicinity of virgin forest stand. Data gathering was done using total measurement method on permanent experimental plots of 1ha in virgin forest stand and two-storied stand on location 'Medvjeđa lokva' and on circular plots in diameter of 12.62 m. Positions of circular experimental plots were determined by systematic sample in form of grid on intersections of Gauss-Krueger system, in intervals of 100 meters. Grid is laid in three transects of 27 plots each that is spread across forest compartments number: 111, 113, 114 and 115 of Management unit „Igman", location 'Ravna vala'. We have placed two experimental square plots of 1ha; one in virgin forest reservation 'Ravna vala' for preservation of assortment, status without human impact (compartment 106, MU „Igman"), and the other in management forest of this area "Medvjeđa lokva" (compartment 117, MU „Igman") for specific structure of assortment. Square 1ha plots were divided by grid of squares 10 x 10 m into 100 small plots.

***Key words**: fir, regeneration, structured, canopy density degree, mixture ratio.*

INTRODUCTION – *Uvod*

According to preliminary results of the Second forest inventory in Bosnia and Herzegovina (2006 – 2009) out of total area of all high forests (1,652,400 ha), 42.5 %

[1]Faculty of Forestry, University of Sarajevo, Zagrebačka 20, 71000 Sarajevo, Bosnia and Herzegovina
[2]PE „ŠPD ZDK" ltd Zavidovići, Alije Izetbegovića 25, 72220 Zavidovići, Bosnia and Herzegovina, PU „Šumarija" Vareš

is covered by conifer and broadleaved forests in forest area of beech and fir (with spruce). In Federation of Bosnia and Herzegovina, out of total area of high forests (869,000 ha) beech and fir forests (with spruce) cover 46%.

According to the same source total volume of usable timber of available high production forests in Bosnia and Herzegovina amounts to 353,599,353 m^3. Volume of usable timber of available high production forests in communities of coniferous and mixed forests in forest area of beech and fir (with spruce) is 184,535,411 m^3, or 52.19 % of total volume. Volume of usable timber of fir in these forests is 66,584,166 m^3 which makes 18.83 % of total volume in mentioned community. Mean total increment of usable timber of all high forests of production character in Bosnia and Herzegovina amounts to 9,069,660 m^3. Mean total increment of fir in these forests amounts to 1,946,530 m^3 which points out the share of fir in increment of 21.46 %.

Based on mentioned, we can state that beech and fir forests (with spruce) are economically the most significant forest communities in Bosnia and Herzegovina. Besides that, due to specific mixing of species and number of vascular flora, these forests are ecologically the most stable and have significant importance on biodiversity preservation.

European silver fir (*Abies alba*) is main species of selection forests that in its structure per area unit have trees of different species, heights and diameters. Those forests look equally the same externally. In them, relations between the trees are marked by constant struggle for space in the ground and above ground of those trees that are located on different height levels of the stand and in different horizontal structural distribution. In normal growing stock that is distributed in selection structure, those forests have maximum production and optimal and permanent natural regeneration, and good stability (MATIĆ and others, 2001).

Area of distribution of fir forests and its share out of total area under forests has been reduced in the last 200 years in most European countries. Reasons for this relate to human influnce, through uprooting of trees, excessive exploitation, forcing fast-growing allochthones species, improper forest management and air pollution (WOLF, 2003). Symptoms are manifesting by falling off of needles, early defoliation and final dying of trees (KRAUSE and others, 1986). Emissions of air pollutants from different industries and social activities have large impact on floral organisms growing in those areas. Main air pollutants are road transport means, heat energy producers, industry and agriculture (WOLF, 2003).

Fir as significant stabilizer–species of our most important forest ecosystems lately focuses attention of large number of European scientists. Reasons should be looked for in hundred-year endangerment of fir as tree species in central European forests, due to changeable habitat conditions and application of management system. Only in 50s of past century we have started to intensively work on improvement of ecological conditions of fir and creation of favorable ecosystems as a road to revitalization of existing communities. One other road that requires long-term observation is to find out vital proveniences (MEKIĆ, 1991).

Present manner of management on Igman led to the situation interruptions in canopy density was mainly too strong, which caused the intensive inflow of light. Therefore, we have overgrowing with weeds on many surfaces, which almost disabled appearance of natural young growth, and even if it did show up, it was suffocated by large quantities of weed. Therefore, we can say that the most common cause of absence of natural young growth is exactly too strong inflow of light, with all negative consequences (PINTARIĆ, 1970).

RESEARCH AREA AND METHODS – *Područje istraživanja i metode*

Research objects in this work were experimental plots of circular shape and experimental plots of rectangular shape.

Positions of experimental plots of circular shape were determined by systematic sample in a form of grid on intersections of Gauss-Krueger system, in intervals of 100 meters. Grid is laid in three transects of 27 plots each that is spread across forest compartments number: 111, 113, 114 and 115 of management unit “Igman”, location Ravna vala (Figures 2 and 3.). On intersections of the grid we have placed 81 plots. To determine structural characteristics of assortment we have positioned circular plots of fixed diameter r = 12.62 m (area of 500 m2) while, for evaluation of status and quality of natural young trees on same habitats (centers) we used circular plots of fixed diameter r = 3 m (28.27 m2) (Figures 2. and 3.).

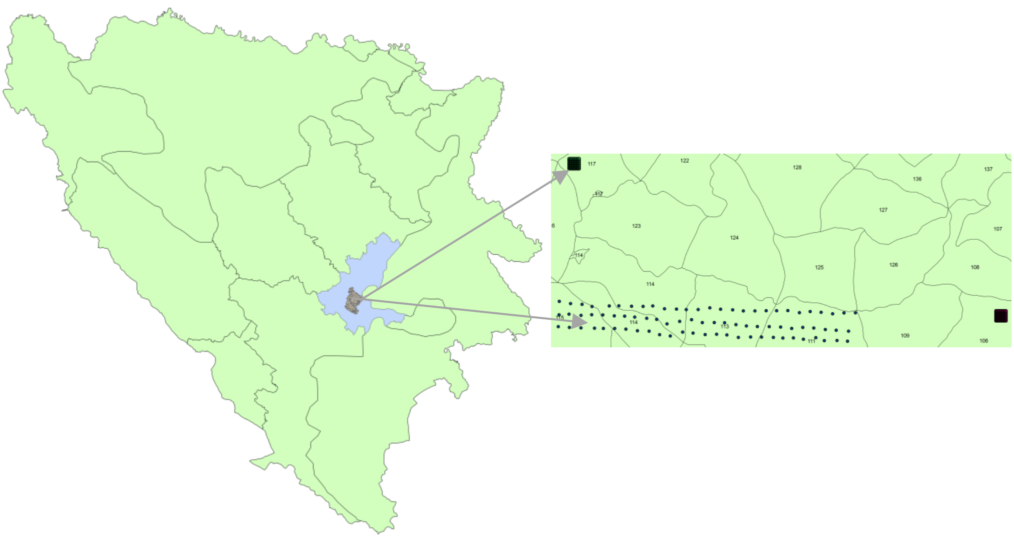


Figure 1. The position of experimental plots in Bosnia and Herzegovina, Canton Sarajevo and MU "Igman"

Slika 1. Položaj eksperimentalnih ploha u Bosni i Hercegovini, Kantonu Sarajevo i GJ „Igman“

We have placed two experimental plots in a form of a square of 1ha area (Figures 2. and 3.), out of which, one is in virgin forest reservation 'Ravna vala' for preservation of assortment, status without human impact (compartment 106, management unit "Igman" – Figures 2. and 3.), and the other in management forest of this area 'Medvjeđa lokva' (compartment 117, management unit "Igman" – Figure 2.) for specific structure of assortment. Plots of 1ha rectangular shape were divided by grid of squares 10 x 10 m into 100 small plots (Figure 3). Data gathering on experimental plots was conducted from beginning of summer 2012 to autumn 2014.

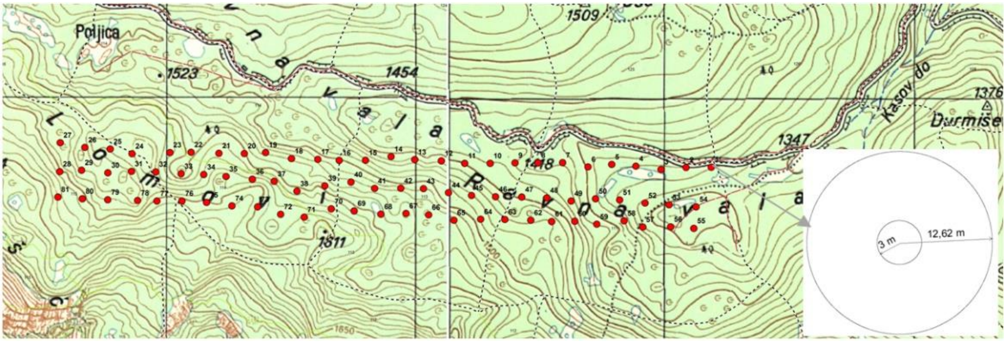


Figure 2. Position and design of circular experimental plots of radius 12.62 m and 3 m

Slika 2. Položaj i dizajn kružnih eksperimentalnih ploha radijusa 12,62 m i 3 m

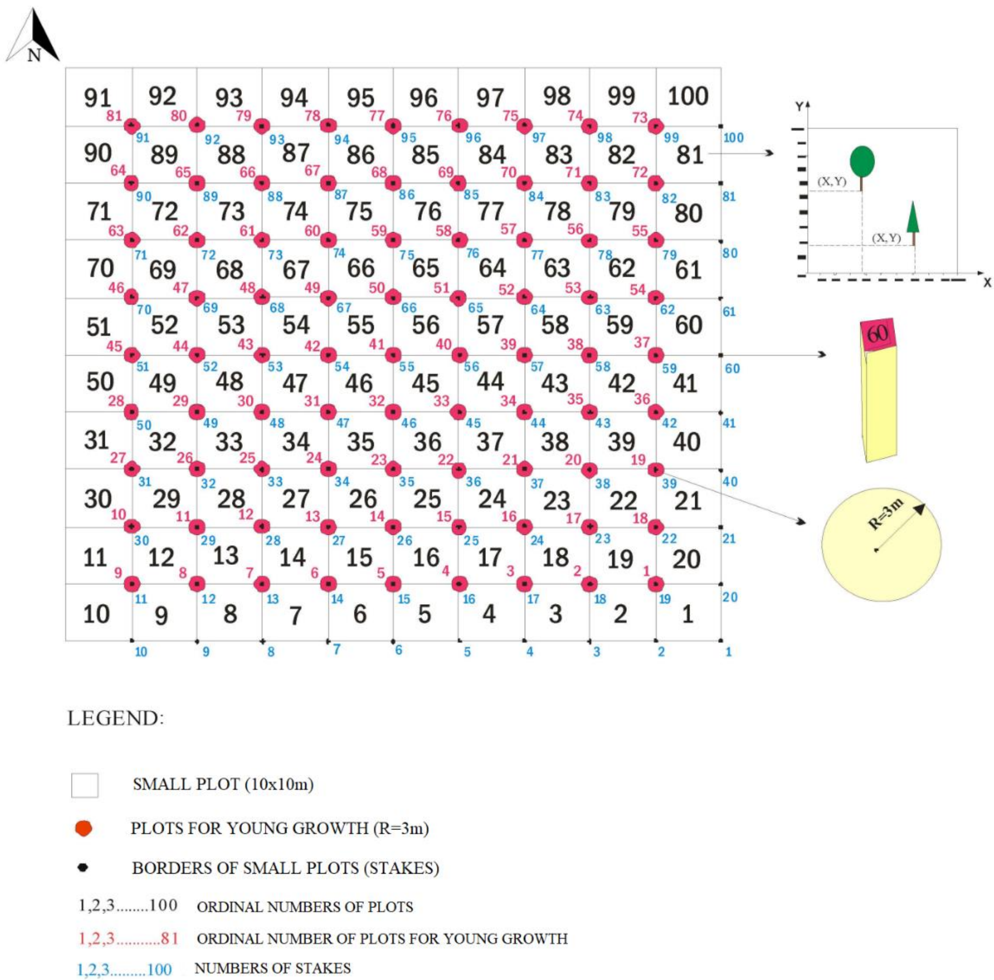


Figure 3. Design of experimental plots of square shape area of 1 ha
Slika 3. Dizajn eksperimentalne plohe kvadratnog oblika površine 1 ha

On experimental plots of circular shape, diameter 12.62 m, we have completely measured trees and gathered following data:

- tree species origin,
- tree diameter on height of 1.3 m (for trees of diameter exceeding 5 cm),
- tree height,
- position of the tree in relation to center of the plot via polar method (four dominant trees, in each quadrant one tree on all four sides of the world),

- current annual increment in diameter (in last 11 years – for dominant trees) and
- degree of canopy density via Fisheye method.

Fisheye method of determining degree of canopy density includes recording of hemispheric photos (using "fish eye" lenses). Recording of photos was conducted on circle centers to record young trees from the height of 50cm (young tree zone). Recorded photos were processed in software *Paint net* to determine the relation of covered and uncovered parts of the land in assortments' tree tops.

To gain better insight in status of young trees, its numbers, structure, taxation origin, damage and trees with stunted/undergrown canopy (obsolescence), we have recorded young trees on secondary small plots of circular shape, 3m radius with common circle centers with plots of 12.62m diameter.

Young trees were recorded considering the number and origin to the given species and according to growth was classified into (LOJO and others 2008):

- seedling of 0.1 – 9.9cm growth,
- young trees of 10.0 – 49.9cm growth,
- young trees of 50.0 – 130.0cm growth, and
- young trees of diameter at breast height of 0.1 – 5.0 cm.

Besides these characteristics, young trees were described as per the manner of appearance (individually or in groups), origin (generative or vegetation), trees with stunted/undergrown canopy (obsolescence) (with or without stunted/undergrown canopy (or young growth obsolete or not obsolete)) and damage (damaged or undamaged). For two growth categories of young trees (from 50 to 130 cm of height and diameter at breast height of 0.1 to 5 cm) we have determined growth increment for last 10 years (for all present units of these two categories on each experimental plot).

Experimental square plots (Figure 3) were staked out so that the sides are stretching in direction of main sides of the world. Marking of boundaries of plot 100 x 100 m and internal division to small plots 10 x 10 m was done using wood stakes of dimensions 5 x 5 x 50 cm. All small plots within the plot of 1 ha are numbered. With numbering we started from the first border stake of permanent plot (1 ha) that is located in direction of south-east looking from the center of the plot. Small plot on whose corner is the side; the start stake has ordinal number 1. Number 2 is small plot located to the left of the first small plot and it goes so on until the tenth small plot when we are moving into the second row and it goes on (without interruptions/breaks) in the form of snake all the way to the last small plot number 100. Numbers of small plots are written on the head of the stake with arrows pointing to the small plot origin (Figure 3).

Borders of experimental plots were marked, geo-coded and transferred into Gauss-Krueger coordinate system. Besides that, we staked out centers of circles to determine status of natural young growth and degree of canopy density. On each experimental plot we conducted complete measurement of all living standing trees of diameter at breast height above 5 cm.

On all plots were have numbered trees. It has been done for each plot of 10 x 10 m inside the plot of 1 ha separately. On each plot (10 x 10 m) number of trees starts from ordinal number 1. Marks of plots and number of trees are written on aluminum tape (dimensions 2.5 x 5 cm) which is fixed to the tree on a height of 1.8 m and always on the upper side of the tree. The tape on its upper half has written affiliation to the plot, and under it is number of the tree.

All trees above taxation threshold ($d_{1,3} \geq 5$ cm) are marked on height of 1.3 m, on sloped terrain calculating the height of the upper portion of the tree. As we measured two crossed diameters, than trees were marked on all four sides with the mark in shape of circle in radius of 4cm by using blue paint or spray. Marks on trees are oriented toward sides of the world.

On experimental plots of 1ha square shapes we have conducted total measurement and gathered following data:

- tree species origin,
- tree diameter on height of 1.3m (for trees of diameter exceeding 5 cm)
- tree height,
- position of the tree in space (orthogonal method),
- degree of canopy density via *Fisheye* method.

Plot centers for recording of natural young trees were on intersections of grid 10 x 10 m. Completely positioned 81 circular shape (radius 3m) plot each to measure young trees on both plots of square shape (‘Medvjeđa lokva’ and Virgin Forest) (Figure 3). On experimental plots of square shape, we gathered data on young tree status with the same methodology as on experimental plots of circular shape.

RESULTS – *Rezultati*

Analysis of fir regeneration in differently structured stands of beech and fir (with spruce) forests was done by comparison of the number of young firs, per growth categories, and total number of young fir in degree of canopy density of 0.7 (0.60 – 0.79) and 0.9 (0.80 – 1.00), and mixture ratio–share of fir (spruce) of 0.7 (60 – 79 %) and 0.9 (80 – 100 %).

Table 1. Analysis of the variance for the number of young fir of the growth category from 0.1 to 9.9 cm in height in different structured stands
Tabela 1. Analiza varijanse za brojnost podmlatka jele uzrasne kategorije od 0,1 do 9,9 cm visine u različito strukturiranim sastojinama

Sources of variation	Sum of the squares	Number of degrees of freedom	Mid squares - variances	F - variance ratio	P - level of significance
Between the groups	3,14473E8	2	1,57236E8	29,28	0,0000
Inside the groups	1,22969E9	229	5,3698E6		
Total (Correction)	1,54416E9	231			

According to Analysis of variance (ANOVA) for the number of young fir of the growth category from 0.1 to 9.9 cm in height in different structured stands, presented in table above, we can see that observed stands statistically are significantly different per number of units of young fir.

Table 2. Analysis of the variance for the number of young fir of growth category from 10.0 to 49.9 cm in height in different structured stands
Tabela 2. Analiza varijanse za brojnost podmlatka jele uzrasne kategorije od 10,0 do 49,9 cm visine u različito strukturiranim sastojinama

Sources of variation	Sum of the squares	Number of degrees of freedom	Mid squares - variances	F - variance ratio	P - level of significance
Between the groups	3,27373E8	2	1,63687E8	23,95	0,0000
Inside the groups	1,56522E9	229	6,83501E6		
Total (Correction)	1,89259E9	231			

According to Analysis of variance (ANOVA) for the number of young fir of growth category from 10.0 to 49.9 cm in height in different structured stands, it has been determined that observed stands statistically are significantly different per number of young fir of mentioned growth category ($P<0,05$).

Table 3. Analysis of the variance for the number of young fir of growth category of height from 50 to 130 cm in different structured stands
Tabela 3. Analiza varijanse za brojnost podmlatka jele uzrasne kategorije od 50 do 130 cm visine u različito strukturiranim sastojinama

Sources of variation	Sum of the squares	Number of degrees of freedom	Mid squares - variances	F - variance ratio	P - level of significance
Between the groups	1,51086E8	2	7,55432E7	79,12	0,0000
Inside the groups	2,18647E8	229	954792,		
Total (Correction)	3,69734E8	231			

According to Analysis of variance (ANOVA) for the number of young fir of growth category of height from 50 to 130 cm in different structured stands, we can see that researched stands statistically are significantly different per number of young growth of analyzed growth category ($P<0,05$) at probability of 95 %.

Table 4. Analysis of the variance for the number of young fir of the growth category from 0.1 to 5.0 cm diameter at breast height in different structured stands
Tabela 4. Analiza varijanse za brojnost podmlatka jele uzrasne kategorije od 0,1 do 5,0 cm prsnog prečnika u različito strukturiranim sastojinama

Sources of variation	Sum of the squares	Number of degrees of freedom	Mid squares - variances	F - variance ratio	P - level of significance
Between the groups	2,01485E8	2	1,00742E8	85,34	0,0000
Inside the groups	2,70334E8	229	1,1805E6		
Total (Correction)	4,71818E8	231			

Results of Analysis of variance (ANOVA) for the number of young fir of the growth category from 0.1 to 5.0 cm diameter at breast height in different structured stands, it has been determined that observed stands statistically are significantly different per number of units of young fir of mentioned growth category ($P<0,05$) at probability of 95 %.

Table 5. Analysis of the variance for the total number of young firs at the canopy density degree of 0.7 in differently structured stands
Tabela 5. Analiza varijanse za ukupnu brojnost podmlatka jele pri stepenu sklopa 0,7 u različito strukturiranim sastojinama

Sources of variation	Sum of the squares	Number of degrees of freedom	Mid squares - variances	F - variance ratio	P - level of significance
Between the groups	3,06304E7	2	1,53152E7	3,24	0,0444
Inside the groups	3,63632E8	77	4,7225E6		
Total (Correction)	3,94263E8	79			

Previous table shows the results of Analysis of variance (ANOVA) for the total number of young firs at the canopy density degree of 0.7 in differently structured stands. According to Analysis of variance we can see that researched stands statistically are significantly different per total number of units of young fir in conditions of canopy density degree of 0.7 at probability of 95 % ($P<0,05$).

Table 6. Analysis of the variance for the total number of young fir at the canopy density degree of 0.9 in differently structured stands
Tabela 6. Analiza varijanse za ukupnu brojnost podmlatka jele pri stepenu sklopa 0,9 u različito strukturiranim sastojinama

Sources of variation	Sum of the squares	Number of degrees of freedom	Mid squares - variances	F - variance ratio	P - level of significance
Between the groups	1,17918E8	2	5,8959E7	12,38	0,0000
Inside the groups	3,83491E9	805	4,76387E6		
Total (Correction)	3,95283E9	807			

Previous table contains results of Analysis of variance (ANOVA) for the total number of young fir at the canopy density degree of 0.9 in differently structured stands. Level of significance (P<0,05) shows that researched stands statistically are significantly different per total number of young fir per equal degree of canopy density (0.9).

Table 7. Analysis of the variance for the total number of young fir by the mixture ratio - the share of fir (spruce) 0.7 in differently structured stands
Tabela 7. Analiza varijanse za ukupnu brojnost podmlatka jele pri omjeru smjese – učešću jele (smrče) 0,7 u različito strukturiranim sastojinama

Sources of variation	Sum of the squares	Number of degrees of freedom	Mid squares - variances	F - variance ratio	P - level of significance
Between the groups	4,35692E7	1	4,35692E7	12,87	0,0005
Inside the groups	4,13088E8	122	3,38597E6		
Total (Correction)	4,56658E8	123			

According to the results of Analysis of variance (ANOVA), from table above, we can see that management forest and virgin forest stands statistically are significantly different (P<0,05) per total number of units of young fir in conditions of mixture ratio where fir (spruce) has a share of 0.7, i.e. where their share in total volume of the stand is 60 to 79 %.

Table 8. Analysis of the variance for the total number of young fir at the mixture ratio - the share of fir (spruce) 0,9 in differently structured stands
Tabela 8. Analiza varijanse za ukupnu brojnost podmlatka jele pri omjeru smjese – učešću jele (smrče) 0,9 u različito strukturiranim sastojinama

Sources of variation	Sum of the squares	Number of degrees of freedom	Mid squares - variances	F - variance ratio	P - level of significance
Between the groups	2,60024E7	1	2,60024E7	5,74	0,0176
Inside the groups	7,69662E8	170	4,52742E6		
Total (Correction)	7,95665E8	171			

Previous table contains results of the Analysis of variance (ANOVA) for the total number of young fir at the mixture ratio - the share of fir (spruce) 0,9 for management forest and virgin forest stands. Level of significance ($P<0,05$) confirms that these two stands statistically are significantly different per total number of the young fir in equal mixture ratio at probability of 95 %.

Accepting the results of Analysis of variance for the number of individual growth categories of young fir depending on stands of different structural development/growth, we can state that significance of stand structure impact increases with the increase in growth of young fir. Namely, value “F” increases from 29.28 for seedlings to 85.34 for the highest growth category of young fir.

DISCUSSION – *Diskusija*

Analysis of regeneration of fir in differently structured stands of virgin forests, ‘Medvjeđa lokva’ and experimental plots in management forest was done by comparison of determined number of young fir as per growth categories. Virgin forest as representative of status without impact of silvicultural measures, and other two stands as representatives of management forest in which through silvicultural measures we have formed stands of different structure.

Results of the analysis of variance confirm that three observed stands statistically are significantly different per determined number of each growth category of young fir.

When we are considering young units in virgin forest, during decision making on evaluation of regeneration one needs to be careful because young growth is very uneven. Reason for that is that the virgin forest itself is different per growth phases, and in it there are parts where regeneration is not present or is weakly expressed, but also those areas where regeneration is exuberant, which is linked to appearance of „gaps“– openings, clearings in the stand (KLOPČIČ and DIACI, 2009; MIKAC and others, 2009). Mentioned statement is confirmed with the results of this research where we can see that in virgin forest the largest number of units was recorded only in smallest growth category, while number of other growth categories is smallest compared to other analyzed stands. Reason for these results we can look for in large number of experimental areas that have had completely full canopy density, while very small number of analyzed areas had smaller degree of canopy density.

Appearance of young fir in management forest has opposite tendency than the appearance of young fir in virgin forest. While in management forests larger clearings (gaps) occurred due to intensive harvest could be a reason for reduction of number of young growth or obstacle in appearances of natural young growth, in virgin forest we have completely different situation where clearings are the main predispositions for renewal (KLOPČIČ and DIACI, 2009; MIKAC and others, 2009). In management forest through silviculture measures we can impact on degree of canopy density i.e. on quantity of available light in layer of young growth. We should not forget that the light is ecological factor on which we can have direct impact with silviculture activities/endeavors (OSTROGOVIĆ and others, 2010).

Observing the results of received dependence of numbers of young fir in differently structured stands, and in different mixture ratios, we can determine that largely the numbers of young fir depends upon the presence of beech in upper growth. However, in conditions of mixture ratio where beech is prevailing, we have recorded the smaller number in each of observed stands, while maximum numbers was determined in mixture ratio of 0.7 (60 to 80 %) fir (spruce). According to research conducted by UGARKOVIĆ and others (2011) situation with regeneration in fir-beech forests is very sensitive process which is in complex connection with numerous factors. Also, GAŠPERŠIĆ, (1974) emphasizes that on regeneration of fir the large impact is present by biochemical and microbiological processes in humus layer of the soil, connected to quantity of beech i.e. fir litter. The same author in his doctoral dissertation provides explanation in a sense that for regeneration of fir in 'Snežnik-Javornik' forests of beech and fir (in Slovenia – on border with Croatia) bioecological process which cannot be directed, stopped, or accelerated through simple technical processes and for a short time. He further concludes that for natural regeneration of fir, the more important is biological impact than ecological one. Climate impacts are not significant, but the soil type is important. He also claims that the structure of the stand is not in correlation with regeneration, stating that also not important aspects are absolute quantity of growing stock, quantity of light and absolute intensity of harvest in the past. And on the other hand, he states that largely its regeneration is impacted by the mixture of tree species in wood mass of past harvests. Especially he emphasizes errors in mass extermination of beech which results in creation of pure fir stand.

According to statements of ANIĆ, (2007) related to density of young growth and its dependence on periodicity of yield in seed, and that it changes year in and year out, the similar situation is with young growth in height of 50 cm, because mortality of young generation is intense in first years of growth. If into analysis we take only those plants whose height exceeds 50 cm than it results that status of regeneration of European silver fir is better in management and artificially directed stands comparing to virgin forest stand.

In one document, 60 years ago, ŠAFAR, (1957) suggested to us that fir is better and cheaper regenerated by maintaining such habitat and stand circumstances that suite to special biological characteristics of young fir, especially younger growth phases, presence in optimum of air and soil moisture, small microclimate extremes and good physical soil properties. This actually, from the aspect of forest tree growing, tells us that we must not too much and too suddenly open canopy density, but maintain it in a form of more dense vertical and gradual canopy density with regeneration in groups.

CONCLUSIONS – *Zaključci*

1. Maximum number of units of all growth categories of young fir has been determined with degree of canopy density of 0.7 – 0.9 and mixture ratio of 0.5 beech: 0.5 fir (spruce). Mentioned conditions of coverage of land by tree canopy and mixture ratio of tree species are optimum for regeneration of fir in researched stands.

2. Analysis of regeneration of fir in stands of different structure establishes the statistically significant differences between the number of units of young fir in differently structured stands.

3. Favorable conditions for unobstructed growth and development of individual growth categories of young fir are in stands of different structural growth/development.

4. Optimum conditions for appearance and unobstructed growth and development, for each growth category of young fir, is possible to be ensured by forming regeneration areas on which based on growth of young units, one will grow appropriate stand structure through silvicultural activities.

REFERENCES – *Literatura*

ANIĆ, I. (2007): Utjecaj strukture i pomlađivanja na potrajnost šuma bukve i jele te šuma bukve nacionalnog parka Plitvička jezera. Završno izvješće. Zagreb 2007. Str.1-62. (Impact of structure and regeneration to sustainability of beech and fir forests, and beech forests of national park 'Plitvička jezera'. Final report. Zagreb 2007. Pages 1-62.)

GAŠPERŠIČ, F. (1974): Zakonitosti naravnega pomlajevanja jelovo-bukovih gozđov na visokem Krasu Snežničko-Javorniškega masiva (Properties of natural regeneration of fir-beech forests on high karst of Snežnik-Javornik massif). Institut za gozdno in lesno gospodarstvo, Biotehniška fakulteta Univerze v Ljubljani, 1974.

Disertacija. Stranica 133. u Šafar, J., 1975: Presjek doktorske disertacije, Šumarski list broj 1-3/1975. str. 91. Zagreb.

KRAUSE, G. H. M., ARNDT, U., BRANDT, C. J., BUCHER, J., KENK, G., MATZNER, E. (1986): Forest decline in Europe; Development and possible causes. Water, Air, and Soil Pollution, 31: 647-668.

KLOPČIČ, M., DIACI, J. (2009): Gap characteristics and development of regeneration following a blowdown in old-growth forest remnant Pečka. In: Prašumski ekosustavi dinarskog krša i prirodno gospodarenje šumama u Hrvatskoj. Ed. Matić, S, Anić, I. HAZU Zagreb: 55-70.

LOJO, A., BEUS, V., MEKIĆ, F., KOPRIVICA, M., MUSIĆ, J., TREŠTIĆ., T., BALIĆ, B., ČABARAVDIĆ, A., HOČEVAR, M. (2008): Metodika druge inventure šuma na velikim površinama u Bosni i Hercegovini = Methodology of Second Forest Inventory on large areas in B&H / - Radovi Šumarskog fakulteta u Sarajevu, Sarajevo, Posebna izdanja br. 20, sv. 1, 2008. – str. 1-156.

MATIĆ, S., ORŠANIĆ, M., ORLIĆ, S., ANIĆ, I. (2001): Sjemenarstvo, rasadnička proizvodnja i šumske kulture obične jele (*Abies alba* Mill.), Monografija Obična jela (*Abies alba* Mill.) u Hrvatskoj, Akademija šumarskih znanosti, Zagreb. (2001: Seedling production, nursery production and forest species of European silver fir (*Abies alba* Mill.), Monography European silver fir (*Abies alba* Mill.) in Croatia, Academy of forestry sciences, Zagreb.)

MEKIĆ, F. (1991): Morfološke karakteristike petogodišnjih sadnica jele (*Abies alba* Mill.) sa devet lokaliteta u BiH, Univerzitet u Beogradu, Glasnik Šumarskog fakulteta, Beograd br. 73. (1991: Morphological characteristics of five-year old seedlings of European silver fir (*Abies alba* Mill.) from nine locations in B&H, University in Belgrade, Magazine of Forestry Faculty, Belgrade no. 73)

MIKAC, S., ROZENBERGAR, D., ANIĆ, I., DIACI, J. (2009): Značajke podmlađivanja u progalama dinarskih bukovo – jelovih prašuma. In: Prašumski ekosustavi dinarskog krša i prirodno gospodarenje šumama u Hrvatskoj. Ed. Matić, S, Anić, I. HAZU Zagreb: 41-54. (2009: Characteristics of regeneration in clearings of Dinaride beech-fir virgin forests. In: Virgin forest ecosystems of Dinaride karst and natural management of forests in Croatia. Ed. Matić, S, Anić, I. HAZU Zagreb: 41-54.)

OSTROGOVIĆ, M. Z., SEVER, K., ANIĆ, I. (2010): Utjecaj svjetla na prirodno pomlađivanje hrasta lužnjaka (*Quercus robur* L.) u park – šumi Maksimir u Zagrebu. Šumarski list, 134 (3–4): 115–123. (2010: Impact of light on natural regeneration of common oak (*Quercus robur* L.) in park – forest Maksimir in Zagreb. Forestry magazine, 134 (3–4): 115–123)

PINTARIĆ, K. (1970): Uticaj zasjenjenosti i pripreme zemljišta na pojavu prirodnog podmlatka jele u prebornim šumama jele, smrče i bukve na Igmanu, Radovi Šumarskog fakulteta i Instituta za šumarstvo u Sarajevu, Godina XIII (1968), Knjiga 13, sveska 3. (1970: Impact of shadow cover and preparation of soil to appearance of natural young fir in selection forests of fir, spruce and beech on Igman, Documents of Forestry Faculty and Institute for Forestry in Sarajevo, Year XIII (1968), Book 13, item 3.)

ŠAFAR, J. (1957): O podmlađivanju jele na planinskom području Hrvatske. Šumarski list broj 11-12 1957. str. 403-417. Zagreb. (On regeneration of fir on mountainous area of Croatia. Forestry magazine 11-12 1957. pages 403-417. Zagreb)

UGARKOVIĆ, D., TIKVIĆ, I., SELETKOVIĆ, Z., ORŠANIĆ, M., SELETKOVIĆ, I., BLAŽNIKOV, M., MRKONJIĆ-FUKA, M., REDŽEPOVIĆ, S. (2011): Neke mikrobiološke značajke tala i prirodno pomlađivanje šumskih otvora oštećenih šumskih ekosustava obične jele (*Abies alba* Mill.) u Gorskom Kotaru. Šumarski list br. 3–4, CXXXV (2011), 99-111. Zagreb. (2011: Some micro-biological properties of soils and natural regeneration of forest openings of damaged forest ecosystems of European silver fir (*Abies alba* Mill.) in Gorski Kotar. Forestry magazine no. 3–4, CXXXV (2011), 99-111. Zagreb)

WOLF, H. (2003): EUFORGEN Technical Guidelines for genetic conservation and use for silver fir (*Abies alba* Mill.). International Plant Genetic Resources Institute, Rome, Italy, 6 pages, Rome.

SAŽETAK

U ovom radu vršena su istraživanja podmlađivanja jele u različito strukturiranim sastojinama šuma bukve i jele (sa smrčom) na planini Bjelašnici nedaleko od Sarajeva. Analiza podmlađivanja jele u različito strukturiranim sastojinama izvršena je poređenjem broja jedinki podmlatka jele, po uzrasnim kategorijama, te ukupne brojnosti podmlatka jele pri stepenu sklopa od 0,7 (0,60 – 0,79) i 0,9 (0,80 – 1,00), te omjerom smjese – učešćem jele (smrče) 0,7 (60 – 79 %) i 0,9 (80 – 100 %). Poređenja su vršena između prašumske sastojine bukve i jele (sa smrčom) Ravna vala, zatim, dvoetažne sastojine gdje je evidentirana smjena vrsta drveća (bukva preovladava u nadstojnoj etaži dok je u podmlatku pretežno zastupljena jela) na lokalitetu Medvjeđa lokva i sastojine tipične raznodobne gospodarske šume bukve i jele (sa smrčom) u neposrednoj blizini prašumske sastojine. Prikupljanje podataka je izvršeno metodom totalnog premjera na stalnim eksperimentalnim plohama površime 1ha u prašumskoj sastojini i dvoetažnoj sastojini na lokalitetu Medvjeđa lokva, te na kružnim plohama poluprečnika 12,62 m. Pozicije eksperimantalnih ploha kružnog oblika određene su sistematskim uzorkom u obliku mreže na sjecištima Gauss-Krügerovog sistema, u razmacima od 100 metara. Mreža je položena u tri transekta po 27 ploha koji se prostiru kroz šumska odjeljenja broj: 111, 113, 114 i 115 gospodarske jedinice „Igman“, lokalitet Ravna vala. Dvije eksperimentalne plohe u obliku kvadrata površine 1 ha postavljene su, jedna u prašumskom rezervatu Ravna vala radi očuvanosti sastojine, stanje bez utjecaja čovjeka (odjeljenje 106, GJ „Igman“), a druga u gospodarskoj šumi ovog područja Medvjeđa lokva (odjeljenje 117, GJ „Igman”) radi specifične strukture sastojine. Plohe kvadratnog oblika od 1 ha površine podijeljene su mrežom kvadrata 10 x 10 m na 100 plohica. Rezultati istraživanja pokazuju da je maksimalan broj jedinki svih uzrasnih kategorija podmlatka jele utvrđen pri stepenu sklopa 0,7 – 0,9 i omjeru smjese 0,5 bukva : 0,5 jela (smrča). Navedeni uvjeti stepena zastrtosti zemljišta krošnjama stabala i omjera smjese vrsta drveća su optimalni za podmlađivanje jele u istraživanim sastojinama. Analizom podmlađivanja jele u sastojinama različite strukture ustanovljene su statistički značajne razlike između broja jedinki podmlatka jele u različito strukturiranim sastojinama. Povoljni uvjeti za nesmetan rast i razvoj pojedinih uzrasnih kategorija podmlatka jele su u sastojinama različite strukturne izgrađenosti. Optimalne uvjete za pojavu i nesmetan rast i razvoj, za svaku uzrasnu kategoriju podmlatka jele, moguće je obezbijediti formiranjem podmladnih površina na kojima će se u zavisnosti od uzrasta podmlatka, uzgojnim zahvatima izgraditi odgovarajuća struktura sastojine.

Corresponding author: Sead Ivojević, Faculty of Forestry University of Sarajevo; Zagrebačka 20, 71000 Sarajevo, Bosnia and Herzegovina; e-mail address: s.ivojevic@sfsa.unsa.ba

Works of the Faculty of Forestry
University of Sarajevo
No. 2, 2018 (17-32)

UDK 630*36:631.372]:65.015(497.6)

PRODUCTIVITY OF THE ECOTRAC 120V SKIDDER FOR TIMBER SKIDDING IN THE AREA OF *MU „IGMAN “*

Produktivnost skidera Ecotrac 120V pri privlačenju drveta na području PJ „Igman”

Jelena Knežević[1], Safet Gurda[1], Jusuf Musić[1], Velid Halilović[1], Aldin Vranović[1]

Abstract

This paper presents the research results of the skidding productivity for the Ecotrac 120V skidder in mountainous areas of MU „Igman” in Bosnia and Herzegovina. Time and work study were performed. Multiple regression analysis was used for determination of work operations time consumption depending on influencing factors. The following influencing factors were recorded: the condition of the tractor road (surface), the skidding distance, the winching distance, number of pieces in the load, the volume of the load and the slope of the tractor road. The share of productive time in the total work time is 58.47%. The average value of the influencing factors was established: unloaded travel distance 585.26 m, loaded travel distance 490.49 m, winching distance 16.83 m, number of pieces in the load 5.95, the volume of the load 5.17 m^3 and the volume of the piece in the load 1.02 m^3. The half-tree length method was used. Standard time for skidding and daily skidding productivity were expressed depending on the skidding distance, while average values were used for other influencing factors. The standard time for skidding was 6.57 min/m^3 at a skidding distance of 100 m, i.e. 17.60 min/m^3 at a skidding distance of 1,500 m. The daily skidding productivity ranges from 73.07 m^3/day at a skidding distance of 100 m to 27.28 m^3/day at a skidding distance of 1,500 m. Comparison of the daily skidding productivity with the results of other researches showed that the Ecotrac 120V skidder in this particular case realizes approximately the same skidding productivity under similar working conditions.

Key words: *timber skidding, Ecotrac 120V, skidding productivity, time and work study.*

INTRODUCTION - *Uvod*

The forest areas of Bosnia and Herzegovina are primarily located in hilly and mountainous regions. The orographic terrain structure causes a complicated and expensive timber transport in all phases (MIHAĆ, 1977). Timber skidding represents the

[1] University of Sarajevo, Faculty of Forestry, Zagrebačka 20, 71000 Sarajevo, Bosnia and Herzegovina

key phase of forest harvesting from the aspect of labor cost as well as damaging the stands and forest soil (KULUŠIĆ, 1990).

Timber skidding represents the transport of cut wood in different production degrees (from the finalized wood assortment to the whole tree) from the stump to the closest road or, in rare cases, to the production or distribution facility (KULUŠIĆ, 1990). The most common timber transport type is skidding, respectively hauling by tractors, and in Bosnia and Herzegovina it is almost exclusively skidding by tractors on the ground (SOKOLOVIĆ and MUSIĆ 2009).

The most common means of work in Bosnia and Herzegovina are a chainsaw in the felling and processing phase and a cable skidder in the skidding phase. Animals, cableways and other means of work are used to a lesser extent, far lesser than it is demanded by the terrain and stand conditions.

The research of means of work for skidding phase in the Federation of Bosnia and Herzegovina showed that timber skidding is carried out by 195 tractors, out of which 85% are skidders (HALILOVIĆ et al. 2015). Different Timberjack and LKT types are the most common among the skidders. In recent years there has been interest by forest enterprises in acquiring the Ecotrac skidders produced by the Croatian manufacturer Hittner and their employment in the timber skidding phase.

The research of skidding productivity in the area of Bosnia and Herzegovina began in the 1970s (MIHAĆ, 1977; KULUŠIĆ and MIODRAGOVIĆ 1979; JOVANOVIĆ, 1980; ŠIPAD - IRC 1989; JOVANOVIĆ, 1990; JAKUPOVIĆ, 2003; HALILOVIĆ, 2012; MARČETA, 2015) and included different skidder types (IMT 533, IMT 558, IMT 560, IMT 561, IMT 567, IMT 577, IMT 586, Belt GV 70, Tree Farmer C4 D, Tree Farmer C5 D, LKT 80, LKT 81, LKT 81T, LKT 120, Timberjack 208 D, Timberjack 209 D, Timberjack 225, Timberjack 350A).

More recent research in the forest harvesting in our country offer an overview of LKT 81T skidding productivity. Daily skidding productivity of the above-mentioned skidder ranges from 42.29 m^3/day for a load volume of 2.80 m^3 and cut to length method to 83.64 m^3/day for a load volume of 6.62 m^3 and the half-tree length method. The above showed skidding productivities have been determined for skidding distance of 250 m (MARČETA, 2015).

BORZ, (2015) offered a general overview of Romanian and international research on wood skidding. Net skidding productivity (without delays) is in a range between 1.26 m^3/h and 22.93 m^3/h, averaging 7.89 m^3/h.

Skidding productivity of the Ecotrac 120V skidder depending on the most important influencing factors has not been the subject of research in Bosnia and Herzegovina. The productivity and morphological features of the skidder in the area of Croatia were presented in the works by ZEČIĆ, (2006), HORVAT et al. (2007) and ZEČIĆ et al. (2008).

ZEČIĆ, (2006) was researching the skidding productivity of the Ecotrac 120V in two working areas, hilly (Koprivnica) and mountainous (Senj) conditions, i.e. in preparatory and selective felling. The daily skidding productivity for the first area was determined in a range from 62.22 m^3/day at a skidding distance of 50 m to 35.74 m^3/day at a skidding distance of 500 m, and on the other area, from 50.53 m^3/day at a skidding distance of 50 m to 35.54 m^3/day at a skidding distance of 500 m.

According to the research by ZEČIĆ et al. (2008), the daily skidding productivity of the Ecotrac 120V skidder is 44.08 m^3 for regeneration felling in hilly and lowland areas in Croatia. The skidder productivity is presented for the average skidding distance of 300 m on skid roads and 50 m on the roadside landing, average load volume of 2.78 m^3 and average volume of the piece in the load of 0.35 m^3.

ZEČIĆ and VUSIĆ (2009) offered an overview of skidding productivity for the Ecotrac 120V skidder created for the purposes of the enterprise „Hrvatske šume" d.o.o. The skidding productivity was determined for timber skidding without chokerman.

AKAY et al. (2004) distinguish the timber skidding distance as a factor with the most important influence on the total transport cycle time during timber skidding using forest skidders. A longer skidding distance increases the transportation time. The slope of the skid road influences the total transport cycle time in a manner that on steep skid roads, the moving speed is lower which increases the duration of the cycle. The load weight also influences the decrease in moving speed, especially on steep roads during uphill timber skidding.

MATERIAL AND METHODS - *Materijal i metode*

The research was conducted in the area managed by *Forest enterprise „Sarajevo šume "d.o.o. Sarajevo*, in forest compartment 151, management unit „Igman". The area of compartment is 56,96 ha. A total of 1.818,59 m^3 net wood was marked for felling, 69% broadleaves and 31% conifers. Timber skidding was conducted by the Ecotrac 120V skidder. This is a four-wheeled (4x4) vehicle which, together with the operator, weights 7,257 kg, 59% of which is at the front and 41% on the rear axle. It comes with a Diesel engine (Deutz D914-L06) of a nominal power of 86 kW. It is equipped with a double-drum winch of 80 kN nominal tractive force. The winch cable is 14 mm in diameter and 70 m long in each drum. The winch is driven hydraulically, and the steering is electro-hydraulical. The rear anchoring blade is used for receiving, protecting and anchoring purposes and it can be lifted or lowered using two hydraulic cylinders. The Ecotrac 120 V skidder is characterized by a small width considering its length, due to the need of moving on built skid roads of a total width of 2.5 m. The unfavourable increase of the skidder length does not impact its mobility due to the centrally installed articulated joint. Due to the increased engine power relative to skidder mass, it is possible to increase travelling speed and provided the wheel thrust force required for overcoming the tractive and rolling resistance, by which work efficiency would also be increased and particularly so on sloped terrain (HORVAT et al. 2007).
Time and work study were performed. The duration of certain categories of work time was determined using the „snap-back chronometry method" which is often used in research of skidding productivity (KULUŠIĆ and MIODRAGOVIĆ 1979; JOVANOVIĆ,

1980; SABO and PORŠINSKY 2005; ZEČIĆ, 2006; ZEČIĆ and VUSIĆ 2009; ZEČIĆ et al. 2011; HALILOVIĆ, 2012; VUSIĆ et al. 2013; MARČETA, 2015).

The total work time is divided to productive time and delay times. The following work operations are part of productive time: unloaded travel, positioning of the skidder, pulling out the winch cable, hooking the load, winching, forming the total load, driving for collecting the load, loaded travel, winching during the loaded travel, unhooking the load and decking. Delay times are divided into allowance time, avoidable delays and delays due to recording. Allowance time encompasses preparatory-final time and unavoidable delay times (KULUŠIĆ and MIODRAGOVIĆ 1979). The following allowance time categories have been specified: preparatory-final time, organizational delays, technical delays, meal time, delays due to rest and personal needs of workers, delays due to load and other unavoidable delays. During the implementation of the time and work study avoidable delays which represent subjectively motivated delays without justified need were also recorded. A special category within the work delay times were delays due to unfavorable weather conditions which include delays caused by rain or snow. Avoidable delays, delays due to recording and delays due to unfavorable weather conditions were not considered while calculating standard time for skidding and daily skidding productivity.

The duration of work time categories was recorded using the *Hanhart* stopwatch which measures time in minutes and hundredths of a minute ($\text{min}\cdot10^{-2}$; 1/100 min). This is the most common technique in conducting work studies (MAGAGNOTTI and SPINELLI 2012). The following influencing factors were recorded: the condition of the tractor road (surface), skidding distance, winching distance, number of pieces in the load, the volume of the load and the slope of the tractor road.

Skidding distance was measured using a measuring tape, and the winching distance using the *Haglöf Vertex* instrument. The recording showed that the skidding distance is not a unique value for unloaded and loaded travel due to load formation on a several places along the tractor road. Therefore, the unloaded travel distance was determined separately from the loaded travel distance. The volume of the load was determined by measuring the diameter and length of certain pieces using caliper and measuring tape. The measurements were conducted in accordance with the JUS D.BO. 022 standard from 1984. The average slope of the tractor road was calculated as the weighted arithmetic mean of measured lengths of uniform slope segments with the related measured slope, according to the methodology used by ZEČIĆ and VUSIĆ (2009). The tractor road slope is presented in percentage (%). The inclination mark (-/+) was determined in the direction of loaded travel. The mark „-" signifies downhill timber skidding and the mark „+" signifies uphill timber skidding. Slope measurement was conducted using the *Haglöf Vertex III* instrument. The statistical program *STATGRAPHICS Centurion XVII* was used for data processing and result interpretation.

RESULTS - *Rezultati*

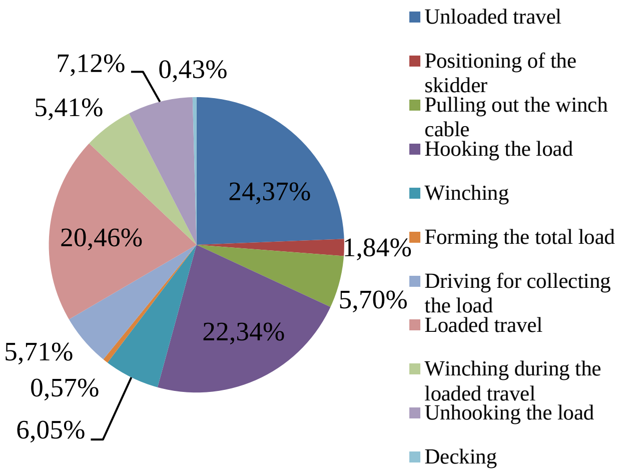
The recording of skidding productivity was conducted during the winter work season. There was no snowfall during the recording. The average air temperature determined at the nearest meteorological station „Bjelašnica" was 0.3ºC. The work organization 1+1 was applied, skidder operator and chokerman. This work organization means that the operator only operates the skidder and winch, while the chokerman performs the tasks of pulling out the winch cable, hooking the load and unhooking the load. Forty-three cycles were recorded. A total of 222.36 m^3 timber was skidded, 54% broadleaves (beech), and 46% conifer (fir and spruce). The half-tree length method was applied.

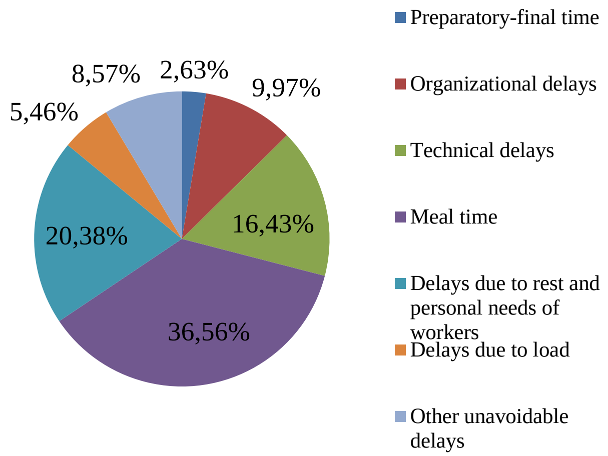
Work time analysis - *Analiza radnog vremena*

The structure of total work time is presented in Table 1, and the structures of productive and allowance time are shown in Graph 1 and 2.

Table 1. Structure of total work time
Tabela 1. Struktura ukupnog radnog vremena

Work time category	Total duration of the work time category (min)	Percentage share in the total work time (%)
Productive time	1,539.53	58.47
Allowance time	597.13	22.68
Avoidable delays	143.99	5.46
Delays due to unfavorable weather conditions	346.27	13.15
Delays due to recording	6.29	0.24
Total work time	2,633.21	100.00
Volume of skidded timber (m^3)	222.36	
Productive time per unit (min/m^3)	6.92	
Total time per unit (min/m^3)	11.84	
Average daily productivity (m^3/day)	31.77	



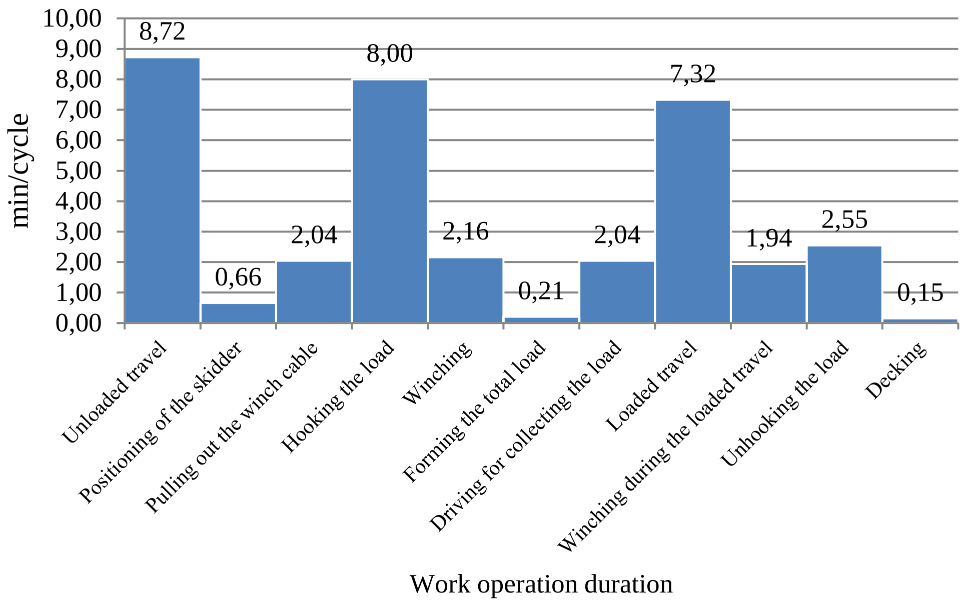


Graph 1. Productive time structure
Grafikon 1. Struktura operativnog vremena

Graph 2. Allowance time structure
Grafikon 2. Struktura dodatnog vremena

The share of productive time in total work time is 58.47%, and the share of allowance time is 22.68%. The largest share in productive time has the unloaded travel (24.37%), and the smallest decking (0.43%). In the category of allowance time, the most common are delays due meal time (36.56%), and the smallest share has preparatory-final time (2.63%).

The analysis of work operations within the cycle (Graph 3) showed that the longest average duration has unloaded travel (8.72 min/cycle). The shortest duration has decking (0.15 min/cycle).



Graph 3. Average duration of work operations
Grafikon 3. Prosječno trajanje radnih operacija

Influencing factors analysis - *Analiza uticajnih faktora*

The data on the influencing factors is presented in Table 2. The surface of the tractor road is described as dry to moist during 95% of the cycles, i.e. wet during 5% of the cycles. The slope of the tractor road for certain cycles was in the range from -21.52% to 20.04%. The average slope of tractor roads, determined as the weighted arithmetic mean of certain cycles slopes and corresponding skidding distances of loaded travels, was -12.05%.

Table 2. Basic statistical indicators of recorded influencing factors
Tabela 2. Osnovni statistički pokazatelji snimljenih uticajnih faktora

Influencing factor	Unit of measure	Average value	Minimum value	Maximum value	Standard deviation
Unloaded travel skidding distance	m	585.26	27.00	1,791.00	532.38
Loaded travel skidding distance	m	490.49	17.00	1,526.00	486.60
Winching distance	m	16.83	5.00	36.50	7.48
No. of pieces in the load		5.95	1.00	11.00	2.45
Volume of the load	m^3	5.17	1.11	9.67	1.69
Average volume of piece in the load	m^3	1.02	0.28	2.91	0.52

Standard time for skidding and daily skidding productivity - ***Norme vremena i učinka traktora***

The influence of certain influencing factors on the standard time for skidding and daily skidding productivity was determined using the multiple regression analysis according to the following general equation (ČABARAVDIĆ, 2017):

$$\hat{Y}_e = \beta_0 + \beta_i x_{ie} + ... + e_e \text{ ; with:}$$

$\hat{Y}_e$ - estimate of the depending variable in the population (e = 1, ...n),
β_i - model parameters (i = 1, ...k),
x_{ie} - independent variables,
e_e - random mistake.

Stepwise regression was applied. This procedure encompasses choosing a model which contains only statistically relevant independent variables but does not exclude any useful variables. The *Backward Selection* option was used, which begins with the model with all variables included and then excludes one variable at a time until the model is reached in which all the remaining variables are statistically important. One selection criterion was the p-value of 0.05.

The results of the conducted regression analysis are presented in Table 3. The duration of unloaded travel was analyzed according to influencing factors of the skidding distance and the slope of the tractor road; the analysis of duration of loaded travel also included the load volume and number of pieces in the load. The duration of pulling out the winch cable and winching was analyzed depending on the following influencing factors: winching distance, number of pieces in the load and load volume, and the duration of hooking the load, forming the total load, unhooking the load and decking depending on the number of pieces in the load and the volume of the load. The selected regression model for certain work operations encompassed only the statistically significant independent variables. The duration of work operations: positioning of the skidder, driving for collecting the load and winching during the loaded travel is expressed as an average value of the recorded data. The statistical significance of analyzed independent variables on the duration of the work operation decking has not been confirmed, thus the average value of recorded data was used in calculating standard time for skidding and daily skidding productivity.

Table 3. Regression analysis results
Tabela 3. Rezultati regresione analize

Dependent variable	Independent variable(s)	Determination coefficient (R^2)	Standard Error of Estimation	Estimation importance level (p)	Regression model/ Average duration of the work operation (min/cycle)
T_{UT}	utsd	97.68	1.32	0.0000	T_{UT}=0.3237+0.0159·utsd
T_{SP}	-	-	-	-	T_{SP}=0.66
T_{PW}	wd	31.09	0.94	0.0009	T_{PW}=-0.5854+0.0778·wd+0.2279·np
	np			0.0013	
T_H	np	49.96	2.33	0.0000	T_H=0.9789+0.7298·np+0.5514·lv
	lv			0.0192	
T_W	wd	25.70	0.98	0.0019	T_W=-0.2034+0.0753·wd+0.1921·np
	np			0.0080	
T_{FTL}	lv	15.43	0.42	0.0387	T_{FTL}=-0.3349+0.1163·lv
T_{CL}	-	-	-	-	T_{CL}=2.04
T_{LT}	ltsd	95.28	1.47	0.0000	T_{LT}=1.1170+0.0134·ltsd
T_{WD}	-	-	-	-	T_{WD}=1.94
T_{UH}	np	58.98	0.83	0.0000	T_{UH}=0.1607+0.4012·np
T_D	np	-	-	-	T_D=0.15
	lv				

T_{UT} - time consumption for unloaded travel; T_{SP} - time consumption for skidder positioning; T_{PW} - time consumption for pulling out the winch cable; T_H - time consumption for the hooking the load; T_W - time consumption for the winching; T_{FTL} - time consumption for the forming the total load; T_{CL} - time consumption for the driving for collecting the load; T_{WD} - time consumption for the winching during the loaded travel; T_{LT} - time consumption for the loaded travel; T_{UH} - time consumption for the unhooking the load; T_D - time consumption for the decking; utsd - unloaded travel skidding distance (m); wd - winching distance (m); np - number of pieces in the load; lv - volume of the load (m^3); ltsd - loaded travel skidding distance (m).

The determined standard time for skidding and daily skidding productivity are presented in Table 4. The standard time for skidding was calculated by dividing the productive work time increased by the coefficient of allowance time with the average volume of the load, and the daily skidding productivity was calculated by dividing the eight-hour work day (480 min) with the standard time for skidding. The coefficient of allowance time is 1.39. The results are presented depending on the skidding distance, while for other influencing factors, average values have been used.

Table 4. Standard time for skidding and daily skidding productivity
Tabela 4. Norme vremena i učinka

Skidding distance (m)	Standard time for skidding (min/m^3)	Daily skidding productivity (m^3/day)	Daily skidding productivity decrease factor
100	6.57	73.07	1.00
200	7.36	65.24	0.89
300	8.14	58.93	0.81
400	8.93	53.74	0.74
500	9.72	49.38	0.68
600	10.51	45.68	0.63
700	11.30	42.49	0.58
800	12.08	39.72	0.55
900	12.87	37.29	0.51
1,000	13.66	35.14	0.48
1,100	14.45	33.23	0.46
1,200	15.23	31.51	0.43
1,300	16.02	29.96	0.41
1,400	16.81	28.55	0.39
1,500	17.60	27.28	0.37

The standard time for skidding is 6.57 min/m^3 at a skidding distance of 100 m, i.e. 17.60 min/m^3 at a skidding distance of 1,500 m. The daily skidding productivity ranges from 73.07 m^3/day at a skidding distance of 100 m to 27.28 m^3/day at a skidding distance of 1,500 m. The standard time for skidding is 9,65 min/m^3, daily skidding productivity 49,76 m^3/day at average skidding distance for loaded travel (490,49 m).

DISCUSSION - *Diskusija*

The determined percentage share of productive time in total work time (58.47%) has been compared to the results of other researches of the skidding productivity for the Ecotrac 120V skidder or other skidders under similar work conditions. ZEČIĆ, (2006) found the share of productive time in the total work time for timber skidding by the Ecotrac 120V skidder in hilly and mountainous conditions, i.e. the preparatory and selective felling in amount of 47.06%, i.e. 80.20%. MARČETA, (2015) determined a higher share of productive time in total time (76.25%) compared to the presented result in timber skidding by the LKT 81T skidder for the half-tree length method. SABO and PORŠINSKY (2005) state that the share of productive time in total work time is 67.50%, i.e. 68.16% in fir timber skidding using the forest Timberjack 240C cable skidder with a double-drum winch at two compartments with different levels of stoniness. ZEČIĆ et al. (2011) reached similar results (64.39%) for the same type of skidder (Timberjack 240C) with a double-drum winch while skidding timber in selection forests using the half-tree length method.

The determined productive time per product unit (6.92 min/m^3 and 11.84 min/m^3) is shorter regarding to the results reached by ZEČIĆ, (2006). This author determined the following values while skidding timber by the same skidder: 8.06 min/m^3 and 17.14 min/m^3 in hilly conditions, respectively 9.88 min/m^3 and 12.31 min/m^3 in mountainous work conditions. The determined daily skidding productivity (31.77 m^3/day) is similar to the result reached by the before-mentioned author for mountainous work conditions (31.88 m^3/RD).

The determined coefficient of allowance time (1.39) is somewhat larger comparing to the results determined by ZEČIĆ, (2006) who found the factors of allowance time 1.34 and 1.18 for same skidder and MARČETA, (2015) who determined coefficients of allowance time 1.30 and 1.31 while using the assortment, respectively half-tree length method during timber skidding by the LKT 81T skidder.

The structure of productive work time showed that unloaded travel has the largest share in productive work time (24.37%) and decking the smallest (0.43%). Loaded travel time has a smaller share in the productive work time (20.46%) comparing to unloaded travel. However, if we add the time of winching during the loaded travel to the loaded travel time, we reach a share of 25.87%. MARČETA, (2015) determined that the highest percentage share in productive work time has the loaded travel (22%), and the lowest forming of load (4%). ZEČIĆ, (2006) states that the largest share in productive work time has the work at the felling site (36.02%, i.e. 48.96%) on both sites, in hilly and mountainous work conditions. If we sum up all the work operations connected to the felling site, we reach that the percentage share of work at the felling site in the total work time for the conducted research is 34.66%. SABO and PORŠINSKY (2005) also confirmed that in the structure of productive work time, felling site work has the largest share on both sites of the research (44.60% and 46.40%).

In the category of allowance time, the most common are delays due to meal time (36.56%), while preparatory-final time has the lowest share (2.63%). ZEČIĆ, (2006) also ascertained that delays due to meal time has the largest share in allowance time (38.60% and 36.29%). The results of the same research show a significantly larger share of the preparatory-final time (35.10% and 21.28%) comparing to recorded data. MARČETA, (2015) states that personal delays have the largest share in allowance time (33%), and the technical delays the lowest share (17%) for half-tree length method.

Comparing the characteristics of the load with the results of other researches brings us to the conclusion that the presented results (Table 2) are very similar to the results reached by ZEČIĆ, (2006) for researching the skidding productivity of the Ecotrac 120V skidder in mountainous conditions (average load volume: 5.34 m^3; average number of pieces in the load: 5.70 and average volume of the pieces in the load: 0.93 m^3). A smaller average volume of the load and the pieces in the load was determined while operating the same skidder in hilly conditions compared to the presented results (Table 2). ZEČIĆ et al. (2008) found that average volume of the load for timber skidding by the Ecotrac 120V skidder in the regeneration fellings in hilly and lowland areas of Croatia is 2.78 m^3, and average volume of pieces in the load is 0.35 m^3 using the half-tree method. MARČETA, (2015) determined the average volume of the load to be 3.56 m^3, average number of pieces in the load 11.09, average volume of the piece in the load 0.33 m^3, i.e. 6.62 m^3, 9.57, 0.75 m^3 for timber skidding by the LKT 81T forest skidder and the half-tree method in two sites.

Performing of the multiple regression analysis it was determined that the loaded travel skidding distance has an exclusive statistically significant influence on the loaded travel time consumption, while the influence of the volume of the load, number of pieces in the load and the slope of the tractor road is not statistically significant. The research by ZEČIĆ and MARENČE (2005) showed that the skidding distance and the slope of tractor road have a statistically significantt influence ($p<0.05$) on the work operation loaded travel for the Ecotrac V 1033 F skidder, while the influence of the volume of the load and the number of pieces in the load has not been statistically significant. In addition, JOVANOVIĆ, (1990) states that the skidding distance best characterizes the times of unloaded and loaded travel of the tractor. The performed regression analysis did not show statistically significant influence of the load volume and the number of the pieces in the load on the work operation of decking. In analyzing the results of published Romanian and international research in the area of timber skidding, BORZ, (2015) concluded that the time consumption per cycle depends on the skidding distance, winching distance and the number of pieces in the load, while the skidder productivity is likely to be affected also by the used practice such as the load volume, which can compensate for the long skidding distances in terms of productivity. The conducted research determined the statistically significant influence of the before-mentioned factors on the duration of individual work operations of the cycle.

The determination coefficient higher than 90% was determined for the dependence of time consumption of unloaded travel and loaded travel depending on the skidding distance of the unloaded, i.e. loaded travel.

The skidding productivity ranges from 73.07 m^3/day at a skidding distance of 100 m to 27.28 m^3/day at a skidding distance of 1,500 m. The presented results are calculated for average values of influencing factors: winching distance 16.83 m, number of pieces in the load 5.95, volume of the load 5.17 m^3 and the volume of the piece in the load 1.02 m^3. The average slope of tractor roads for loaded travel is -12.05%. ZEČIĆ, (2006) determined that the daily skidding productivity of the same skidder in timber skidding in similar stand and field conditions ranges from 50.53 m^3/day at a skidding distance of 50 m to 35.54 m^3/day at a skidding distance of 500 m. The average volume of the load in the presented research was 5.34 m^3, the average number of pieces in a load was 5.70 and the average volume of the pieces in the load was 0.93 m^3. The average slope of the tractor roads for loaded travel was -9%. In addition, the same method (half-tree length) was applied. The share of beech in the skidded timber was 84.30 %, and fir 15.70%. ZEČIĆ et al. (2008) state that the daily skidding productivity for the Ecotrac 120V skidder is 44.08 m^3/day at an average skidding distance of 300 m on skid trails and felling site and 50 m at the roadside landing. The results are presented for to the regeneration felling in hilly and lowlands areas in Croatia for the half-tree length method, average load volume of 2.78 m^3 and average volume of the piece in the load of 0.35 m^3.

CONCLUSIONS - *Zaključci*

Timber skidding using cable skidders is the most common manner of timber transport in Bosnia and Herzegovina. In the last years, we have witnessed the modernization of means of work in the timber skidding phase which does not follow the determination of their objective productivity depending on the most influencing factors. The presented results contribute to establishing standard time for skidding and skidding productivity in the work of the Ecotrac 120V skidder for the area of Bosnia and Herzegovina. The comparison of determined work skidding productivity with results from other researches showed that the Ecotrac 120V skidder, in this particular case, realizes approximately the same skidding productivity under similar work conditions. Based on the conducted analysis, it can be concluded that there is the possibility of an enhanced productivity through better work organization and lowering the share of delays in the total work time.

REFERENCES - *Literatura*

AKAY, A.E., ERDAŞ, O., SESSIONS, J. (2004). Determining Productivity of Mechanized Harvesting Machines. *Journal of Applied Sciences*. 4(1): 100-105.

BORZ, S.A. (2015). A review of the Romanian and international practices in skidding operations. *XIV World Forestry Congress*. Durban, South Africa, 7-11 September 2015.

ČABARAVDIĆ, A. (2017). *Biometrika u šumarstvu i hortikulturi*. Sarajevo: Šumarski fakultet Univerziteta u Sarajevu.

GURDA S., JOVANOVIĆ, B., MUSIĆ, J., HALILOVIĆ, V. (2010). Tehnologije u šumarstvu, standardi šumskih drvnih sortimenata i šumska biomasa. Završni izvještaj studije. Sarajevo: Federalno Ministarstvo poljoprivrede, vodoprivrede i šumarstva.

HALILOVIĆ, V. (2012). Komparacija metoda dobivanja šumske biomase kao obnovljivog izvora energije iz hrastovih sastojina. Doktorska disertacija. Sarajevo: Univerzitet u Sarajevu, Šumarski fakultet.

HALILOVIĆ, V., GURDA, S., SOKOLOVIĆ, DŽ., MUSIĆ, J., BAJRIĆ, M. (2013). Analiza utroška vremena pri sječi i izradi stabala hrasta kitnjaka primjenom sortimentnog metoda rada. *Naše šume*. 30-31: 4-13.

HALILOVIĆ, V., MUSIĆ, J., GURDA, S., TOPALOVIĆ, J. (2015). Analysis of the means of forest harvesting in the Federation of Bosnia and Herzegovina. *Glasnik Šumarskog fakulteta Univerziteta u Beogradu*. Posebno izdanje (2015): 55-62.

HORVAT, D., ZEČIĆ, Ž., ŠUŠNJAR, M. (2007). Morfološke i proizvodne značajke traktora Ecotrac 120V. *Nova mehanizacija šumarstva*. 28, Posebno izdanje 1: 81-92.

IZVEDBENI PROJEKAT (2017). *Odjeljenje 151 PJ „Igman"*. Kantonalno javno preduzeće za gospodarenje državnim šumama „Sarajevo šume "d.o.o. Sarajevo.

JAKUPOVIĆ, DŽ. (2003). Istraživanje optimalne tehnologije sječe, izrade i transporta drveta iz prorednih sječa u kulturama bijelog bora. Magistarski rad. Sarajevo: Univerzitet u Sarajevu, Šumarski fakultet.

JOVANOVIĆ, B. (1980). Istraživanja utroška vremena za dvije tehnologije rada kod eksploatacije bukovih šuma u SR Bosni i Hercegovini. Magistarski rad. Zagreb: Sveučilište u Zagrebu, Šumarski Fakultet.

JOVANOVIĆ, B. (1990). Komparativno istraživanje tehničko-tehnoloških karakteristika traktora pri privlačenju drva. Doktorska disertacija. Zagreb: Sveučilište u Zagrebu, Šumarski fakultet.

JOVANOVIĆ, B., GURDA, S., MUSIĆ, J., BAJRIĆ, M., LOJO, A., VOJNIKOVIĆ, S. ČABARAVDIĆ, A. (2005). Šumska biomasa - potencijalni izvor obnovljive energije u Bosni i Hercegovini. Posebno izdanje, 19. Sarajevo: Univerzitet u Sarajevu, Šumarski fakultet.

KULUŠIĆ, B. (1990). Karakteristike šumskih terena kao indikatori izbora tehnologije privlačenja drveta. *Šumarski list*. 114(11-12): 463-473.

KULUŠIĆ, B., MIODRAGOVIĆ, D. (1979). Prilog istraživanju tehnološkog procesa sječe, izrade i privlačenja drveta pri iskorišćavanju borovih i hrastovih šuma u BiH. *Radovi Šumarskog fakulteta i Instituta za šumarstvo u Sarajevu*. 22(5-6): 3-93.

MAGAGNOTTI, N., SPINELLI, R. (EDS.) (2012). COST Action FP0902 – *Good Practice Guidelines for Biomass Production Studies*. Firence: CNR IVALSA.

MARČETA, D. (2015). Comparison of technologies of wood biomass utilization in beech stands. Doctoral dissertation. Ljubljana: University of Ljubljana, Biotechnical faculty.

MIHAĆ, B. (1977). Privlačenje, utovar i transport drveta. *Radovi Šumarskog fakulteta i Instituta za šumarstvo u Sarajevu*. 21(1-2): 3-63

SABO, A., PORŠINSKY, T. (2005). Skidding of fir roundwood by Timberjack 240C from selective forests of Gorski Kotar. *Croatian Journal of Forest Engineering*. 26(1): 13-27.

SOKOLOVIĆ, DŽ., MUSIĆ, J. (2009). Privlačenje drveta šumskim žičarama. *Naše šume*. 14-15: 33-41.

ŠIPAD - IRC (1989). Tehničke norme rada u iskorišćavanju šuma. Sarajevo: ŠIPAD - IRC, OOUR SILVA.

VUSIĆ, D., ŠUŠNJAR, M., MARCHI, E., SPINA, R., ZEČIĆ, Ž., PICCHIO, R. (2013). Skidding operations in thinning and shelterwood cut of mixed stands - Work productivity, energy inputs and emissions. *Ecological engineering*. 61: 216-223.

ZEČIĆ, Ž. (2006). Usporedba djelotvornosti traktora Ecotrac 120 V pri privlačenju drva u brdskim i gorskim uvjetima. *Glasnik za šumske pokuse*. Posebno izdanje br. 5: 557-571.

ZEČIĆ, Ž., MARENČE, J. (2005). Mathematical models for optimization of group work in harvesting operation. *Croatian Journal of Forest Engineering*. 26(1): 29-37.

ZEČIĆ, Ž., PENTEK, T., VUSIĆ, D., NEVEČEREL, H., STANKIĆ, I., LEPOGLAVEC, K., BOSNER, A. (2008). Exploitation and Productivity Characteristics of the new Croatian Skidders Ecotrac 55 V and Ecotrac 120 V. In: *Proceedings of „Formec" 41. International Syposium*. Schmallenberg, Germany, 2-5 June 2008.

ZEČIĆ, Ž., VUSIĆ, D. (2009). *Računalne norme privlačenja drva traktorima (RANOP)*. Zagreb: Šumarski fakultet Sveučilišta u Zagrebu.

ZEČIĆ, Ž., VUSIĆ, D., MILKOVIĆ, D., ZORIĆ, M. (2011). Skidder with single-drum or double drum winch in mountainous areas – A case study from selective forests of Croatia. In: *44th International Symposium on Forestry Mechanisation: „Pushing the Boundaries with Research and Innovation in Forest Engineering"*. Graz, Austria, 9-13 October 2011.

SAŽETAK

U radu su prikazani rezultati istraživanja efekata rada šumskog zglobnog traktora Ecotrac 120V, koji se sve više koristi za privlačenje drveta u bosanskohercegovačkim preduzećima šumarstva. Istraživanje je provedeno u šumskom odjeljenju 151 PJ „Igman", planinskog područja Igman. Primijenjen je studij rada i vremena. Trajanje radnog vremena je ustanovljeno primjenom povratnog metoda snimanja. Zavisnost vremena trajanja radnih operacija od uticajnih faktora je utvrđena uz primjenu višestruke regresione analize. Primijenjen je poludeblovni metod izrade drveta. Snimljeni su sljedeći uticajni faktori: stanje traktorskog puta (podloge), distanca privlačenja drveta traktorom, distanca primicanja drveta vitlom, broj komada u teretu, zapremina tereta i uzdužni nagib traktorskog puta. Udio operativnog vremena u ukupnom radnom vremenu iznosi 58,47%, a udio dodatnog vremena 22,68%. Najveći dio operativnog vremena otpada na radnu operaciju prazna vožnja (24,37%), a najmanji na radnu operaciju meglanje (0,43%). U kategoriji dodatnog vremena najzastupljeniji su prekidi zbog jela (36,56%), dok najmanji udio ima pripremno-završno vrijeme (2,63%). Analiza radnih operacija u okviru transportnog ciklusa je pokazala da najveće prosječno trajanje ima radna operacija prazna vožnja (8,72 min/tc). Najmanje prosječno trajanje ima radna operacija meglanje (0,15 min/tc). Utvrđena je prosječna vrijednost uticajnih faktora: distanca prazne vožnje 585,26 m, distanca pune vožnja 490,49 m, distanca primicanja 16,83 m, broj komada u teretu 5,95, zapremina tereta 5,17 m^3 i prosječna zapremina komada u teretu 1,02 m^3. Primjenom višestruke regresione analize

je utvrđeno da na vrijeme radnih operacije prazna vožnja i puna vožnja statistički značajan uticaj imaju distanca prazne vožnje i distanca pune vožnje. Vrijeme radnih operacija izvlačenje užeta vitla i primicanje vitlom zavisi od distance primicanja i broja komada u teretu. Vrijeme radne operacije vezivanje tereta zavisi od broja komada u teretu i zapremine tereta, vrijeme radne operacije formiranje ukupnog tereta od zapremine tereta a vrijeme radne operacije odvezivanje tereta od broja komada u teretu. Norme vremena i učinka su izražene u zavisnosti od distance privlačenja, dok su za druge uticajne faktore korištene prosječne vrijednosti. Utvrđena je norma vremena od 6,57 min/m^3 za distancu privlačenja drveta 100 m, odnosno 17,60 min/m^3 za distancu privlačenja 1.500 m. Dnevni učinak traktora se kreće u intervalu od 73,07 m^3/RD za distancu privlačenja 100 m do 27,28 m^3/RD za distancu privlačenja 1.500 m.

Corresponding author: Jelena Knežević; University of Sarajevo, Faculty of Forestry; Zagrebačka 20, 71000 Sarajevo, Bosnia and Herzegovina; e-mail address: j.knezevic@sfsa.unsa.ba

Works of the Faculty of Forestry
University of Sarajevo
No. 2, 2018 (33-40)

UDK 631.547.1:582.665.11]:630*232(560)
631.547.1: 582.746.46]:630*232(560)

DETERMINATION OF GERMINATION CHARACTERISTICS OF *Calligonum polygonoides* AND *Koelreuteria paniculata* SEEDS

Utvrđivanje karakteristika klijavosti sjemena vrsta *Calligonum polygonoides i Koelreuteria paniculata*

Fahrettin Atar[1], Ali Bayraktar[1], Nebahat Yildirim[1], İbrahim Turna[1]

Abstract

The success of the afforestation works (ecological and biological compatibility, economic success, etc.) depends on the use of seeds of known origin or quality seedlings. For this reason, it is important to determine seed characteristics and to eliminate dormancy. In this study, it was aimed to determine the germination characteristics of seeds of *Calligonum polygonoides* L. collected from Iğdır and *Koelreuteria paniculata* Laxm. obtained from Trabzon. In order to eliminate the dormancy for *Calligonum polygonoides*, 11 different pretreatments including control, cold water (1-2 days), hot water (10-15 min), gibberellic acid (GA_3 1000 ppm, GA_3 3000 ppm), sulfuric acid (H_2SO_4, 5-10 min), 5 min with H_2SO_4 + 20 min with GA_3 1000 ppm and 10 min with H_2SO_4 + 20 min with GA_3 3000 ppm were applied. The highest germination percentage was obtained as 50% in sulfuric acid (5 min) pretreatment, while the lowest germination percentage was obtained as 3.33% in control pretreatment. In hot water pretreatments, germination didn't occur. In order to eliminate the dormancy for *Koelreuteria paniculata*, pretreatments including control, cold water (1 day), hot water (10 min), GA_3 1000 ppm, GA_3 3000 ppm, H_2SO_4 5-10 min, 5 min with H_2SO_4 + 20 min with GA_3 1000 ppm and 10 min with H_2SO_4 + 20 min with GA_3 3000 ppm were applied. While the lowest germination percentage occurred as 73.33% in H_2SO_4 (10 min) pretreatment, the highest germination percentage took place as 93.33% in 10 min with H_2SO_4 + 20 min with GA_3 3000 ppm and cold water (1 day) pretreatments.

***Key words**: Calligonum polygonoides, Koelreuteria paniculata, seed, dormancy, pretreatment.*

INTRODUCTION - *Uvod*

Seed germination and seedling establishment are the most crucial periods in the plant life cycle (MAYER and POLJAKOFF-MAYBER, 1989). Germination starts with water uptake by seeds and terminates with the initial elongation of the embryonic axis (BEWLEY, 1997). Completion of germination can be seen by the emergence of the radicle (OGAWA et al., 2003). On the other hand, seed dormancy is a physiological condition in which the seeds cannot germinate even under the most suitable germination conditions or do not exhibit uniform germination. Seed germination is generally hampered by external factors (oxygen, temperature, humidity and light) and internal factors (e.g. seed coat, endosperm embryo) (BEWLEY and BLACK, 1982; BRADBEER, 1988; COPELAND and MCDONALD, 2001; KOORNNEEF, et al., 2002; BASKIN and BASKIN, 2004; BLACK et al., 2008).

Goldenrain-tree (*Koelreuteria paniculata* Laxm.) spread as native species in China and well established in Korea. It is a woody perennial, mainly used for landscape purposes due to its beautiful yellow flowers and green leaves. It is wide spread as an ornamental tree but the propagation is difficult because of apparent seed dormancy (PARK and REHMAN, 1999; REHMAN and PARK, 2001). Seed coat, embryo or the combination of the two can be reason the dormancy; this is why the seeds need to be well prepared before sowing (PARK and REHMAN, 1999; SABINA, 2009; SABINA and CORNELIA, 2011; REHMAN and PARK, 2000a).

Calligonum polygonoides L. (*Polygonaceae*) is a dominant perennial shrub in active sand dunes and stabilized sand fields (MAO and PAN, 1986; TAO, 2000). The species can persist in mobile sandy dunes under extreme drought conditions (LIU, 1985-1990). It is known for high tolerance to water deficiency in the Tunisian Saharian regions and appears to be appropriate for revegetation of desert (MAO et al., 1983; MAO and PAN, 1986; ZHANG, 1992; TAO, 2000). This shrub has great potentialities to provide different products and services as forage, traditional medicine, halting desert encroachment and stabilizing sand dune (LIU, 1985-1990; TAO, 2000). Seed coat hardness and impermeability to water may be the most important causes of *Calligonum* spp. dormancy (YU and WANG, 1998; TAO et al. 2000; REN and TAO, 2004).

Unfortunately, there is limited information concerning the potential seed dormancy problems of *Koelreuteria paniculata* and *Calligonum polygonoides*. For this reason, the objective of the present study was to devise an effective method for breaking dormancy of *Koelreuteria paniculata* and *Calligonum polygonoides* seeds.

In this study, it is examined that the effects of several pretreatments on germination of *Koelreuteria paniculata* and *Calligonum polygonoides* seeds, with the goal of providing practical suggestions for breaking dormancy.

MATERIALS AND METHODS - *Materijal i metode*

It was aimed to determine the germination characteristics of seeds of *Calligonum polygonoides* L. collected from Iğdır and *Koelreuteria paniculata* Laxm. obtained from Trabzon. After the collection of seeds, empty and rotten seeds were removed. *Koelreuteria paniculata* seeds were manually scarified by piercing seeds with a needle at the cotyledon end. Seeds were allowed to air-dry and stored at ambient temperature (25 °C). Germination experiments were conducted at 25±2 ºC temperature and 70±2% humidity level at the Research and Application Greenhouse. Peat+soil+perlite determined by 7:2:1 ratio was used as germination medium. Line sowing method was used in the sowing of the seeds and sowing was conducted based on the randomized complete block design. In the prepared crates, lines were opened to the depth of 2-3 times of the thickness of the seed with the line opening bar. Seeds were sowed with 3x10 sampling in October. Each treatment was replicated three times and

10 seeds were used in each replicate. In total, it was used 270 seeds for *Koelreuteria paniculata* and 330 seeds for *Calligonum polygonoides* in the scope of this study. In order to eliminate the dormancy for *Calligonum polygonoides*, 11 different pretreatments including control, cold water (1-2 days), hot water (10-15 min), gibberellic acid (GA_3 1000 ppm, GA_3 3000 ppm), sulfuric acid (H_2SO_4, 5-10 min), 5 min with H_2SO_4 + 20 min with GA_3 1000 ppm and 10 min with H_2SO_4 + 20 min with GA_3 3000 ppm were applied. *Koelreuteria paniculata*, 9 different pretreatments including control, cold water (1 day), hot water (10 min), GA_3 1000 ppm, GA_3 3000 ppm, H_2SO_4 5-10 min, 5 min with H_2SO_4 + 20 min with GA_3 1000 ppm and 10 min with H_2SO_4 + 20 min with GA_3 3000 ppm. Germination status was recorded every day. Seedling emergence (cotyledons visible at the media surface) was expressed as the percentage of viable seeds.

Germination data related to this study were analyzed using the SPSS 23 statistical program.

RESULTS - *Rezultati*

As a result of the study, the results of variance analysis and the germination percentage related to applied pretreatments for removing of dormancy in seeds of *Calligonum polygonoides* and *Koelreuteria paniculata* are given in Table 1.

Table 1. The results of germination percentages related to pretreatments
Tabela 1. Rezultati procenta ostvarene klijavosti u odnosu na tretmane

Species	Treatments	Germination Percentage (%)	F	P
Koelreuteria paniculata	1-Control	76.67	164.769	0.000*
	2-Cold water (1 day)	93.33		
	3-Hot water (10 min)	86.67		
	4-GA_3 1000 ppm (30 min)	83.33		
	5-GA_3 3000 ppm (30 min)	83.33		
	6-H_2SO_4 5 min	76.67		
	7-H_2SO_4 10 min	73.33		
	8-H_2SO_4 5 min + GA_3 1000 ppm (20 min)	90.00		
	9-H_2SO_4 10 min + GA_3 3000 ppm (20 min)	93.33		
Calligonum polygonoides	1-Control	3.33	1238.657	0.000*
	2-Cold water (1 day)	36.67		
	3-Cold water (2 day)	40,.0		
	4-Hot water (10 min)	0.00		
	5-Hot water (15 min)	0.00		
	6-GA_3 1000 ppm (30 min)	26.67		
	7-GA_3 3000 ppm (30 min)	33.33		
	8-H_2SO_4 (5 min)	50.00		
	9-H_2SO_4 (10 min)	46.67		
	10-H_2SO_4 5 min + GA_3 1000 ppm (20 min)	36.67		
	11-H_2SO_4 (10 min) + GA_3 3000 ppm (20 min)	20.00		

* $P<0.05$ (There is a statistically significant difference.)

As can be seen from Table 1, there were statistically significant differences ($P<0.05$) in terms of pretreatments for both species. While the lowest germination percentage in *Koelreuteria paniculata* seeds occurred as 73.33% in H_2SO_4 (10 min) pretreatment, the highest germination percentage took place as 93.33% in 10 min with H_2SO_4 + 20 min with GA_3 3000 ppm and cold water (1 day) pretreatments. For the seeds of *Calligonum polygonoides*, the highest germination percentage was obtained as 50% in sulfuric acid (5 min) pretreatment, whereas the lowest germination percentage was obtained as 3.33% in control pretreatment. In hot water pretreatments, germination didn't occur in *Calligonum polygonoides* seeds.

Duncan test was performed to determine the groups that were occurred in terms of pretreatments for germination percentages (Figure 1 and Figure 2).

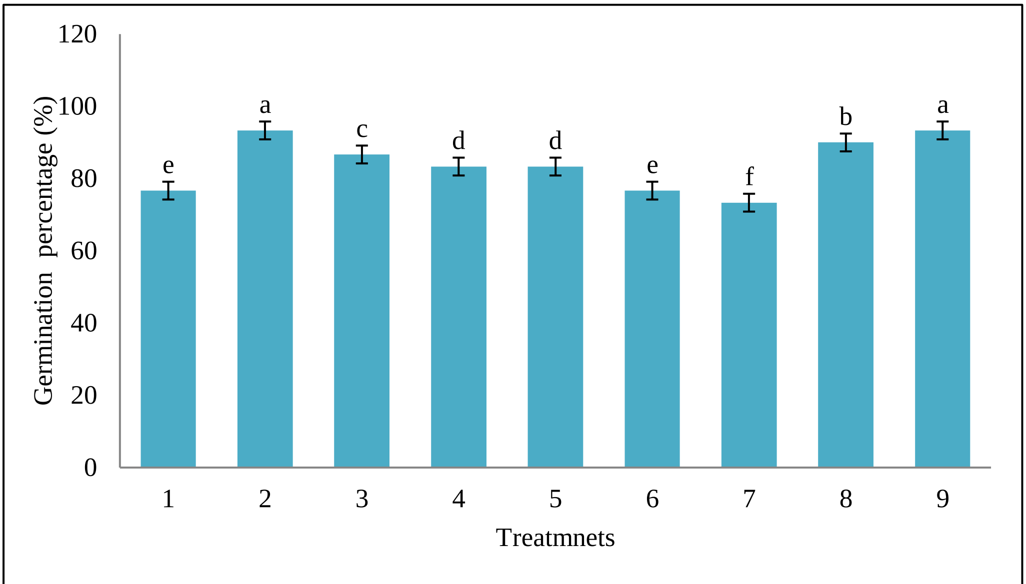


Figure 1. Duncan test results for *Koelreuteria paniculata*
Figure 1. Rezultati Duncan testa za Koelreuteria paniculata

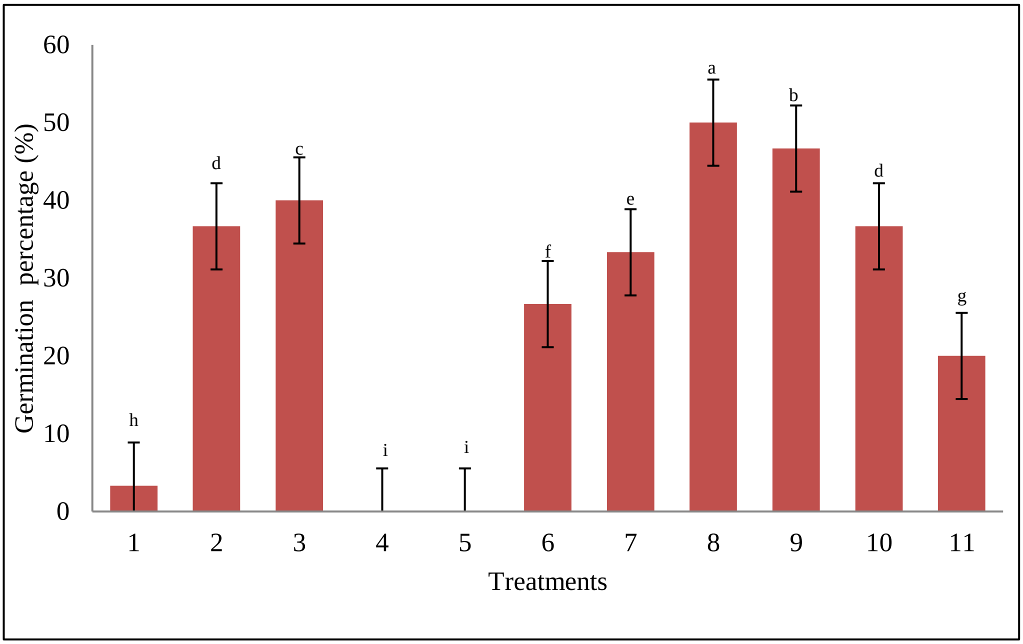


Figure 2. Duncan test results for *Calligonum polygonoides*
Figure 2. Rezultati Duncan testa za *Calligonum polygonoides*

As a result of the Duncan test, it was seen that there were 6 groups in *Koelreuteria paniculata* and 9 different groups in *Calligonum polygonoides*. For *Koelreuteria paniculata*, Cold water (1 day) and H_2SO_4 10 min + GA_3 3000 ppm (20 min) pretreatments created first group with the highest values, and H_2SO_4 (10 min) took place the last group having the lowest value. For *Calligonum polygonoides*, first group was created by H_2SO_4 5 min pretreatment, while the last group was formed by hot water 10 min and 15 min pretreatments.

DISCUSSION - *Diskusija*

REHMAN and PARK (2000a) reported that scarified seeds of goldenrain tree, without soaking or after soaking–redrying, had 44% germination after 60 days of moist chilling, which was increased to more than 50% when Seeds were soaked or soaked–redried in DW or GA_3 for 5 h and moist chilled for 60 days (DW) and 30 days (GA_3). However, germination of seeds soaked for 24 h and moist chilled was very low, but increased if the seeds were redried after soaking. Dry chilling after soaking or soaking–redrying for 24 h also promoted germination and a maximum of >50% germination was achieved after 15 days of dry chilling. In other research, exogenous application of 100, 200 and 300 ppm GA_3 increased germination of scarified seeds from 0 (control) to 17, 18 and 15%, respectively. Pre-chilling in distilled water (DW) for 60 days increased germination to 44%. Compared with DWchilled seeds, germination of seeds chilled for

15 days in GA3 was significantly increased and germination of Seeds chilled in 100, 200 and 300 ppm GA3 was 60, 51 and 54%, respectively, after 30 days (REHMAN and PARK, 2000b). The highest germination (94%) was obtained using 100 mL/L EM 1 application and stratification for 45 days at 4°C. Stratification was also effective for breaking dormancy of *K. paniculata* seeds with EM 1 and 45 days or 60 days of stratification (ERTEKIN, 2011). RUDOLF, (1974), examined untreated seeds and found germination of only 2% after 29 days, whereas germination increased to 52% after acid plus stratification treatment. No unscarified seed germinated in any of the treatments, indicating that goldenrain tree seeds have hard, impermeable seed-coat dormancy. In this study, high germination (93.33%) was obtained in 10 min with H_2SO_4 + 20 min with GA_3 3000 ppm and cold water (1 day) pretreatments.

The germination response of *Calligonum azel*, *C. arich* and *C. comosum* to mechanical, physical and chemical scarifications, applied for overcoming dormancy, has been studied under controlled conditions. In all three *Calligonum* species, the germination of the untreated (control) seeds was relatively low, indicating the presence of coat-imposed dormancy in a fraction of the studied seeds. Chemical scarification with sulphuric acid (96%) was effective in breaking seed dormancy and consequently in increasing the rate and the final percentage of germination (DHIEF et al., 2012). YU and WANG (1998), showed that the seed dormancy rates of the three *Calligonum* species are more than 95%, and the dormant degrees are rather deep. REN and TAO (2004), studied the effects of abrasion, sulphuric acid, boiling water, cold stratification and seed exudates (water-soluble inhibitors from the testa) treatments on the germination of 10 *Calligonum* species. They concluded that the rate and the percentage of the germination of these species are greatly increased by mechanical or chemical scarification; however, the lowest values are obtained with the exudate treatment. According to ZHANG (1992), the most appropriate pretreatments for *Calligonum* species are sulfuric acid and cold stratification. In the present study, the seed germination percentage of *Calligonum polygonoides* was enhanced by an immersion time in sulphuric acid and increased with time until 5 min.

In conclusion, 10 min with H_2SO_4 + 20 min with GA_3 3000 ppm and cold water (1 day) pretreatments can successfully break dormancy in goldenrain tree seeds, resulting in the easy production of seedlings. Hence, goldenrain tree is a suitable for planting in urban parks and gardens. Sulfuric acid (5 min), with the highest germination percentage (50%), can be used in order to eliminate the dormancy for *Calligonum polygonoides*. In the context of the potential use of *Calligonum* species as an alternative in the arid desert regions, it can be suggested that seed germination and seedling emergence under the natural environmental conditions still deserve further research.

ACKNOWLEDGEMENT

The study was published as a summary text on abstract book of in International Symposium "People-Forest-Science", October 10-12, 2018, Sarajevo, Bosnia and Herzegovina.

REFERENCES - *Literatura*

BEWLEY, J.D. (1997): Seed Germination and Dormancy. Plant Cell 9, 1055–1066.

DHIEF, A., GORAI, M., ASCHI-SMITI, S., NEFFATI, M. (2012): Effects of Some Seed-Coat Dormancy Breaking Treatments on Germination of Three *Calligonum* species occurring in Southern desert of Tunisia. Ecol Med, 38, 19-27.

ERTEKIN, M. (2011): Effects of Microorganisms, Hormone Treatment and Stratification on Seed Germination of Goldenrain Tree (*Koelreuteria paniculata*). International Journal of Agriculture and Biology, 13(1).

KOORNNEEF, M., BENTSINK, L., HILHORST, H. (2002): Seed Dormancy and Germination. Curr. Opin. Plant Biol. 5, 33–36.

LIU, Y.X. (1985-1990): Flora in Desertis Reipublicae Populorum Sinarum, I-III. Science Press, Beijing.

MAYER, A. M., POLIJAKOFF-MAYBER, A. (1989): The Germination of Seeds, 4th ed. Pergamon Press, London, 270 p.

MAO, Z.M., YANG, G., WANG, C.G. (1983): Study on the Evolution Relation of Genus *Calligonum* from Xinjiang Based on Number of chromosome and anatomic characteristics assimilative shoot. Acta Phytotaxon. Sin., 21, 44-48.

MAO, Z.M., PAN, B.R. (1986): The Classification and Distribution of the Genus *Calligonum* L. in China. Acta Phytotaxon. Sin., 24, 98-107.

OGAWA, M., HANADA, A., YAMAUCHI, Y., KUWAHARA, A., KAMIYA, Y., YAMAGUCHI, S. (2003): Gibberellin Biosynthesis and Response During Arabidopsis Seed Germination. The Plant Cell, 15(7), 1591-1604.

PARK, I.H., REHMAN, S. (1999): Studies on Seed Dormancy: Seeds Maturation in Relation to Dormancy in Goldenrain-Tree (*Koelreuteria paniculata* Laxm.). Acta Horticulturae 504 (eds.) Liptay, A., C.S. Vavrina and G.E. Welbaum, Proceedings of the sixth Symposium.

POȘTA DANIELA SABINA, (2009): Arboricultură Ornamentală. Editura Agroprint, Timișoara.

POŞTA DANIELA SABINA, HERNEA CORNELIA. (2011): Reseach Concerning the Production of Planting Material Using Generative Propagation on *Albizzia julibrissin*. Durazz. Buletin of University of Agricutural science and Veterinary Medicine Cluj-Napoca, pp. 423-429.

REHMAN, S., PARK, I.H. (2000a): Effect of Pre-Treatments on Dormancy of Goldenrain-Tree *(Koelreuteria paniculata* Laxm.) Seeds. J. New Seeds, 2: 29–36.

REHMAN, S., PARK, I. H. (2000b). Effect of Scarification, GA and Chilling on the Germination of Goldenrain-Tree (*Koelreuteria paniculata* Laxm.) Seeds. Scientia Horticulturae, 85(4), 319-324.

REHMAN, S., PARK, I. H. (2001): Effect of Pre-Treatments on Dormancy of Goldenrain-Tree (*Koelreuteria paniculata* Laxm.) Seeds. Journal of New Seeds, 2(4), 29-36.

REN, J., TAO, L. (2004): Effects of different pre-sowing seed treatments on germination of 10 *Calligonum* species. For. Ecol. Manage. 195: 291-300.

RUDOLF, P.O. (1974): *Koelreuteria paniculata* Laxm., Panicled Goldenrain Tree. In: Schopmeyer, C.S. and T. Coord (eds.), Seeds of Woody Plants in the United States, pp: 474–475. Agriculture Handbook, 450, USDA Forest Service, Washington DC.

TAO, L., REN, J., LIU, X.M. (2000): Study on the Waterabsorbing Model of Two Calligonum Species Seeds. J. Arid Land Resour. Environ. 14: 89-91.

TAO, L. (2000): Genetic Diversity and Systematical Taxonomy of Genus *Calligonum* L. PhD Thesis, Environment and Engineering Institute of Cold and Arid Regions, The Chinese Academy of Sciences, PR China, 281 p.

YU, Z., WANG, L.H. (1998): Causes of Seed Dormancy of Three Species of *Calligonum*. J. NW For. Coll. 1: 9-13.

ZHANG, H.N. (1992): A study on the Species Selection of *Calligonum* and Its Forestation in the Drift-Sand Area of Cele County. Arid Zone Res., 9, 8-12.

SAŽETAK

Uspjeh pošumljavanja (ekološka i biološka kompatibilnost, ekonomska opravdanost, itd.) zavisi od upotrebe sjemena poznatog porijekla ili kvalitetnih sadnica. U ovu svrhu, važno je utvrditi karakteristike sjemena i eliminisati dormantnost. Cilj ovog rada bio je utvrditi klijavost sjemena *Calligonum polygonoides* L. sakupljenog u Iğdıru i *Koelreuteria paniculata* Laxm. Sakupljenog u Trabzonu. Da bismo eliminisali dormantnost za sjeme *Calligonum polygonoides*, uključili smo 11 različitih pre-tretmana, uključujući kontrolu: hladna voda (1-2 dana), vrela voda (10-15 min), giberelinska kiselina (GA_3 1000 ppm, GA_3 3000 ppm), sumporna kiselina (H_2SO_4, 5-10 min), 5 min sa H_2SO_4 + 20 min sa GA_3 1000 ppm i 10 min sa H_2SO_4 + 20 min sa GA_3 3000 ppm. Najveća klijavost, od 50% ostvarena je u pre-tremanu sa sumpornom kiselinom (5 min), dok je najmanji procenat klijavosti (3,33%) bio u kontrolnom pre-tretmanu. U pre-tretmanu sa vrelom vodom nije bilo klijavosti. Za sjeme vrste *Koelreuteria paniculata*, u svrhu eliminisanja dormantnosti izvršili smo slijedeće pre-tretmane sa kontrolom, hladna voda (1 dan), vrela voda (10 min), GA_3 1000 ppm, GA_3 3000 ppm, H_2SO_4 5-10 min, 5 min sa H_2SO_4 + 20 min sa GA_3 1000 ppm i 10 min sa H_2SO_4 + 20 min sa GA_3 3000 ppm. U ovom slučaju, najniži procenat klijavosti (73,33%) uočen je u pre-tretmanu sa H_2SO_4 (10 min), dok je najveća klijavost od 93.33% zabilježena u pre-tretmanu sa 10 min u H_2SO_4 + 20 min sa GA_3 3000 ppm i hladnoj vodi (1 dan).

Corresponding Author: Ali Bayraktar: Karadeniz Technical University, Faculty of Forestry, Department of Forest Engineering, 61080, Trabzon-Turkey. e-mail address: alibayraktar@ktu.edu.tr

Works of the Faculty of Forestry
University of Sarajevo
No. 2, 2018 (41-53)

UDK 556.115:574.587(282.249 Neretva)

A BIOLOGICAL WATER QUALITY ASSESSMENT BASED ON PHYTOBENTHOS AND MACROINVERTEBRATES AT THREE STATIONS ON THE RIVER NERETVA

Biološka procjena kvalitete vode na tri postaje na rijeci Neretvi temeljena na zajednicama fitobentosa i makrozoobentosa

Anita Dedić[1], Tanja Galić[2], Svjetlana Stanić-Koštroman[1], Dragan Škobić[1], Anđelka Lasić[1] and Dubravka Hafner[3]

Abstract

This paper presents the research results of benthos community (phytobenthos and macroinvertebrates) on three locations of the Neretva River: Glavatičevo, Žitomislići and Višići. According to typology of rivers, the site Glavatičevo belongs undertype 10a, while sites Žitomislići and Višići are undertype JIVT (heavily modified water bodies). Research of the benthos community has been done in December 2016 with the simultaneous monitoring chemical parameters of water. All research states showed a great number and a high diversity of benthic taxa, although sampling was spent in December. The saprobic values of benthos community at the site Glavatičevo indicates to oligosaprobic level, the water unloaded with organic substances. The site Žitomislići points to oligo/betamesosaprobic level, the water a bit loaded with organic substances. The site Višići according to phytobenthos demonstrates to oligo/betamesosaprobic level, while according to benthic macroinvertebrates point to betamesosaprobic level (the water loaded with organic substances). Based on saprobic values and chemical parameters of water in keeping with *The decision on the characterization of the surface and underground water, reference conditions and parameters for the detection of water state and water monitoring* (Official newspapers FBiH, No. 1/14), a maximum ecological potential has been registered on sites Žitomislići and Višići, while a high ecological status has been registered on the site Glavatičevo.

Key words: *phytobenthos, macrozoobenthos, ecological status, ecological potential*

INTRODUCTION - *Uvod*

Biodiversity of freshwater ecosystems are under increasing influence of negative anthropogenic activity. Consequently, there are more visible changes in biota and biological processes in water (NORRIS and BARBOUR, 2009). The traditional water quality assessment has been based exclusively on measuring physical and chemical parameters of water, but later this was not enough and biological parameters

[1] University of Mostar, Faculty od Science and Education, Bosnia and Herzegovina
[2] Kočerin, b.b., Široki Brijeg, Bosnia and Herzegovina
[3] Bartulovići 4, HR-20357, Croatia

were included. Organisms community in freshwater ecosystems are sensitive indicators of water status, because they integrate and maintain the influence of various environmental factors, various types of contamination, degradation, fragmentation of habitats and etc. (NORRIS and BARBOUR, 2009).

According to The Water Framework Directive (2000/60/EC), the most important part of the EU legislation on the water, all the EU member states are required to make an assessment of the status of water bodies as well as their classification. Goals of water protection and management in FB&H are defined by the Water Act FB&H (Official Newspaper FBiH, No. 70/06) and Water management strategy FB&H (adopted by The House of Representatives and The House of Peoples of the Bosnia and Herzegovina Parliament 2010, respectively 2011 with plan valid until 2022).

The Water Framework Directive is the most important part of the EU legislation on water. It designed to improve and integrate the way water bodies across Europe are managed, ensure sustainable management, prevent further destruction of the surface and groundwater and ensure the least good status of all water bodies (HERCEG, 2013). According to WFD the ecological status of surface water involves the analysis of biological elements of water quality, basic chemical and physical and-chemical elements supporting the biological elements and hydromorphological elements. If the status of the biological and physical and-chemical element is assessed as good, and of the hydromorphological as moderate, total ecological status will be estimated as moderate. The ecological status is esteemed on the basis of the worst rated component.

Phytobenthos represents the community composition of algae, cyanobacteria and heterotrophic microorganisms, who cover free object surface within the water (PLENKOVIĆ-MORAJ et al., 2009). Benefits of phytobenthos as indicators of the ecological status and monitoring are: the great taxonomic diversity, short generation time and a quick response to stress, respectively to changes in ecological conditions. Phytobenthos communities are the first to react to the change that has occurred in the water, respectively they behave as early detectors of the problem.

Benthic macroinvertebrates, especially aquatic insects, represent a choice group of organisms used in the biological monitoring programs. Macroinvertebrates within the same system may be residents for several months to multiple years, depending on the lifespan of the particular organism. Macroinvertebrate communities therefore reside in an aquatic system long enough to reflect the chronic effects of pollutants, and yet short enough to respond to relatively acute changes in water quality. Thus, because of the limited mobility of macroinvertebrates and their relative inability to move away from adverse conditions, the location of the chronic sources of pollution often can be pinpointed by comparing communities of these organisms. Benthic macroinvertebrates are used as a bioindicators for environmental stress in aquatic ecosystems at different levels, including morphological deformities.

Similar researches have been made earlier, as evidenced by published papers (JERKOVIĆ, 1976; BLAGOJEVIĆ, 1976; MARINKOVIĆ-GOSPODNETIĆ, 1978; BLAGOJEVIĆ and HAFNER, 1981, 1983; BLAGOJEVIĆ et al., 1986). This papers mostly have been referred to assessment of the water quality. Also, published data about benthos community points to the specificity of the area as well as the high degree of endemism (KAĆANSKI, 1978; MARINKOVIĆ-GOSPODNETIĆ, 1978).

In recent times, more precisely since establishing a water agency for the Adriatic Sea, regular biomonitoring programs are being conveyed within the framework of monitoring the state of the Neretva River.

This thesis presents assessment of ecological status on three locations of Neretva river using phytobenthos and macroinvertebrates community and chemical elements of water.

MATHERIAL AND METHODS - *Materijal i metode*

Research of benthos was made in December 2016. Phytobenthos, macroinvertebrates were sampled and chemical parameters of water were measured. The assessment of the ecological status has been made according to the applicable legal regulations, respectively *the decision on the characterization of the surface and underground water, reference conditions and parameters for the detection of water state and water monitoring* (Official newspapers FBiH, No. 1/14).

Chemical parameters were measured by an ecological probe type WTW Multi-Parameter Instruments. pH values were measured by the pH-meter, model HANNA HI 98127, conductivity was measured by WTW field meter, model Cond 3110, and dissolved oxygen was measured by WTW field meter, model Ox 3205. Of chemical analyses the content of total carbon (TOC) and the content of total organs of carbon (NPOC) were determined by TOC analyzer. Samples for analyses concentrations of ammonium, nitrate and phosphates also were sampled. They were measured in the laboratory using a UV-visible spectrophotometer. Chemical analysis was done in Institute of Public Health FB&H Mostar.

Phytobenthos samples were taken according to European Standard EN 13 946 (2016). Phytobenthos were sampled from the surface of the rocks by scraping with a scalpel and a toothbrush. The samples of phytobenthos (diatoms and the other algae) were fixed in 4% formaldehyde at the site. Diatoms were determined from the permanent preparations that were made after the chemical processing of materials by HUSTEDT, (1930). Algae were determined using ZEISS light microscope (Axio Imager A2). The diatoms were identified at a high magnification (100X) while using immersion oil, and the other algae were identified under different magnification (4x, 10x and 40x). Counting of taxa was made in arbitrary transcriptions counting 400 frustules on a light microscope with the contrast (DIC) on magnification 1000x. The indetification of the species was made using the keys: GOLERBACH et al. (1953), HINDAK et al. (1978), HUSTEDT, (1927 - 1966, 1930), KOMAREK and ANAGNOSTIDIS (1999), LENZENWEGER, (1996), ZABELINA et al. (1951), WEST, (1905), KRAMMER and LANGE-BERTALOT (1986 - 1991), KRAMMER, (2000 - 2003), LANGE-BERTALOT (2001, 2002).

Based on the qualitative and quantitative composition of phytobenthos, the saprobiological state of the investigated stations was determined. The indicator values of taxa were defined by WEGL, (1983) and the saprobity index was estimated according to PANTLE-BUCK, (1955) and ZELINKA-MARVAN, (1961). The relative abundance was expressed by number 1, 3 and 5 (1-single, 3-usual, 5-dominant). Water quality category was given by LIEBMANN, (1962) (Table 1).

The samples macrozoobenthos were sampled by AQEM method and multi-habitat sampling sheme. It covers the collection of material from all microstation of the defined station, which is represented by at least 5% coverage (totally 20 subsamples). In this study Surber's net a surface area of $0.1m^2$ was used and a grinder mill with a diameter of 150 µm. The samples of macrozoobenthos were fixed in 80% EtOH at the site. The qualitative and quantitative analysis and determination of materials were made in the scientific research laboratory "Ruđer Bošković" Faculty of Science and Education at the University of Mostar. The determination of species was made using the keys for certain groups of macroinvertebrates: ASKEW, (1988), BELIFORE, (1983), CARCHINI, (1983), CONSIGLIO, (1980), ELLIOTT et al. (1988), ENGBLOM, (1996), HICKIN, (1967), NILSSON, (1996), PELEGER, (1999), WARINGER and GRAF (2011), WATSON and DALLWITZ (2005) under the sterezoom microscope Olympus SZX10. The Pantle-Buck saprobic index was used for assessing the ecological status and burden of organic pollution of aquatic ecosystems. Saprobic value of the taxa was defined by MOOG, (2002) and data base (freshwaterecology.com). The relative abundance was defined by RUSSEV, (1993). The water quality category was given by LIEBMANN, (1962) (Table 1).

Table 1. The water quality category according to the saprobic index
Tablica 1. Kategorija kvalitete vode prema saprobnom indeksu

SAPROBITY DEGREE	INDEX SAPROBITY	DESCRIPTION OF A WATER BIOTOPE
Oligosaprobic	1.00 – 1.50	Unloaded to very little loaded
Oligo to β-mesosaprobic	1.51 – 1.80	Little loaded
β-mesosaprobic	1.81 – 2.30	Moderately loaded
β to α-mesosaprobic	2.31 – 2.70	Medium loaded
α-mesosaprobic	2.71 – 3.20	Medium to a lot loaded
α to polisaprobic	3.21 – 3.50	Loaded
Polisaprobic	3.51 – 4.00	Very much loaded

The study area: The Neretva River is the largest river of the Adriatic catchment area. It flows 203 km through Bosnia and Herzegovina, and the last 22 km through the Croatia. River water flows mainly through limestone in accordance with the hydrogeological characteristics of the karst flow. Climate characteristics in the river basin vary with the distance from the sea. The climate is Mediterranean in the lowland area close to the sea, while the middle part has a continental climate and higher areas have a mountainous climate. The average rainfall is 1.650 1/m^2, and varies between 1.500 and 1800 1/m^2. Temperatures range between -29 and +43 °C, and the annual evapo-transpiration is 500-900 mm.

Three investigated stations are presented in this paper (Photo 1). The first site: Glavatičevo (Photo 2) is on 358 m atitude. According to typology of rivers, it belongs undertype 10a (medium high mountain stream on the carbonate substrate). The second site: Žitomislići (Photo 3) is on 19 m atitude. According to typology of rivers, it belongs undertype JIVT (heavily modified water body). The third site: Višići (Photo 4) is on 8 m atitude. It belongs undertype JIVT (heavily modified water body).

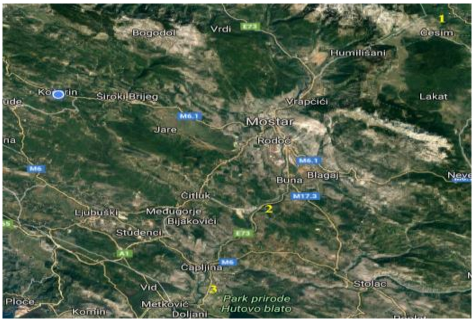


Photo 1. Research sites at Neretva River
Slika 1. Područja istraživanja na rijeci Neretvi

Photo 2. Neretva: Glavatičevo site
Slika 2. Neretva: postaja Glavatičevo

Photo 3. Neretva: Žitomislići site
Slika 3. Neretva: postaja Žitomislići

Photo 4. Neretva: Višići site
Slika 4. Neretva: postaja Višići

RESULTS AND DISCUSSION - *Rezultati i rasprava*

The results of selected chemical parameters of water at investigated stations are shown in Table 2.

Table 2. Values of physico-chemical and chemical parameters of water of the Neretva River at the Glavatičevo, Žitomislići and Višići sites
Tablica 2. Vrijednosti fizikalno-kemijskih i kemijskih čimbenika vode rijeke Neretve na postajama: Glavatičevo, Žitomislići i Višići

	Conductivity (*µS/cm)*	pH	Dissolved oxygen (*mgO₂/l)*	Saturation *O2 %*	BPK_5	KPK-Mn *(mgO₂/l)*	Ammonium *(mgN/l)*	Nitrati *(mgN/l)*	TP *(mgP/l)*
Glavatičevo	284	8	13.2	105.6	0.63	0.64	<0.005	0.263	0.007
Žitomislići	380	7.8	11.59	96.4	0.67	0.64	0.01	0.517	0.012
Višići	456	8	12.86	113.1	0.51	0.77	0.017	0.602	0.047

All the stations showed a high oxygen value (dissolved oxygen-11.59-13.20 mg L^{-1} and saturation -96.4-113%). Reason for that can be the less values of water temperature, porosity of aquifer rock and contact with groundwater with atmosphere (CANTONATI, 1998). Conductivity was ranged between 284 and 456 µS/cm (table 2). The measured value of electrical conductivity can assess the degree of mineralization of water and also to evaluate of the kind of water (WALTON, 1989). Our values are in agreement with values for limestone substrate (MOGNA et al., 2015). Also, our values are in agreement with values of factors for the Žitomislići and Višići sites who were presented in the paper by IVANKOVIĆ et al. (2017).

In accordance with *The decision on the characterization of the surface and underground water, reference conditions and parameters for the detection of water state and water monitoring* (Official newspapers FBiH, No. 1/14), all the obtained values of chemical parameters of water at the Žitomislići and Višići sites are within the limits of maximum ecological potential, and at the Glavatičevo site are within the limits of a high ecological state.

In terms of phytobenthic communities, it was recorded a great number and high diversity of taxa. A total of 67 taxa of phytobenthos were determineted at all stations (Glavatičevo 26, Žitomislići 46 and Višići 20 taxa). The most common and the most numerous were representative from the classes of *Bacillariophyceae*. Species *Cocconeis placentula* Ehrenberg, *Diatoma vulgaris* Bory, *Encyonema silesiacum* (Bleisch) D. G. Mann, *Navicula tripunctata* (O. F. Müller) Bory, *Rhoicosphenia abbreviata* (C. Agardh) Lange-Bertalot and *Ulnaria ulna* (Nitzsch) Compère were registered at all stations. All presented taxa are cosmopolitan with a wide amplitude of appearances. Saprobic index for the phytobenthos at the site Glavatičevo was 1.41, at the site Žitomislići 1.7 and at the site Višići 1.8. According to the saprobic index site Glavatičevo belongs to I category of water quality or oligosaprobic water level (the unloaded to very little loaded waters), while the Žitomislići and Višići sites belong to I-II category of water quality or oligo-betamesosaprobic water level (the litlle loaded waters). According to the research results conducted by TROŽIĆ-BOROVAC et al. (2013) in the period from 2005. to 2010. were determined 62 taxa at the Žitomislići site and 47 at the Višići site. The reason for their greater number of taxa is certainly the greater number of samples as well as the longer period of research. The most numerous genera in this paper: *Cocconeis*, *Encyonema*, *Diatoma*, *Gomphonema* and *Navicula* were recorded in the study of other authors of karst rivers (WOJTAL, 2009), NOGA et al. (2013), MOGNA et al. (2015), IVANOV et al. (2006)). According to the list of indicator types (VAM DAM et al., 1994), the most abundant taxa at the sites on the Neretva River are alkaliphilous and circumneutral species, which corresponds to the measured pH values.

In terms of macroinvertebrates 198 individuals of 16 taxa were dermineted at the site Glavatičevo, 346 individuals of 16 taxa at the site Žitomislići and 381 individuals of 13 taxa. The most diverse groups at all stations were insect class representatives Insecta, especially orders Trichoptera, Ephemeroptera and Plecoptera. The species *Gammarus balcanicus* Schäferna, 1922, was the most diverse species at the Žitomislići and Višići sites. Saprobic index at the site Glavatičevo was 1.48, at the site Žitomislići 1.58 and at the site Višići 1.89. According to the saprobic index the site Glavatičevo belongs to I category of water quality or oligosaprobic water level (the unloaded to very little loaded waters), the site Žitomislići belongs to I-II category of water quality or oligo-betamesosaprobic water level (the litlle loaded waters) and the site Višići belongs to betamesosaprobic water level (moderately loaded waters).

Comparison of the values of saprobic index for both biological parameters indicates the relative uniformity.

CONCLUSION - *Zaključci*

Based on the results obtained by researching the benthic communities at the three Neretva River stations we make the following conclusions:

- Data of chemical variables show good aeration, pH typical for carbonate bed/origin and generally oligotrophic conditions.
- According to the chemical parameters of water, the largest number of benthic taxa are alkaliphilous and circumneutral species, and they are mesosaprobic indicators.
- In the Neretva river were recorded high number and high diversity of phytobenthos and macrozoobenthos taxa.
- According to the research results, the site Glavatičevo points to the good water quality, while the Žitomislići and Višići sites evaluated to the presence of organic contamination.
- The high ecological status was assessed for the site Glavatičevo, and for the Žitomislići and Višići sites were assessed maximum ecological potential.

REFERENCES - *Literatura*

ASKEW, R. R. (1988). The Dragonflies of Europe. Harley Books, Essex. pp 29.

BAUERNFEİND, E., SOLDÁN, T. (2012). The mayflies of Europe. Apollo Books. pp 781.

BELİFORE, C. (1983). Efemerotteri (Ephemeroptera). In: Ruffo, S.(ed.): Guide per il riconoscimento delle specie animali delle acque interne Italiane. Consiglio nazionale delle ricerche, Verona. pp 113.

BLAGOJEVİĆ, S. (1976): Prilog poznavanju algi krških izvorišta u Bosni i Hercegovini. I. Chrysophyceae, Xanthophyceae, Bacillariophyceae. Godišnjak Biološkog instituta Univerziteta u Sarajevu. 29: 5-21.

BLAGOJEVİĆ, S., HAFNER D. (1981): Floristička-ekološka istraživanja cijanofita i algi fitobentosa i biosestona u srednjem toku rijeke Neretve i njenim pritokama. Elaborat Biološkog Instituta Univerziteta u Sarajevu.

BLAGOJEVİĆ, S., HAFNER D. (1983): Naselje cijanobakterija i algi u rijeci Neretvi. Elaborat, Biološki aspekt kvaliteta vode ekosistema rijeke Neretve. Biološki Institut Univerziteta u Sarajevu.

BLAGOJEVİĆ, S., HAFNER, D., KRİVOKAPİĆ, K., KAĆANSKİ, D. (1986): Neke hidrobiološke karakteristike akumulacionih jezera na Neretvi i Trebišnjici. Prirodno – Matematički fakultet Univerziteta u Sarajevu.

BRİTTAİN, J. E., SALTVEİT, S. J. (1996). Plecoptera, Stoneflies. In: Nilsson, A. (ed.): Aquatic Insects of North Europe, Apollo Books, Stenstrup. 55-76.

CARCHİNİ, G. (1983). Odonati (Odonata). In: Ruffo, S. (ed.): Guide per il riconoscimento delle specie animali delle acque interne Italiane. Consiglio nazionale delle ricerche, Verona. pp 80.

COESEL, P.F.M. (1991). De Desmidiaceeën van Nederland Deel 4. Fam. Desmidiaceae (2) Wetensch. Meded. K.N.N.V. 202, Utrecht.

CONSİGLİO, C. (1980). Plecotteri (Plecoptera). In ruffo, S. (ed.): Guide per il riconoscimento delle specie animali delle acque interne Italiane. Consiglio nazionale delle ricerche, Verona. pp 68.

ELLİOTT, J.M., HUMPESCH, U.H., MACAN, T.T. (1988). Larvae of the British Ephemeroptera: a key with ecological notes, Freshwater Biological Association, Ambleside, 145 pp.

ENGBLOM, E. (1996). Ephemeroptera Mayflies. In: Nilsson, A. (ed.): Aquatic Insects of North Europe. Apollo Books, Stenstrup. 13 – 54.

EU, 2000. Directive 2000/60/EC of the European Parliament and of the Council of 23 October 2000 establishing a framework for Community action in the field of water policy. Official Journal of the European Coounities L 327, 22.12.2000, Luxembourg, pp. 72.

GHETTİ, PF. (1986). I macroinvertebrati nell´analisi di qualitá dei corsi d´acqua. Trento: Provincia Autonoma di Trento. 169 p. Manuale di applicazione. Volume allegato agli atti del convegno "esperienze e confronti nell´applicazione degli indici biotici in corsi d´acqua italiani

GOLERBACH, M. M., KOSİNSKAJA, E. K., POLJANSKİ V. I. (1953): Sinzelenije vodorosli. Gos. Izd. Sovjetskaja nauka, Moskva.

HERCEG, N. (2013). Okoliš i održivi razvoj. Synopsis. Zagreb.

HİCKİN, N. E. (1967): Caddis larvae (Larvae of British Trichoptera), Hutchinsin & Co. London, pp. 476.

HİNDAK, F. (1988): Studies on the Chlorococcal Algae (Chlorophyceae). IV. Slovak Academy of Science, Bratislava.

HİNDAK, F., CYRUS, Z., MARVAN, P., JAVORNİCKY,P., KOMAREK, J., ETTL. H., ROSA, K., SLADEČKOVA, A., POPOVSKİ,J., PUNOCHAROVA, J., LHOTSKY, O. (1978): Slatkovodne riasy, Slovenske pedagogičke nakladateljstvo, Bratislava.

HİNDAK, F., MARVAN, P., ROSA, K., POPOVSKY, J., LHOTSKY, O. (1978): Sladkovodne riasy, Slovenske Pedagogicke Nakladateljstvo, Bratislava.

HUSTEDT, F. (1930): Bacillariophyta (Diatomeae). In Die Süsswasserflora Mittelleuropas vol 10. 2nd Jena, Pascher A. (ed.), Germany, G. Fischer.

IVANKOVİĆ, A., PETROVİĆ, D., IVANKOVİĆ, P. I MAJSTOROVİĆ, J. (2017): Monitoring of Water Salinity of the Lower River Neretva (B&H). International Journal of Energy and Environmental Science. 2: 136-143.

JERKOVIĆ, L. (1978). Dijatomeje sliva gornjeg toka rijeke Neretve. Godišnjak Biološkog instituta Univerziteta u Sarajevu.

JOHN, D.M., WHİTTON, B.A., BROOK, A.J. (2002). The Freshwater Algal Flora of the British Isles: An Identification Guide to Freshwater and Terrestrial Algae. Cambridge University Press. New York. 37.

KELLY, M.G., JUGGİNS, S., BENNİON, H., BURGESS, A., YALLOP, M., HİRST, H., KİNG, L., JAMİESON, B.J., GUTHRİE, R., RİPPEY, B. (2008): Use of diatoms for evaluating ecological status in UK freshwaters. Environment Agency, United Kingdom.

KOMÁREK, J., ANAGNOSTİDİS, K. (1999). Cyanoprokaryota 1. Teil: Chroococcales. In H. Ettl, G. Gärtner, H. Heynig, and D. Mollenhauer (Eds.). Süsswasserflora von Mitteleuropa 19/1, Gustav Fischer Verlag, Jena-Stuttgart-Lübeck-Ulm, Germany. 548 pp.

KRAMMER, K. (2000). Diatoms of Europe. Diatoms of the European Inland Waters and Comparable Habitats. Vol. 1. The genus Pinnularia. A.R.G. Gantner Verlag K.G, Ruggell.

KRAMMER, K. (2002). Diatoms of Europe. Diatoms of the European Inland Waters and Comparable Habitats. Vol. 3. Cymbella. A.R.G. Gantner Verlag K.G, Ruggell.

KRAMMER, K. (2003). Diatoms of Europe. Diatoms of the European Inland Waters and Comparable habitats. Vol. 4. Cymbopleura, Delicata, Navicymbula, Gomphocymbellopsis, Afrocymbella. A.R.G. Gantner Verlag K.G, Ruggell.

KRAMMER, K., LANGE-BERTALOT, H. (1986). Bacillariophyceae, 1. Teil: Naviculaceae. U : Ettl, H., Gerloff, J., Heynig, H., Mollenhauer, D. (Eds): Süsswasserflora von Mitteleuropa 2/1. – G.Fischer-Verlag, Stuttgart, 876 pp.

KRAMMER, K., LANGE-BERTALOT, H. (1988). Bacillariophyceae, 2. Teil: Bacillariaceae, Epithemiaceae, Surirellaceae. U: Ettl, H., Gerloff, J., Heynig, H., Mollenhauer, D. (Eds): Süsswasserflora von Mitteleuropa 2/2. – G. Fischer-Verlag, Stuttgart.

KRAMMER, K., LANGE-BERTALOT, H. (1991a). Bacillariophyceae, 3. Teil: Centrales, Fragilariaceae, Eunotiaceae. – In: Ettl, H., Gerloff, J., Heynig, H., Mollenhauer, D. (Eds), Süsswasserflora von Mitteleuropa 2/3. – G. Fischer-Verlag, Stuttgart.

KRAMMER, K., LANGE-BERTALOT, H. (1991b). Bacillariophyceae, 4. Teil: Achnanthaceae. Kritische Ergänzungen zu *Navicula* (Lineolatae) und *Gomphonema*, Gesamtliteraturverzeichnis. U: Ettl, H., Gerloff, J., Heynig, H., Mollenhauer, D.

LANGE-BERTALOT, H. (2001). Navicula sensu stricto. 10 Genera separated from Navicula sensu lato, Frustulia. In: Diatoms of Europe: diatoms of the European inland waters and comparable habitats, Ruggell A.R.G. Gantner Verlag. K.G., pp. 526.

LANGE-BERTALOT, H. (2002). Diatoms of Europe: diatoms of the European inland waters and comparable habitats. Vol. 3, Cymbella, A. R. G. Ganter; Koeltz Scientific Books, Rugell, Königstein.

LANGE-BERTALOT, H. (2001). Navicula sensu stricto, 10 genera separated from Navicula sensu lato, Frustulia. In: Lange-Bertalot, H. (ed.), Diatoms of Europe, 2. A. R. G. Gantner Verlag K. G., Ruggell, Liechtenstein

LAZAR, J. (1960). Alge Slovenije: Seznam slatkovodnih vrst in ključ za dolčanje. SAZU, Ljubljana.

LENZENWEGER, R. (1996). Desmidiaceenflora von österreich, Teil 1, Bibliotheca Phycologica, Band 101.

LİEBMAN, H. (1962). Handbuch der Frishwasser und Abwasser biologie, Vol II, 2 nd-edn. Oldenbourg, Munich, pp, 588.

MARINKOVIĆ-GOSPODNETIĆ, M. (1978). Trichoptera sliva rijeke Neretve. Godišnjak Biološkog instituta Univerziteta u Sarajevu.

MOGNA, M., CANTONATİ, M., ANDREUCCİ, F., ANGELİ, N., BERTA, G., MİSERERE, L. (2015): Diatom communities and vegetation of springs in the sout-western Alps. Acta Botanica Croatica. 74: 265-285.

MOOG, O. (2002). Fauna Aquatica Austriaca, Edition 2002. Wasserwirtschaftskataster Bundesministerium für Land- und Forstwirtschaft, Umwelt und Wasserwirtschaft, pp. 684, Wien.

MORETTİ, G. (1983). Tricotteri (Trichoptera). In: Ruffo, S. (ed.). Guide per il riconoscimento delle specie animali delle acque interne Italiane. Consiglio nazionale delle ricerche, Verona. 156 str.

MÜLLER-LİEBANAU, I. (1969). Revision der europäischen Arten der Gattung Baetis Leach, 1815 (Insecta, Ephemeroptera). Jahrgang. 216 str.

NİLLSON, A. (1996). Aquatic insect of North Europe. Apollo Books, Stenstrup. 274 str.

NOGA, T., STANEK-TARKOWSKA, J., PESZEK, Ł., PAJĄCZEK, A. and KOWALSKA, S. (2013): Use of diatoms to asses water quality of anthropogenically modified Matysówka stream. Journal of Ecological Engineering. 14: 1-11.

NORRİS, R.H., BARBOUR, M.T. (2009). Bioassessment of Aquatic Ecosystem, Pollution and Remediation. Elsevier Inc.

PANTLE, R., BUCK , H. (1955): Die biologische Überwachung der Gewässer und die Darstellung der Ergebnisse. Besondere Mittelung und Deutschen Gewässerkundlichen 12:135-143

PANTLE, R., BUCK , H. (1955): Die Biologische Uberwaschung der Gewaser und die darstellung der Ergebnisse Gas und Waserfach 96: 604.

PATRİCK, R., PALAVAGE, D. M. (1994): The Value of Species as Indicators of Water Quality. Proceedings of the Academy of Natural Sciences of Philadelphia. 145: 55-92.

PFLEGER, V. (1999). Molluscs. Blitz Editions. Leicester. 216.

PLENKOVİĆ-MORAJ, A., GLİGORA UDOVİĈ, M., KRALJ BOROJEVİĆ, K., ŢUTİNİĆ, P. (2009): Fitobentos u: EK-KO projekt Habdija, I., Kerovec, M., Mrakovčić, M., Plenković-Moraj, A., Primc Habdija, B. (2009 a, b i c): Ekološko istraživanje površinskih voda u Hrvatskoj prema kriterijima Okvirne direktive o vodama. PMF, Sveučilište u Zagrebu, Zagreb.

ROUND, F.E., CRAWFORD, R.M., MANN, D.G. (2000). The diatoms, Biology & morphology of the genera. Cambrige University Press, Cambridge.

SLADAČEK, V. (1979). System of water quality from the biological point of view. Arch. Hydrobiol. Beih. Ergebn. Limnol., 7 (I – II): 1–218.

SLUŽBENE NOVİNE FEDERACİJE BİH (2013): Zakon o vodama: Odluka o karakterizaciji površinskih i podzemnih voda, referentnim uvjetima i parametrima za ocjenu stanja voda i monitoringu voda. Sarajevo: Službene novine Federacije BiH, broj 70/06, 10-44.

TROŽİĆ-BOROVAC, S., HAFNER, D., ŠARAC, M., ŠKRİJELJ, R., ANTUNOVİĆ, M., GAJEVİĆ, M., LONČAREVİĆ, A. (2011): Qualitative and quantitative composition of benthos community in evaluation of water quality of Neretva River at Visici and Zitomislici sites. Zbornik predavanja: V Međunarodna konferencija „Akvakultura i ribarstvo“

VAN DAM, H., MERTENS, A., SİNKELDAM, J. (1994): A coded checklist and ecological indicator values of freshwater diatoms from the Netherlands. Netherlands Journal of Aquatic Ecology. 28: 117–133.

WALTON, R. G. (1989): Electrical Conductivity and Total Dissolved Solids—What is Their Precise Relationship Desalination, Volume 72, Issue 3, pp 275-292.

WARİNGER, J.,WOLFRAM, G. (1997): Atlas der Österreichischen Kocherfliegenlarven. Facultas – Universitatsverlag, Wien. pp 268.

WARİNGER, J., GRAF, W. (2011). Atlas of Central European Trichoptera Larvae, Eric Mauch Verlag, Germany.

WATSON, L., DALLWİTZ, M. J. (2005): The families of British non-marine molluscs (slugs, snails and mussels). Version: 10th April 2007.

WEGL, R. (1983): Indeks fur die Limnosaprobitat, Waser und Abwasser. 26, 1-175.

WEGL, R. (1983). Index für die Limnosaprobitaet. -Wasser und Abwasser. Beitraege zur

WEST, W., WEST, G.S. (1905). A Monograph of the British Desmidiaceae. Volume II. Adlard and Son, London.

WEST, W., WEST, G.S. (1908). A Monograph of the British Desmidiaceae. Volume III. Adlard and Son, London.

WOJTAL, A. Z. (2009): The diatoms of Kobylanka stream near Kraków (WyĪyna Krakowsko-częstochowska upland, S Poland). Polish Botanical Journal54: 129-330.

ZABELİNA, M.M., KİESELEV, I.A., PROŠKİNA-LAVRENKO, A.I., ŠUŠEKOVA, V.I. (1951): Opredeljitelj presnovodnih vodoroslej SSSR. Diatomovie Vodorosli. Gosudarstvenoe izdateljstvo Sovjetskaja nauka, Moskva.

ZELINKA, M., MARVAN, P. (1961). Zur Prazisierung der biologischen Klassifikation des Reinheit fliessender Gewässer. Arch. Hydrobiol. 57:

SAŽETAK

U ovom radu je predstavljeno istraživanje bentoskih zajednica (fitobentos i krupni beskralješnjaci) na tri postaje na rijeci Neretvi i to; Glavatičevo, Žitomislići i Višići. Rijeka Neretva je najduža i vodom najbogatija rijeka Dinarskog krša. Dužina toka rijeke od izvora do ušća je 240 km. Najvećim dijelom protječe Bosnom i Hercegovinom (90%), dok samo mali dio (10%) protječe teritorijem Republike Hrvatske gdje se ulijeva u Jadransko more. Veće pritoke rijeke Neretve su Ljuta, Rakitnica, Bijela, Trešanica, Kraljušnica, Neretvica, Rama, Doljanka, Drežanka, Radobolja, Jasenica, Trebižat (desne pritoke) i Šištica, Baščica, Prenjska rijeka, Šanica, Bijela, Buna, Bregava, Krupa (lijeve pritoke). Krška geologija područja rezultira velikim interakcijama između površinskih i podzemnih voda. Za potrebe ovog istraživanja odabrane se tri postaje rijeke Neretve, od kojih je jedna (Glavatičevo) u gornjem toku rijeke, a Žitomislići i Višići u donjem toku rijeku.
Cilj istraživanja bio je procijeniti ekološki status istraživanih postaja na temelju zajednica fitobentosa i krupnih beskralješnjaka. Ekološki status je odraz kvaliteta, strukture i funkcije vodenih ekosustava površinskih voda. Prema tipologiji površinskih tekućica postaja Glavatičevo pripada podtipu 10a dok postaje Žitomislići i Višići su JIVT (jako izmijenjena vodna tijela).
Istraživanje bentoskih zajednica je provedeno u prosincu 2016 godine uz istovremeno praćenje kemijskih čimbenika vode. Sve istraživane postaje su pokazale veliku brojnost i raznolikost bentoskih svojti iako su uzorci uzimani u zimskoj sezoni. Postaja Glavatičevo prema dobivenim saprobnim indeksima bentoskih zajednica ukazuje na vodu oligosaprobnog stupnja, odnosno vodu neopterećenu organskim tvarima. Postaja Žitomislići ukazuju na vodu oligo-betamezosaprobnog stupnja, odnosno vodu malo opterećenu organskim tvarima. Postaja Višići prema fitobentosu je oligo-betamezosaprobna dok je prema makroskopskim beskralješnjacima betamezosaprobna (voda opterećena organskim tvarima).

Na temelju dobivenih indeksa i mjerenih kemijskih čimbenika vode u skladu s *Odlukom o karakterizaciji površinskih i podzemnih voda, referentnim uvjetima i parametrima za ocjenu stanja voda i monitoringu voda* (Službene novine FBiH, broj 1/14) maksimalan ekološki potencijal zabilježen je za postaje Žitomislići i Višići dok je za postaju Glavatičevo zabilježeno visoko ekološko stanje.

Corresponding author: Anita Dedić, University of Mostar, Faculty of Science and Education, Rodoč bb, Mostar, E-mail: anita.dedic@fpmoz.sum.ba

Works of the Faculty of Forestry
University of Sarajevo
No. 2, 2018 (54-64)

UDK 639.124(497.11)

VIABILITY OF THE POPULATIONS OF PERDIX PERDIX L. AT MT. FRUŠKA GORA AND SREMSKA RAČA, REPUBLIC OF SERBIA

Održivost populacija *Perdix perdix* L. na Fruškoj Gori i u Sremskoj Rači, Republika Srbija

Vejzagić Selma[1]

Abstract

Perdix perdix L. (also known as the Grey partridge, English partridge, and Hungarian partridge) populations have been declining for years in natural habitats and areas in which this species of wildlife has been introduced. Hunting grounds at the base of *Mt. Fruška Gora* and Sremska Rača in the Republic of Serbia provide excellent conditions for its breeding. In addition to the data from hunting records about population quantity of the *P. perdix*, a direct monitoring allows a relevant inside to its' quantity in hunting associations' hunting grounds. The decline of population quantity is mostly the result of the use of chemicals for protection of agricultural crops (10%), destruction of nests and bird eggs (12.5%), and the failure to implement failure wildlife-protection measures, by forbidding the hunt of *P. perdix* (5%) , and the use of poisons on agricultural crops, such as the forbidden poison *Furadan* (5%). Although no significant results have been obtained on the impact of predators and abandoned animals on the reduction of *P. perdix* population, there is a justified concern by hunting associations' in terms of finding ecologically and biologically viable solutions for impact on predators on feathered game, and especially abandoned dogs. The results of the study were obtained by the method of directly determining the number of *P. perdix* in the crop fields, in the hunting grounds of L.D. "Fazan Mala Remeta", L.D. "Fazan" Jazak, L.D. "Stejanovci" Stejanovci, L.D. "Zec" Vrdnik and L.D. "Srndać" Sremska Rača. The obtained results directly the need to introduce the principle of integral protection of *P. perdix*, which implies control over the implementation of measures for the protection of agricultural crops and the implementation of *P. perdix* protection measures during the organization of hunting on other game species in hunting grounds.

Key words: *P. perdix L., population, hunting ground, agricultural crops, Fruška Gora, Sremska Rača, poison*

INTRODUCTION - *Uvod*

According to OPHOVEN, (2010), the grey partridge comes from family *Perdicinae*. This species can be 29-31 cm wide, and 45-48 cm tall, reaching the total mass of 350-450 g (OPHOVEN, 2010). March and April are mating months, and incubation lasts 24-26 days, after females give 10-25 chicks (OPHOVEN, 2010). According to OPHOVEN (2010), females ley eggs at the edges of cereal winter fields.

[1] *MA Forestry*, Faculty of Forestry, University of Sarajevo

Different impacts from the nature, but also human activity, make this species very sensitive, so its' existance depends on ecological management in wildlife ecosystems. According to MIKSCH et al., (1998-2004), the grey partridge is very sensitive to a hair worm, who leaves eggs in birds' hair, making it host to a parasites. MIKSCH et al., (1998-2004) give *Echinococcus multilocularis* as an example of parasite attacking the grey partridge very often, producing more than 100 eggs in its' hair. In capital originaly named „Die letzen Gefahren im deutschen Wald“, MIKSCH et al., (1998-2004) describe *E. multilocularis* as the greatest parasite of all wildlife in german forests (german name for the worm is *Kleiner Fuchsbandwurm*). The grey partridge is also affected by HN virus, birds' plague and birds' cholera (OPHOVEN, 2010), so not only by parasites, but also by all natural hairy predators, scavenger birds (hawk, buzzard *etc*.), wild cat, bisam rat, eagle *etc*.

Since a female of the investigated species is laying eggs in the ground of crop field, it is important to know the influence of herbicide and pesticides on this species. According to OPHOVEN, (2010), the sooner we understand the use of herbicides and pesticides in the fields' protection, that will provide more chances for the survival of grey partridge and exceed the opportunity to manage this species as hunting. Pesticides and herbicides are retained in the soil, and in the larvae and insects that birds eat. In the Report of the GREENPEACE (May 2015), KÖHLER and TRIEBSKORN (2013) wrote that increasing the number of pesticide and herbicide impact' studies on wildlife had exponentially increased over the last 30 years.

Republic of Serbia is one of the leading producers of food in its' region. It is known by its' large cereal fields but also very diverse wildlife inhabited in crops. Different chemicals used in agriculture make grey partridge sensitive and even vunerable species, so the need of protection of this species is greater than ever. The conducted study needs to identify the problems that cause disappearing of this species from fields and to give possible solutions for resolving the existing problem of decreasing the number of birds in Republic of Serbia, so this study needs to identify the real problems of disappearing partridges.

MATERIAL AND METHODS - *Materijal i metode*

Hunt science research today – *Savremena istraživanja iz Lovstva*

Wildlife management is part of modern Forestry Science - field of Integral protection of forests, wildlife and bioecosystems, that has got very hard task in modern era - to keep the balance between the bioecological characteristics and demand of living organisms and increasing demands and needs of human population on Earth, for its' survival. Beeing a hunt researcher in modern era is a specific and hard work, according all the incoming demands from different stake-holders, interested in protecting the nature resources.

Material of research – *Materijal istraživanja*

In this study, the material of research are live and dead examples of grey partridges, their nests, eggs and chicks, located in five different hunting grounds.

Period of research and specifics of research area – *Vrijeme istraživanja i specifičnosti istraživanog područja*

The evidenting the number of grey partridges was conducted in certain time period, 2016th-2018th year. The research area include hunting ground of five hunting associations: L.D. "Fazan Mala Remeta", L.D. "Fazan" Jazak, L.D. "Stejanovci" Stejanovci, L.D. "Zec" Vrdnik and L.D. "Srndać" Sremska Rača, that manage 2200 ha of crops, inhabited with different hunting wildlife. The climate and vegetation present in theese five hunting grounds has positive impact on grey partridge' reproduction, growth and living. The whole area is rich with natural food and plenty of insects eaten by chicks of partridges. All the crops in hunting grounds present the hunt productive surfaces, except 100 ha of crops in boundaries of L.D. "Fazan Mala Remeta", that is usurpated by the plant nursery in near place.

The need for using method of counting total number of birds – *Potreba za primjenom metode potpunog prebrojavanja ptica*

The counting of all the birds in the hunting grounds is needed in case of missing the relevant data in evidences of hunting associations, but also in case of conducting the serious research, that is related to identifying the precise number of birds affected by certain factor. Precise number of birds is important indicator of biological and ecologycal problems affecting wildlife in certain hunting ground.

Goals needed to be reached by using method of total counting of birds – *Ciljevi koje treba ostvariti primjena metode potpunog prebrojavanja ptica*

In the study, birds and bird flocks were counted directly in hunting grounds in 2018th, and data about quantity of the partridges in period 2016th-2017th were taken from evidences of hunting associations, in aim to comparise results of previous counting of birds with new results, that helped to answer main aims of the research:

1. Explore the number of dead birds in hunting grounds caused by different impacts.
2. Find the relative percentage (%) of dead birds in hunting grounds caused by different impacts (Total number of observed birds N = 400, Absolute percentage = 100%).
3. Identify the main problem affecting birds population in different hunting grounds, shown by relative percentage of dead birds.

Parameters that needs to be measured to reached the goals of using method of total counting – *Parametri koji će se mjeriti kako bi se ostvarili ciljevi primjene metode potpunog prebrojavanja*

There are four measuring parameters in this study: 1) Use of chemicals in protection of agricultural crops; 2) Illegal hunt of partridges; 3) Destruction of nests and bird eggs and 4) Use of poisons in protection of agricultural crops.

RESULTS - *Rezultati*

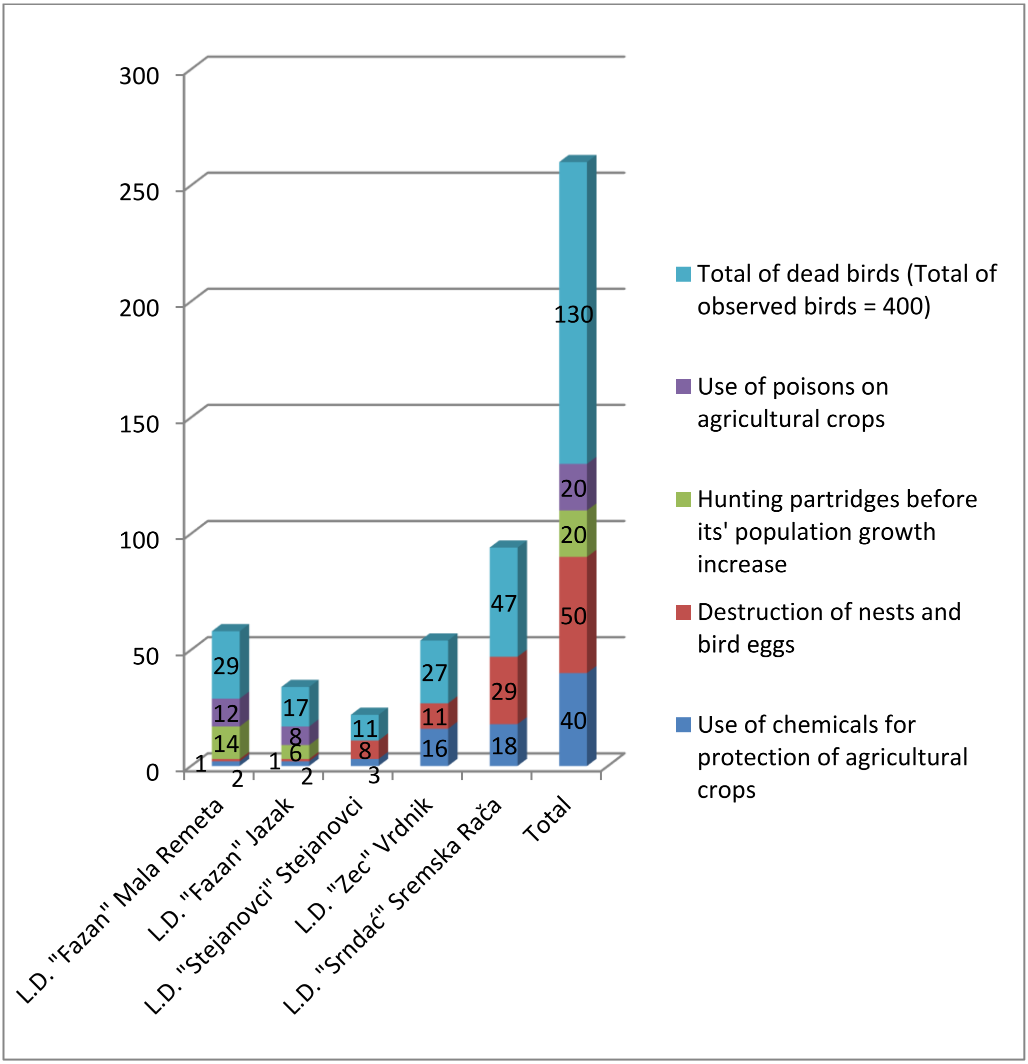
In this study, we got four main results of research, that will help understanding the main problems affecting grey partridge' populations in Republic of Serbia, giving directions how to improve management of this species in hunting grounds.

First result of the study is given in Table 1.

Table 1. Number state of *P. perdix* L. populations of grey partridge (*Perdix perdix* L.) at Mt. Fruška Gora and Sremska Rača for 3-year period (2016-2018)
Tabela 1. Brojno stanje populacija jarebice poljske (Perdix perdix L.) na Fruškoj Gori i u Sremskoj Rači za trogodišnji vremenski period (2016-2018)

Hunting ground	*Number of birds in 2016*	*Number of birds in 2017*	*Number of birds in 2018*
L.D. "Fazan" Mala Remeta	1 flock of 10 pairs of birds = 20 birds	2 flocks of 10 pairs of birds = 40 birds	2 flocks of 12 pairs of birds = 48 birds
L.D. "Fazan" Jazak	1 flock of 10 pairs of birds = 20 birds	1 flock of 10 pairs of birds = 20 birds	2 flocks of 13 pairs of birds = 52 birds
L.D. "Stejanovci" Stejanovci	2 flocks of 6 pairs of birds = 24 birds	3 flocks of 6 pairs of birds = 36 birds	6 flocks of 6 pairs of birds = 72 birds
L.D. "Zec" Vrdnik	2 flocks of 6 pairs of birds = 24 birds	3 flocks of 6 pairs of birds = 36 birds	3 flocks of 6 pairs of birds = 36 birds
L.D. "Srndać" Sremska Rača	8 flocks of 10 pairs of birds = 160 birds	9 flocks of 12 pairs of birds = 216 birds	12 flocks of 8 pairs of birds = 192 birds
Total	248	348	400

The number of dead birds in hunting grounds, caused by different impacts, is given in Graph 1.



Graph 1. Number of dead birds of *P. perdix* L. affected by different impacts, evidented in explored hunting grounds

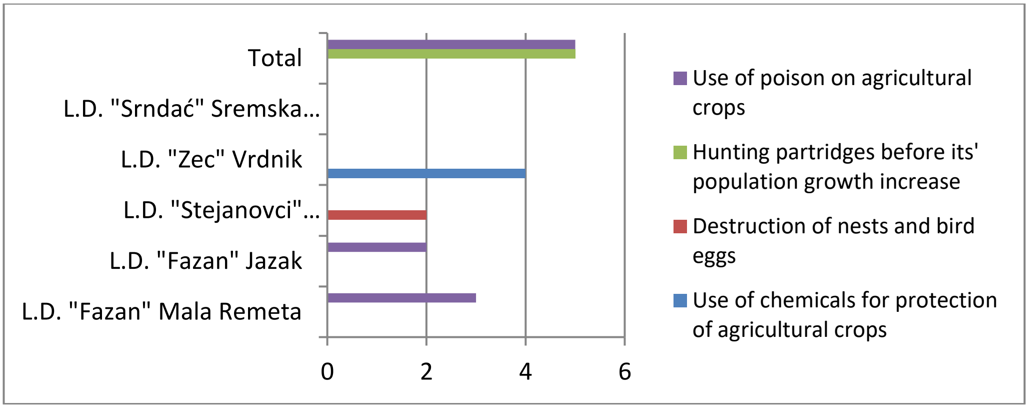
Grafik 1. Broj stradalih ptica P. perdix L. uslijed različitih faktora, evidentiran u istraženim lovištima

Relative percentage (%) of dead birds in hunting grounds caused by different impacts is given in Table 2.

Table 2. Relative percentage (%) of dead birds of *P. perdix* L. in hunting grounds, affected by different impacts (Total number of observed birds = 400, Absolute percentage = 100%)
Tabela 2. Relativno procentualno učešće stradalih ptica P. perdix L. u lovištima, uslijed uticaja različih faktora (Ukupan broj posmatranih ptica = 400, Apsolutni procenat posmatranih ptica = 100%)

Different impacts on birds	*L.D. "Fazan" Mala Remeta*	*L.D. "Fazan" Jazak*	*L.D. "Stejanovci" Stejanovci*	*L.D. "Zec" Vrdnik*	*L.D. "Srndać" Sremska Rača*	*Total*
Use of chemicals for protection of agricultural crops	0,5	0,5	0,75	4	4,5	10,25
Destruction of nests and bird eggs	0,25	0,25	2	2,75	7,25	12,5
Hunting partridges before its' population growth increase	3,5	1,5	0	0	0	5
Use of poison on agricultural crops	3	2	0	0	0	5

The main problem affecting birds population in different hunting grounds, shown by relative percentage of dead birds, is given in Graph 2.



Graph 2. The main problem affecting birds populations of *P. perdix* L. in different hunting grounds at Mt. Fruška Gora, shown by relative percentage of dead birds
Grafik 2. Najvažniji problem koji pogađa populacije ptica vrste P. perdix L. u različitim lovištima na Fruškoj Gori, prikazan relativnim procentualnim učešćem stradalih ptica

DISCUSSION AND CONCLUSIONS – *Diskusija i zaključci*

The obtained results directly indicate to a need of introducing the principle of integral protection of *P. perdix*, which implies control over the implementation of: 1) Protection measures of agricultural crops and 2) Protection measures of *P. perdix*, during the organization of hunting on other game species in hunting grounds.

Populations of grey partridges have been increasing in last three years (from 248 in 2016, to 400 in 2018), thanks to changing the chemicals used in agriculture. According to reports of presidents of hunting associations, in the past there had been used different poisoning chemicals for protecting the fields of vegetables and cerals from birds, rats, insects and also different game species in that area. Inovations in agriculture and buying new chemicals for plant protection brought a new principle of growing food and cereals, but there are still disadvantages in new way of agriculturing crops. The fields today are becoming wider, without natural borders formed by grasses and bushes, as the secure protection for grey partridges from predators, but also causing number of nests deacresed, because birds still have not gotten used on new conditions for mating and reproducing on wider crops (partridges gotten used on making nests on the edges of the smaller fields). In hunding area in Mala Remeta, there is a slower rate of increasing the grey partridges.

According to the report of the president of hunting association, there has been evidented poach, so the partridges are illegaly hunted even in periods when the hunt is forbidden by the law. Small traces of *Furadan* has been found on the surface of fields, and also traces of dead animals consisting digested *Furadan*. The main problem according the use of this forbidden poison is his presence at open market places, where is possible to be found in large amounts. The poison is beeing used the way it is mixed with cow milk, for getting a suspension. That suspension is used to paint the seeds for planting crops, and after drying the seeds, landworkers found plantations and crops, thinking they protected cereals and vegetables from pests.

It is very hard to prove the usage of *Furadan* and its' presence in landworkers' ranches.

The same problems are present in hunting ground in Jazak, because those twoo hunting grounds share the same conditions for breeding the partridges, and there is no evident border between those twoo hunting grounds. The main cause of mortality of partridges in Jazak is usage of chemicals. The difference between protection the wildlife in Jazak and Mala Remeta lay in missing enough roads in Jazak hunting area. The Mala Remeta' hunting ground is divided on twoo sides, by the local road, that helps inspection to explore the hunting area in every occasion. In comparison to Jazak, whose hunting areas, formed from fields, are very far from the road, hunt inspectors find hardly to come and explore hunting areas at the right time, when dead partridges are evidented. In general, it is very easy to cover the traces of poisoning the birds and to remove the remains of dead partridges.

In hunting ground in Stejanovci, according to report of hunters, the main problem in the past was using *Furadan* in protecting the crops. After the forbidding its' use, the population of partridges immediately grew.

The border between hunting grounds of Stejanovci-Mala Remeta revirs is known by increased number of abandoned dogs, but the hunters work on protecting the border and crops from dogs every year. The activities of that kind of wildlife protection are not accepted by non-government organizations, fighting for animal rights, so the functioning of the hunting associations is becoming complicated by, also, this very important factor. In the future, hunting associations should become more protected from conflicts with all parties involved in wildlife protection and protection of domestic animals, because the basic activity of hunting associations is breeding and the protection of animals in their natural habitats.

Deystoring of nests and eggs of grey partridges in Stejanovci is caused by increased usage of tractors. As the natural borders of todays' fields are covered with only small zones of weed vegetation, that does not give needed protection to partridges from the predators and also not enough space for making nests. Birds are making nests at places that are exposed to activity of tractors and heavy mechanization, so huge number of chicks, nests and eggs disappear from fields in Stejanovci in last three years.

Even in wider area of Vrdnik, the partridges are more protected by negative impacts on its' population, so the number of dead birds is especially huge according the presence of using diverse chemicals in protecting the crops. By the way, hunt productive area in Vrdnik is larger than all together areas of other three hunting grounds at *Mt*. Fruška Gora, so the relative number of dead birds, even showing huge level of mortality caused by chemicals' usage, is not indicating alarming state of partridge' population, but it shows that, even the hunting area in Vrdnik is wider, there are not many birds poisoned by chemicals. Greatest problem would be usage of heavy mechanization in agriculture, that affect nests, females and chicks mostly.

In Sremska Rača, the biggest problem affecting the population of grey partridge is usage of heavy mechanization in agriculture, because the hunting association manage mostly the hunt productive fields in boundaries of hunting ground. Those fields are very large and this area of Vojvodina is, also, know by huge rate of modernization of agriculture mechanization. Tractor additions for planting the seeds are modern, developed and consisting more parts of composition, in comparison to older compositions of tractor additions.

After describing results given in tables and graphs in this study, and maintaining the key problems affecting the populations of grey partridge, we concluded that use of pesticides in agriculture caused basic problems in breeding grey partridge in hunting grounds at Mt. Fruška Gora, and usage of heavy mechanization in Agriculture in Sremksa Rača caused main problems in disappearing grey partridges from the fields. We can not identify the absolute number od poisoned birds in past by the pesticides, but we surely can say that protection measures of fields in agriculture represent the key for identifying the real cause of disappearing the grey partridge from their natural habitats.

In Capital of the GREENPEACE' Report, printed in German language, originally named „Pestizide in der Landwirtschaft“ („Pesticides in the Agriculture“), it is stated that the use of chemical-synthetic pesticides in agriculture began in the 1950's. There is also a classification of pesticides, which includes nine basic groups of pesticides used in agriculture, with the basic descriptions of the effects of certain pesticides: 1) Organohloropesticides (WILLET et al., 1998), 2) Organophosphate pesticides (skip OPP), 3) carbamates, according to MORAIS et al. (2012), include *Aldicarb*, *Methiocarb*, *Primicarb*, *Maneb* and *Mancozeb*, 4) Synthetic Pyrethroids, which according to KOUREAS et al. (2012) have a bad influence on the human endocrine system, 5) neonicotinoids, which form a new pesticide group of negative effects on the human nervous system, and have been in use since 1985 (KIMURA-KURODA et al., 2012), 6) paraffins, 8) *glyphosate* (GUYTON et al., 2015) and 9) other types of pesticides of complex chemical structure.

In addition to negative effects of agriculture on grey partridge, it is evident that changing the shape and surface of frields also caused disappearing the grey partridge from fields. The key problem lay in missing enough hiding places, mating spots and making nests' adequate spots in fields.

It is important to imply the need of integral protection measures' control all over the breeding areas of grey partridge, because that species has became very sensitive to all other negative influences from the ecosystem. When its' natural habitat is damaged and affected by negative factors, grey partridge could also get attacked by parasites and infected by diseases.

In capital about the hair worm, MIKSCH et al., (1998-2004) give details of *E. multilocularis* worm female' segmented ovaries, with each of them consisting 300 eggs, from which number the 1/3 is beeing layed in grey partridges' hair. That confirms the alarmance of grey partridges' parasite attacks' problem.

OPHOVEN, (2010) gives twoo different parasites always attacking the grey partridge: 1) The red worm and 2) The hair worms. According to MIKSCH et al., (1998-2004), the hair worms come in different colours when attacking the host, but also changing the colour when host getting sick.

So, if the future managers of hunting grounds would not implement the principle of integral protection of this species, grey partridge could be affected by the biological negative factors, even if the illegal hunt would disappear permanently and even if the chemicals used in agriculture become more ecologically acceptable. Every species is sensitive, not only to chemical and mechanical influences, but also to biological, so the future research of this problem can not stop on identifying only the chemical' and mechanical impacts on this game' survival.

Use of chemicals for protection of agricultural crops caused death of 10% of grey partridges in researched areas. Usage of chemicals is greater with growing needs of human population for bigger quantities of food and cereals. Destruction of nests and bird eggs of grey partridges is evidented in 12.5%, and it is mostly caused by using a heavy mechanization in agriculture. New tractors are bigger and additions for planting seeds are wider and more complex, causing breaking eggs, killing chicks and hens. Even

5% of dead birds are killed in poach, that is very hard to prevent, because the system of monitoring the hunt activities is not full-time and hunting grounds generally do not have installed cameras for tracking the illegal hunt. The greatest problem in poisoning partridges is *Furadan* (5%). This poison is very easy to find on open market places, and its' use is dangerous not only for wildlife, but also for humans. In general, the law should more protect hunting organizations from conflicts with local community and NGO's, because hunters are primarly protectors of the wildlife, that continiously work on improvement of breeding conditions for every game species. Supproting the hunting organizations, the wider area of hunting ground will gain more advantages, not only from aspect of game protection, but also protection of whole natural ecosystems.

ACKNOWLEDGEMENT

This paper was presented at International Symposium "People-Forest-Science", October 10-12, 2018, Sarajevo, Bosnia and Herzegovina.

REFERENCES - *Literatura*

AKTAR, W., SENGUPTA, D., CHOWDHURY, A., (2009): Impact of pesticides use in agriculture: their benefits and hazards. Interdisciplinary Toxicology. Mar; 2(1), p. 1–12

GUYTON K., LOOMIS D., GROSSE Y., EL GHISSASSI F., BRENBRAHIM-TALLAA L., GUHA, N., SCOCCIANTI C., MATTOCK H., STRAIF K. (2015): Carcinogenicity of tetrachlorvinphos, parathion, malathion, diazinos, and glyphosate. Lancet Oncology. Also published online, March 20. DOI: http://doi.org/10.1016/51470-2045 Vol. 15, No. 70134. P. 8.

JOBLING, J.A. (2010): The Helm Dictionary of Scientific Bird Names. London: Christopher Helm. p. 297. ISBN 978-1-4081-2501-4.

KIMURA-KURODA J., KOMUTA., Y., HAYASHI, M., KAWANO, H. (2012): Nicotine-like effects of the neonicotinoid insecticides acetampirid and imidacleoprid on cellullar neurons from neonatal rats. PloS ONE 7. Vol. 324. P. 32.

KÖHLER, H.R. AND TRIEBSKORN, R. (2013): Wildlife exotoxicology of pesticides: can we track effects to the population level and beyond? Science, Vol. 341, P. 759-765., published in *Report of GREENPEACE*, Capital: 3. „Pestizide und unsere Gesundheit“. *DIE SORGE WÄCHST. Mai 2015, Research Laboratories*. P. 3, 6-8 DOI: http://www,greenpeace.org/austria/Global/austria/dokumente/Reports/Bienen/Landwirtschaft_Pestizide-und-unsere-Gesundheit_2015.pdf

KOUREAS M., TSAKALOF, A., TSATSAKIS, A., HADJICHRITODOULOU, C. (2012): Systematic review of biomonitoring studies to determine the association between exposure to organophosphorus and pyrethroid insecticides and human health outcomes. Toxicology Letters Vol. 201. P. 155-168.

LONG, J. (1981): Introduced Birds of the World. Agricultural Protection Board of Western Australia. Terrey Hills, N.S.W. : Reed, p. 21–493.

MIKSCH, G., BANNERT, B., LUCIUS, R. (1998-2004). Parasiten Überlebenskünstlern auf der Spur, *Parasiten, Leben und leben lassen*. KOSMOS, first edition: 1998, *Stuttgarter Beiträge zur Naturkunde, Serie C, 42, 102 S.* © second edition: 2004, *Staatliches Museum für Naturkunde Stuttgart und Franckh – Kosmos Verlags – GmbH&Co.*, Stuttgart. P. 4, 17, 33, 56. Alle Rechte vorbehalten ISBN: 3-440-09991-1.

MORAIS S., DIAS, E., PEREIRA, M.L. (2012): Carbamates: human exposure and health effects. M. Jokanovic (ed.), *The Impact of Pesticides*. WY Academy Press Cheyenne. P. 21-38.

OPHOVEN, E. (2010). Wildtierkunde Biologie, Merkmale, Bejagung, Praxiswissen Jagd, empfolen von *Wild und hund Deutsche Wildtier Stiftung, Einheimische in ihren Lebensräumen földern und erlebbar machen*. KOSMOS. Capital: *Federwild*, p. 68. and *Hühnervögel*, p. 70-71.

WILLET, K.L., ULRICH, E.M., HITES, A. (1998): Differential toxicity and environmental fates of hexachlorocyclohexane isomers. Environmental Science and Technology. Vol. 32. P. 2197-2207.

SAŽETAK

Populacije *Perdix perdix* L. godinama su u padu na prirodnim staništima i područjima u koje je ta vrsta divljači introdukovana. Lovišta u podnožju Fruške Gore i u Sremskoj Rači u Republici Srbiji pružaju odlične uslove za njen uzgoj u prirodi. Pored podataka iz evidencija lovišta o brojnom stanju, relevantan uvid u brojno stanje *P. perdix* na terenu omogućava direktno praćenje stanja populacija u lovnim atarima lovačkih društava. Na opadanje njene brojnosti najviše utiče primjena hemijskih sredstava za zaštitu poljoprivrednih usjeva (10%), uništavanje gnijezda i jaja (12,5%), nepridržavanje odredaba zaštite *P. perdix* kojima se zabranjuje lov dok se njena populacija ne uveća (5%), te upotreba otrova na poljoprivrednim usjevima, poput zabranjenog otrova Furadana (5%). Iako nisu dobijeni značajniji rezultati o uticaju predatora i napuštenih životinja na smanjenje brojnosti *P. perdix*, postoji opravdana zabrinutost lovačkih društava u pogledu pronalaska ekološki i biološki održivih rješenja namnoženja predatora na pernatu divljač i posebno napuštenih pasa. Rezultati istraživanja su dobijeni metodom direktnog utvrđivanja brojnog stanja *P. perdix* na terenu, u lovnim atarima L.D. „Fazan Mala Remeta“, L.D. „Fazan“ Jazak, L.D. „Stejanovci“ Stejanovci, L.D. „Zec“ Vrdnik i L.D. „Srndać“ Sremska Rača. Dobijeni rezultati direktno upućuju na potrebu uvođenja principa integralne zaštite *P. perdix*, koji podrazumijeva kontrolu provođenja mjera zaštite poljoprivrednih usjeva i provođenja mjera zaštite *P. perdix* tokom organizovanja lovova u lovištima na druge vrste divljači.

Corresponding autor: Selma Vejzagić, MA Forestry, Faculty of Forestry, University of Sarajevo, Zagrebačka 20, 71000 Sarajevo, Bosnia and Herzegovina; e-mail address: zastitasuma.bih@gmail.com

Works of the Faculty of Forestry
University of Sarajevo
No. 2, 2018 (65-77)

UDK 639.1.05/.08

APPLICATION OF NEW TECHNIQUES AND TECHNOLOGIES IN HUNTING

Primjena novih tehnika i tehnologija u lovstvu

Marijan Grubešić[1], Saša Kunovac[2], Živko Rapaić[3], Mustafa Bašić[4], Kristijan Tomljanović[1]

Abstract

The development and application of new techniques and technologies in hunting management, scientific research and professional work in the hunting domain is a continuous process. Numerous technical achievements are often applied and targeted operationally in hunting and the exploration of game and its habitat.

When analysing the past period, and the latest technical and technological achievements in hunting, one can point out several very significant examples of the application of new techniques and technologies in hunting, such as:

• The development and application of live game capture methods, with particular emphasis on catching chamois in Bosnia and Herzegovina;
• Chemical immobilization (tranquilizing) in research or transport of live game;
• The use of sensory cameras (photo traps) for game tracking and surveillance of the hunting grounds (ordinary sensory cameras, IC cameras);
• Telemetric tracking of game, from large carnivores up to small game species with classic devices and GPS devices;
• Measuring microclimate elements with precision instruments on selected micro locations in wildlife habitats;
• Use of sensory sound repellents for game-avoidance (ultra - and infrared devices);
• Use of lightweight unmanned aerial vehicles for wildlife habitat analysis using a classical camera;
• Use of lightweight Unmanned aerial vehicles to determine the numerous status and game structure using a thermal imaging camera;

All the above-mentioned techniques and technologies have given, and make, a significant contribution to the scientific research work in the field of hunting and to a large extent in the daily operational application of hunting management, monitoring and protection of game and animal species.

Key words: *hunting, research, technical means, technology, hunting management*

---

[1]Faculty of Forestry of University in Zagreb, Department for Forest Protection and Hunting Management, Svetošimunska 25, HR - 10000 Zagreb
[2]Faculty of Forestry, University of Sarajevo, Zagrebačka 20, 71000 Sarajevo, Bosnia and Herzegovina
[3] Grbavička 2, 71000 Sarajevo Bosnia and Herzegovina
[4] Cantonal Forestry Office, Stanična 43,72270 Travnik, Bosnia and -Herzegovina

INTRODUCTION - *Uvod*

Development and application of new techniques and technologies in hunting, scientific and professional work in the field of game management is a continuous process. Numerous technical achievements often are especially developed for application in game management.

From ancient times, humans developed various techniques prior to game hunt. Later on, those techniques become more useful in scientific work considering the game, its habitats, and behavior or integral activities in people-habitat-game relations.

As well as the first activity of humans was „hunters-gatherers“, some think that the development of hunting techniques and technologies had a significant impact on the social and intellectual development of humans themself. Hunting was a well-known practice for the improvement of different skills, particularly sport or military ones (Blüchel, 2011). some methods but also means for game hunt are still in use today, like nets, traps, snares, hunting with birds of prey, etc. The latest technical accessories are mainly used for scientific work in game management, like sensory cameras, game telemetry, chemical immobilization, sound repellents, portable meteorological instruments or lightweight unmanned aircraft.

AIM OF WORK - *Cilj rada*

Aim of this review is to present different techniques and technologies, which are in use in game management or researches considering game species and their habitats. Some of them can be widely in use (like portable meteorological instruments), and some are specialized just for game capturing and translocation, monitoring or game inventory. However, before the appliance of new devices, techniques, and technologies, it is necessary to test their efficiency and reliability. According to this, in this paper, we presented some of the mentioned techniques and technologies as well as results that are achieved with their use.

METHODS - *Metode rada*

Live game capturing is known for more than 2000 years (Blüchel, 2011), but methods and techniques are still in progress. In the past century, chamois live capturing was conducted in Bosnia-Herzegovina to repopulate habitats in neighboring countries (Serbia, Croatia) as well as in BiH, or to introduce this species in foreign countries (New Zealand, Argentina). This extraordinary project, was realized in very hard terrain conditions and with limited technical and technological resources. Nets were used for chamois capturing, after detail and accurate choice of localities, preparations, nets mounting, education of bitters, co-workers for capturing and further chamois translocation.

Utilization of sensory cameras (photo traps) for game monitoring and surveillance of hunting ground, is an obligatory in practice or research, even for solitary hunters nowadays. There was a need for testing functionality of sensory cameras, their efficiency as well as their disadvantages concerning other means of game monitoring and surveillance of hunting grounds. Those tests were performed concerning the distance of sensor reaction, comparison between cameras with flash or infrared cameras, and the possibility of determination of game age and sex.

Game telemetry with the usage of GPS collars in the Balkan region has its first appliance on large carnivores species. Besides this, there was researches at grey partridge. The telemetry of grey partridges (bred in pheasantries) was conducted to determine their migrations, survival and habitat preferences after introduction in nature.

Portable meteorological instruments were used in numerous locations in Bosnia-Herzegovina, for testing and comparing climate conditions in habitats of rock partridge with official data at State meteorological stations, located mainly in cities or at a significant distance from rock partridge habitats.

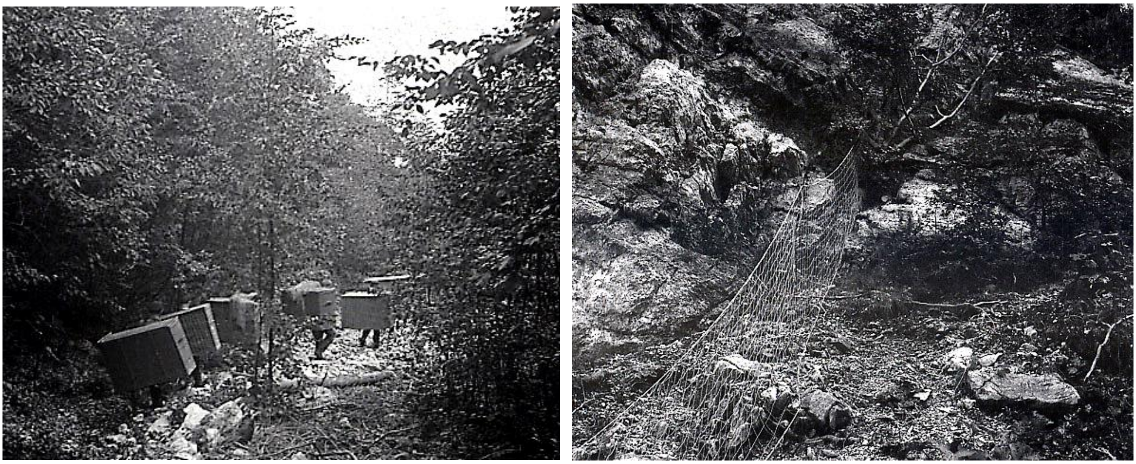
Sensory infra and ultrasonic devices were tested to determine the efficiency of these devices in game damages prevention. Testing was conducted at several locations together with the use of sensory cameras for monitoring game reaction after activation of ultra and infrasonic devices.

Unmanned aerial vehicles (UAV), commonly known as a drone, have widespread usage in game inventory in combination with term vision cameras or habitat structure researches in a combination of ordinary cameras. Drones can provide very detailed and reliable data about the current situation in game habitats as well as population condition. Testing of drones efficiency was realized in Croatia for determining exact surface structure in hunting grounds and for game inventory with total counting at some localities and transect method at large surfaces.

RESULTS - *Rezultati*

Live capturing of chamois in Bosnia-Herzegovina was conducted in mountains Prenj and Čvrsnica. Well-chosen localities for capturing (mainly paths of usual daily migrations), carefully mounted nets in three rows, educated personnel for chasing, capturing, putting in boxes and translocation, resulted in 434 captured and successfully translocated animals. Captured chamois were released at two locations in Croatia, two in Serbia and ten localities in Bosnia-Herzegovina (from which this species were exterminated). The icing on the cake in this project was capturing 37 chamois which were successfully translocated in Argentina and New Zealand.

Loses on chamois in this project were nearly 10%.



Figures 1 and 2. Mounted nets and transport of captured chamois in wood baskets

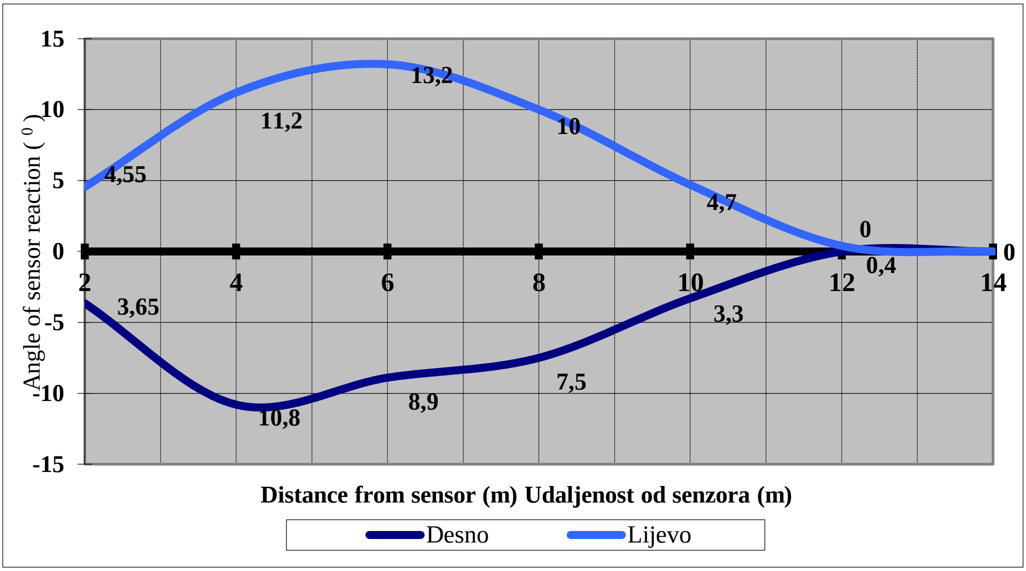
Slike 1 i 2. Postavljene mreže i transport uhvaćenih divokoza u korpama od prućа

Intensive game management, especially increasing demands for introduction, reintroduction or repopulation of game populations caused appropriate development of methods of live capturing. Nowadays, beside nets, we use various traps, snares, cirruses, etc. After capturing, it's common to use systems for immobilizations of game for further treatment, measuring or translocation. With these immobilization systems, we put animals into a position in which it can endanger either personnel or itself.

Another way for capturing, treatment or translocation is ***chemical immobilization***, which is performed with giving sedatives to game animals. Today, mainly Zoletil 50 or 100 in combination with 10% xylazine is in use.

The appliance of sensory cameras in game inventory, age, and sex determination, occurring new game species, etc, is the necessary equipment of every game manager. Instead of hunters-observers, cameras doing this job continuously in certain parts of hunting grounds on a daily/monthly/yearly basis. Today we have numerous manufacturers and types of sensory cameras, but we divide them into two basic types: cameras with flash and infrared cameras.

Cameras with flash provide better photos, especially during the night or in conditions of reduced visibility, but often flash can scare game animals. Infrared cameras are practically indistinguishable, but with less quality photos during the night. The key element in the camera is its sensor. Testing just this element, we concluded that the optimal distance of animals is 10-15 meters(exceptionally up to 20 m) this is a „weak“ point at all types of cameras. This disadvantage can be partly reduced with camera programming to make a photo or clip at certain time intervals.



Graphic 1. Results of sensor testing according distance of object

Grafikon 1. Rezultati testa senzora u odnosu na udaljenost objekta

Figures 3-6. Determination of age and sex, competition between species and detecting rare species using sensory cameras in BiH.

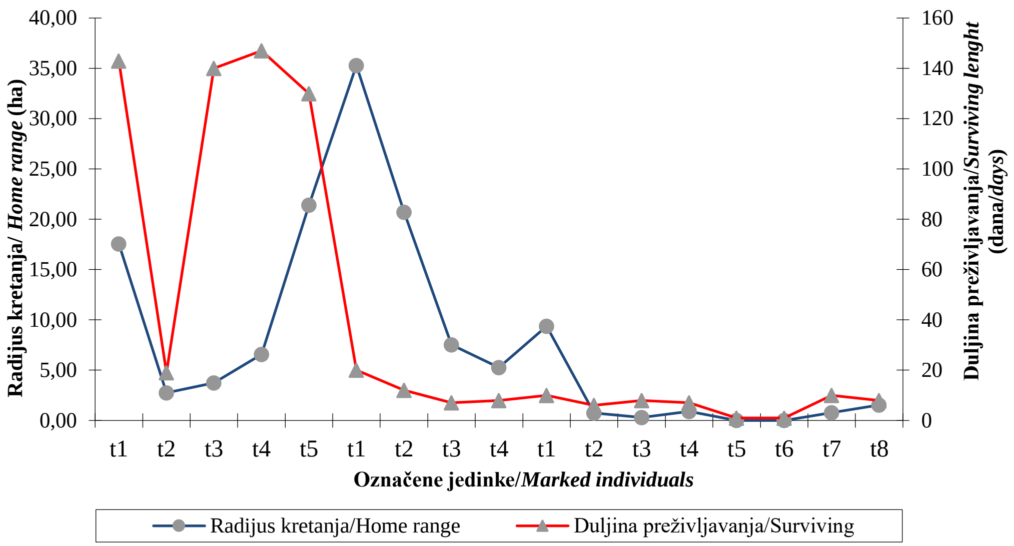
Slike 3-6. Utvrđivanje starosti i pola, kompeticije između vrsta i opažanje rijetkih vrsta pomoću nadzornih kamera u BiH.

Game telemetry has been conducted for more than 30 years. From appliance of classic collars with a transmitter, antenna, and receiver till nowadays when we use GPS collars and satellite tracking of game animals.
Research at grey partridge in Croatia has been done with „classical" telemetry. With this research, we determined the survival rate of released partridges as well as home range after releasing. Results are presented in table 1 and graphic 2:

Table 1. Comparison of the length of survival of released birds at three sites

Tabela 1: Usporedba duljine preživljavanja ispuštenih jedinki na tri lokaliteta

Lokaliteti ispuštanja / Compared locality`s	t-value	df	p
Lokalitet 1 - ljeto vs. Lokalitet 2 - jesen Locality 1 - sumer vs. Locality 2 - autumn	3,75005	7	0,007168
Lokalitet 1 - ljeto vs. Lokalitet 2 – proljeće /Locality 1 - sumer vs. Locality 2 - spring	5,82094	11	0,000116
Lokalitet 2 - jesen vs. Locality 2 – proljeće Locality 2 - autumn vs. Localit 2 - spring	1,98959	10	0,074672

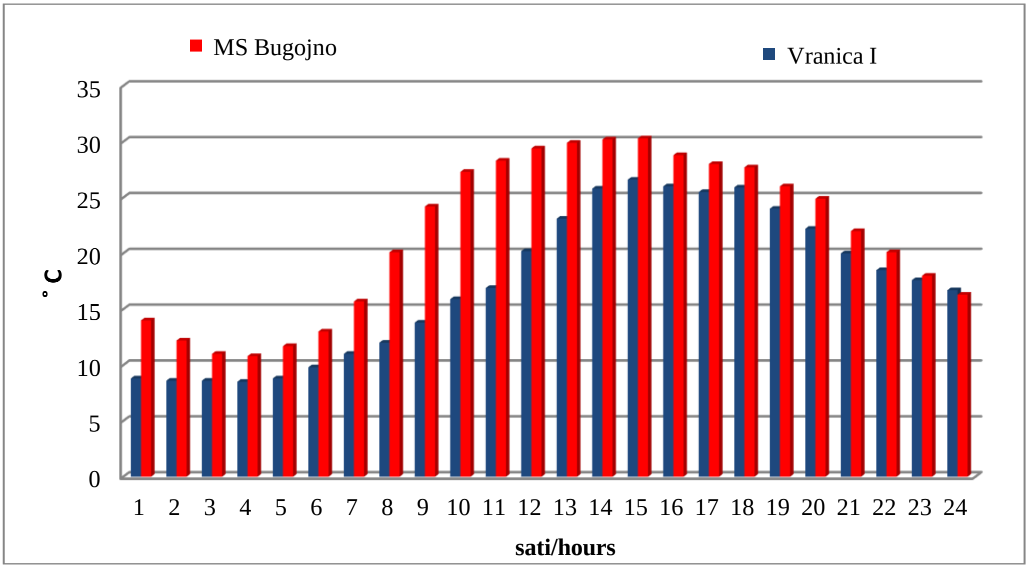


Graphic 2: Home range and survival length of released partridges

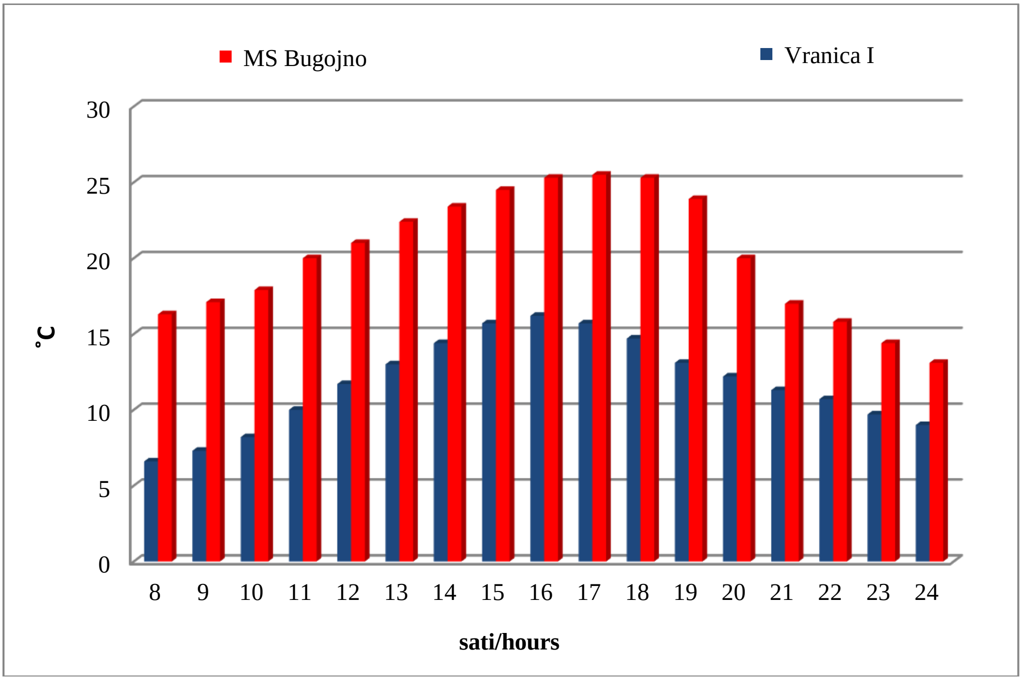
Grafikon 2: Radijus kretanja i dužina preživljavanja ispuštenih jarebica

From table and graphic, we can see that the longest survival rate has partridges that have been released in summer (survived until autumn crops removal), and the shortest partridges released in spring when predators are the most active cause of raising its youngsters.
The home range was largest in autumn and smallest in spring, which can be related to available food and cover, respectively to crop removal in autumn and forcing partridges to change locality of living.

Measuring of micro-climate conditions in rock partridge habitats with ***portable meteorological stations*** has been done in mountains of central Bosnia-Herzegovina. Results showed significant differences between obtained data and data from State meteorological stations, which are mainly located in cities or large settlements. We comared data from State meteorological station located in Bugojno, with data collected at different locations (foothill, middle and top of mountains) at field. With changing of altitude, differences are more significant as shown at the following figures:

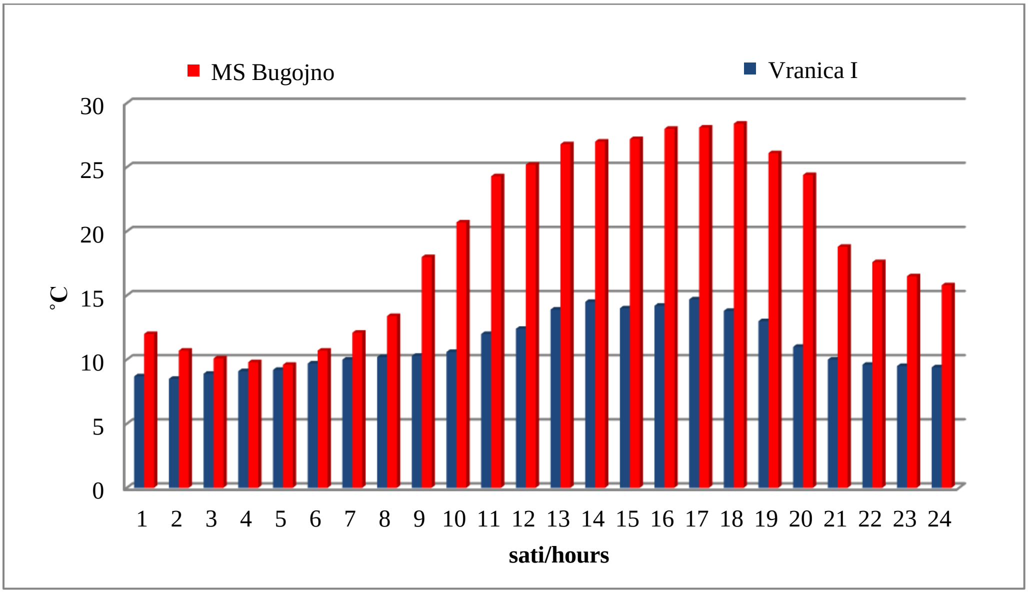


Graphic 3: Temperature differences in foothill of Vranica I locality - 891 m. a.s.l;
Grafikon 3: Mjerenje temperaturnih razlika u podnožju lokaliteta Vranica I – 891 m.n.v;



Graphic 4: Temperature differences in middle of Vranica I locality - 1382 m. a.s.l;

Grafikon 4: Mjerenje temperaturnih razlika u sredini lokaliteta Vranica I - 1382 m.n.v;



Graphic 5: Temperature differences at top of Vranica I locality- 1688 m. a.s.l;

Grafikon 5: Mjerenje temperaturnih razlika na vrhu lokaliteta Vranica I- 1688 m.n.v;

Testing of ***sensory infra and ultrasonic devices*** for preventing game (wild boars and red deer) damages at crops, orchards, etc, were conducted at several locations. Research has been done in combination with sensory cameras to determine wild boar and deer reaction.

Based on the result of research it has been determined that when preventing crop damage, game animals (particularly wild boars) ignore infra and ultrasonic „barrier“. So these devices are not efficient in crop damage prevention. Researches conducted in Slovenia showed sufficient efficiency in preventing game animals to cross traffic roads.

Unmanned Aerial Vehicles

Those devices have different names in literature as UAS (Unmanned Aircraft Systems), or rarely as RPV (Remotely Piloted Vehicles). Common name „drone “comes from the US army, which first uses it as UCAV (Unmanned combat aerial vehicle), combat drone or just drone. Conducted researches with drones had two intentions:

- Habitat analysis
- Game inventory

The first appliance considers determining real conditions of surfaces (forests, meadows, pastures, orchards, etc) in hunting ground for the purpose of accurate assessment of carrying capacity for certain game species. We used high-resolution cameras, mounted on drones and scanned terrain with consecutive photos. Most of the drones have GPS, so every photo taken can be put into space. With the use of specialized programs, we can create a 3D model of whole hunting ground. İn this way, we have a reliable basis for determining carrying capacity. Within the last years, we can use Google Earth. Although Google Earth photos are quite new, sometimes it takes only a year or two that some meadow or pasture become overran with dense vegetation. So, the technology of drones' appliance provides a much better solution considering the price of these operations (Nosek, 2017; Tomljanović, 2018).

Also, we can use drones in the monitoring of some parameters in game populations. İn winter 2017, we conducted a game inventory in densely forested areas in Croatia. The method of a total count of certain game species is appropriate for smaller plots with known size. Transect method, where we count animals at previously determined directions is eligible for larger plots as a sample method. İn testing we noticed that contrast between animals spotted and its surroundings is higher at lower temperatures. The most convenient time for this kind of game inventory (term vision camera mounted at drone) is early morning with frost and clouds. With the daily temperature rising contrast is lower, so detection (count) of game becomes more difficult. Opposite from this, lower temperatures have a significant influence on a drone's battery life, so several batteries are necessary for this kind of research. Obtained results point to large possibilities of drone appliance for the purpose of research but also practical game management. Within minutes, a drone can "cover" almost 100 ha, and detect all game animals in the area. With this, we replace quite a large number of engaged personnel (in regular counts) and reduce the possibility of mistakes (Tomljanović, 2018).

DISCUSSION - *Diskusija*

New techniques and technologies, technical accessories, research equipment and devices are a constituent part of scientific work in hunting, but also in daily activities in game management. Some of the presented technologies or devices provide a great contribution to better knowledge about game species, its habitats and generate changes in game management guidelines. From appliance of the oldest methods of animal capture, which are in use for centuries (traps, nets, snares) to modern systems for animal capture, immobilization, treatment, and translocation.

Nowadays widespread in use, even at an individual level, sensory cameras, replace days and nights of observing certain micro-location on hunting grounds. Besides monitoring, count and determining age and sex, cameras also play an important role in hunting ground surveillance (e.g. poaching).

Game telemetry and constant monitoring of it, using this technology, reveal numerous secrets about game animals, providing necessary data about daily and season rhythm, migration or habitat preference.

Game damage problems, take the first place in the category of human-animal conflicts. Besides classic means of preventing damage as fences, repellents, supplemental feeding, etc, some ultra or infrasonic devices can be used too. Some experiments in preventing car collisions with animals in Slovenia provide positive results (Pokorny, 2006). But preventing crop damage with these devices needs more improvement and research.

The latest technical achievements in game and habitat research are the appliance of Unmanned Aerial Vehicles in combination with different sophisticated cameras. This technique is still in development, will be dominant and widespread in further years both in research and practice. In any case, the development and appliance of techniques and technologies in game management follow other trends and branches in the world.

CONCLUSIONS - *Zaključci*

At the end of this review we can conclude as follows:

- Latest techniques and technologies significantly improve our knowledge about game species;
- In the same time, they make most operations in practice much easier (e.g. game inventory, translocation, or surveillance), with costs reducing;
- Further improvement and development of techniques and technologies have to be supported by game managers and academic institutions in order to achieve sustainable game management;

ACKNOWLEDGEMENT

This paper was presented at International Symposium "People-Forest-Science", October 10-12, 2018, Sarajevo, Bosnia and Herzegovina.

REFERENCES - *Literatura*

BAŠIĆ, M. (2016): Populacıja jarebıce kamenjarke (*Alectoris graeca* Meıssner.), na području Srednjobosanskog kantona, Magistarski rad, Šumarski fakultet, Univerziteta u Sarajevu, str. 1-117. Sarajevo.

GRUBEŠIĆ, M., TOMLJANOVIĆ, K.: (2009): Praćenje divljači automatskim digitalnim fotokamerama, Lovački vjesnik broj 12, str. 42-43. Zagreb.

GRUBEŠIĆ, M., UROŠEVIĆ, B., MIHALJEVIĆ, Z., TOMLJANOVIĆ, K. (2011): Uzgoj i selekcija jelena običnog (Cervus elaphus L) u ograđenom prostoru i mogućnost ispuštanja u otvorena lovišta u Hrvatskoj, 3 Slovenski posvet z mednarodno upravljanju z divjadi: jelenjad. Ed. Poličnik, H., Pokorny, B., ERICO d.o.o., str. 54-57., Velenje.

GRUBEŠIĆ, M., SELETKOVIĆ, A., POLJAK, Ž., ŠĆULAC, T., TOMLJANOVIĆ, K. (2017): Poznavanje promjena u strukturi površina u lovištu kao osnova za smjernice lovnoga gospodarenja, 52nd Croatian and 12th International Symposium on Agriculture, str. 421-426, Dubrovnik, Hrvatska.

HUBER, Đ., JAKŠIĆ, Z., FRKOVIĆ, A., ŠTAHAN, Ž., KUSAK, J., MUSIĆ, J., MAJNARIĆ., D., GRUBEŠIĆ, M., KULIĆ, B., SINDIČIĆ, M., MAJIĆ SKRBINŠEK, A. (2008): Plan gospodarenja smeđim medvjedom u Republici Hrvatskoj, Ministarstvo regionalnog razvoja, šumarstva i vodnoga gospodarstva, Uprava za lovstvo, Zagreb.

KUNOVAC, S. (2009): Uputstvo za prebrojavanje divljači Šumarski fakultet Univerziteta u Sarajevu i Federalno ministarstvo poljoprivrede, vodoprivrede i šumarstva, Sarajevo.

KUNOVAC, S., RAPAİĆ, Ž., POPOVİĆ, Z., SALKİĆ, A., GRUBEŠİĆ, M., KRASİĆ, P., BAČİĆ, M., MAUNAGA, Z. (2010): Korištenje lovišta Atlantik bb d.o.o, Sarajevo-Banja Luka – Priručnik.

KUNOVAC, S., BAŠIĆ, M., GRUBEŠIĆ, M.,TOMLJANOVIĆ, K. (2012): Characteristics of Rock partridge *(Alectoris graeca* Meisner*)* Habitat in Mountains of Bosnia-Herzegovina. Modern aspects of sustainable management of game population. International Symposium on Hunting, Proceedings, Zemun-Belgrade, 122-126.

NOSEK, H. (2017): Upotreba bespilotnih letjelica u lovnom gospodarenju, Diplomski rad, Šumarski Fakultet, Sveučilišta u Zagrebu, str 1-60. Zagreb.

POKORNY, B. (2006): Roe deer vehicle collisions in Slovenia: Situation, mitigation strategy and countermeasures. Veterinarski arhiv 76 (Suppl), str 177-187., Zagreb.

RAPAIĆ, Ž., KUNOVAC, S., SOLDO, V. (2008): Ustanovljenje staništa divokozje divljači u BiH i prijedlog za revitalizaciju populacije. Federalno ministarstvo poljoprivrede, vodoprivrede i šumarstva, str. 1-128. Sarajevo.

TOMLJANOVIĆ, K., GRUBEŠIĆ, M., KRAPINEC, K. (2010): Testiranje primjenjivosti digitalnih senzorskih kamera za praćenje divljači i ostalih životinjskih vrsta, Šumarski list, broj 5-6, str. 287-292. Zagreb.

TOMLJANOVIĆ, K., GRUBEŠIĆ, M. (2015): Gospodarenje sa trčkom (Perdix perdix) u okolici Zagreba, Uzgoj divljači i zaštita biološke raznolikosti; Ed. Florijančić, T., Ozimec, S., str 13. Vinkovci.

TOMLJANOVIĆ, K., GRUBEŠIĆ, M., KONJEVIĆ, D., TOMAŠIĆ, Z. (2013): Uspjeh ispuštanja i podivljavanja trčke (Perdix perdix L.) iz umjetnog uzgoja u lovištima središnje Hrvatske, Šumarski list, broj 3-4, str 185-190. Zagreb.

TOMLJANOVIĆ, K.(2018): Mogućnosti primjene lakih bespilotnih letjelica u lovnom gospodarenju, Lovački vjesnik 3, 127, str. 38-41. Zagreb.

SAŽETAK

U ovom radu dat je pregled do sada najčešće korištenih i razvijanih tehnika i tehnologija, koje se koriste u lovnom gospodarenju. Za hvatanje divljači, koristile su se a i danas, razne vrste klopki, zamki, hvataljki i mreža za hvatanje. Uz hvatanja sitne divljači (zečeva i poljskih jarebica), najznačajnija hvatanja mrežama, vršena su u drugoj polovini prošlog vijeka (1964-1988) u Bosni i Hercegovini, kada je u posebnom lovištu Prenj, uhvaćeno i isporučeno ukupno 434 grla divokoza u Srbiju, Hrvatsku, Argentinu i Novi Zeland, kao i na 10 lokaliteta u BiH.

Po izvršenom hvatanju, posebno krupne divljači, vrši se i hemijska imobilizacija koja se provodi davanjem sredstva za uspavljivanje (ili samo smirenje), što se može dati pomoću puške ili puhalice za uspavljivanje. Na ovaj način se osigurava provođenje predviđenog tretmana ili transporta divljači bez štetnih posljedica po samu divljač ili operatere.

Senzorne kamere se koriste za utvrđivanje brojnosti divljači, polne i starosne strukture, kao i za identifikaciju prisustva rijetkih i pojave novih vrsta divljači. Takođe se koriste za utvrđivanje predatorskih vrsta u staništima velikog tetrijeba, kao i za nadzor lovišta. Ključni element senzornih kamera je - senzor. Testiranjem upravo ovog segmenta došlo se do podatka da je optimalna udaljenost "objekta" 10 - 15 metara (iznimno do 20 metara). Ovo je zapravo "slaba tačka" ovih uređaja. Donekle se ovaj nedostatak može ublažiti da se kamera programira na način da u zadanim vremenskim intervalima načini fotografiju prostora ispred sebe bez obzira da li se nalazi divljač u tom prostoru ili ne.

Telemetrijsko praćenje divljači provodi se već više od 30 godina. Od primjene klasičnih ogrlica s odašiljačem, antenom i prijemnikom do danas kada se koriste GPS ogrlice i satelitsko praćenje jedinki. Ove tehnike primjenjuju se na sve vrste divljači od manjih (poljska jarebica) do najvećih (medvjedi).

Mjerenje elemenata mikroklime preciznim instrumentima (mobilna meteorološka stanica), koja bilježi sve klimatske parametre, izvodi se posebno u staništima koja su teško pristupačna i relativno udaljena od zvaničnih meteoroloških stanica, kako bi se na što precizniji način utvrdili uslovi koji vladaju u datom staništu, a od neminovnog su uticaja na vrstu divljači koju istražujemo.
Testiranje senzornih zvučnih rastjerivača divljači za sprečavanje šteta od divljači provedeno je na više lokacija a usmjerenih prvenstveno na divlje svinje i jelensku divljač. Konstatovana je zadovoljavajuća efikasnost ovih uređaja kod sprečavanja izlaska divljači na puteve u svrhu sprečavanja šteta u saobraćaju, ali efekat ovih uređaja nije zadovoljavajući kada se radi o sprečavanju šteta u poljoprivredi.
Provedena istraživanja primjene bespilotnih letjelica kretala su se u dva smjera:

- Analiza staništa
- Prebrojavanje divljači

Prva primjena odnosi se na snimanje realnog stanja strukture površina unutar lovišta u svrhu što točnije procjene lovnogospodarskog kapaciteta staništa za pojedinu vrstu divljači. Za tu svrhu koristi se kamera visoke rezolucije i snimanje se vrši na način da se teren skenira uzastopnim fotografijama određenog preklopa. Obzirom je većina letjelica opremljena GPS-om svaka snimljena fotografija smještena je u prostor tako da se postupnim skeniranjem površina i potom korištenjem namjenskih programa po potrebi može dobiti slika odnosno 3D model cijelog lovišta. Bespilotnim letjelicama takođe je vršeno prebrojavanje krupne divljači unutar šumskih predjela poznate površine gdje se očekivala povećana koncentracija divljači (branjevine) koristeći različite metode: apsolutnog prebrojavanja svih jedinki neke vrste na plohi poznate površine ili metoda transekta, gdje se na unaprijed određenim pravcima poznate površine prebrojava divljač, pogodna je za veće površine i predstavlja metodu uzorka. Na bespilotnim letjelicama se u ovu svrhu postavljala i termovizijska kamera.
Na kraju, možemo zaključiti da razvoj tehnike i tehnologije u lovnom gospodarenju umnogome povećava naša saaznanja o samoj divljači, te istovremeno olakšava brojne radnje koje se provode u lovnoj praksi.

Corresponding author: Marijan Grubešić, Faculty of Forestry University of Zagreb; Svetošimunska 25, 10000 Zagreb, Croatia; e-mail address: grubesic@sumfak.hr

Reviewers of Works of Faculty of Forestry in 2018 – *Recenzenti Radova Šumarskog fakulteta u 2018*:

1.	Prof. dr. Sead Vojniković	Bosnia and Herzegovina
2.	Prof. dr. Ćemal Višnjić	Bosnia and Herzegovina
3.	Prof. dr. Muhamed Bajrić	Bosnia and Herzegovina
4.	Prof. dr Ana Ješovnik	United States
5.	Prof. dr. Sadbera Trožić- Borovac	Bosnia and Herzegovina
6.	Prof. dr. Ljupčo Nestorovski	Northern Macedonia
7.	Prof. dr. Željko Zečić	Croatia
8.	Prof. dr. Milorad Danilović	Serbia
9.	Prof. dr. Ivana Živić	Serbia
10.	Prof. dr. Jelena Krizmanić	Serbia
11.	Prof. dr. Zoran Ristić	Serbia
12.	Prof. dr. Zoran Popović	Serbia
13.	Prof. dr. Murat Ertekin	Turkey
14.	Doc. dr. Erna Karalija	Bosnia and Herzegovina
15.	Dr. Šefik Koričić	Bosnia and Herzegovina
16.	Prof. dr. Jasmina Čakar	Bosnia and Herzegovina
17.	Prof. dr. Edina Muratović	Bosnia and Herzegovina
18.	Prof. dr. Jusuf Music	Bosnia and Herzegovina
19.	Prof. dr. Azra Tahirović	Bosnia and Herzegovina