

**DIVERSITY AND AUTECOLOGY OF WOOD ANTS IN CENTRAL
BOSNIA AND HERZEGOVINA (FORMICIDAE: *FORMICA* S. STR.)**

**Diverzitet i autekologija šumskih mrava u centralnoj
Bosni i Hercegovini (Formicidae: *Formica* s. str.)**

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Abstract

In this paper new data on diversity of wood ants in Bosnia and Herzegovina are presented. First record of *Formica truncorum* Fabricius, 1804 from Dubočica is reported for Bosnia and Herzegovina. With this new finding total number of species from subgenus *Formica* s. str. known in Bosnia and Herzegovina is raised on five. Analysis of wood ants in central Bosnia indicated presence of *Formica rufa* Linnaeus, 1761 on mountains Trebevic, Ozren, Perun while *Formica polycтена* Förster, 1850 was collected only on Mt. Čemerska.

Morphometrical and ethological intermediary indicate different *Formica rufa* phenotypes or hybrid *Formica rufa* x *polycтена* in investigated area. Polydomy was observed in *Formica polycтена* and *F. rufa*. On the mountain Perun 30 colonies of *Formica rufa* in one kilometer transect were found, which represents the highest known density in Bosnia-Herzegovina.

Key words: *Formica*, wood ants, Bosnia, coniferous forests, conservation.

INTRODUCTION – Uvod

In Europe *Formica rufa* group is represented by nine species (RADCHENKO, 2015). *Formica rufa* Linnaeus, 1761, *F. polycтена* Förster, 1850, *F. pratensis* and *F. lugubris* are reported for Bosnia and Herzegovina (VESNI, 2011). Extensive ecological studies of forest ants on Mount Igman were carried out during the 60's of the last century (LUTERJEK, 1970).

Wood ants, *Formica rufa* species group are important ecological component of conifer forest fauna. Colonies of wood ants have up to six million workers and they are important in regulation of plant eating insects (GÖSSWALD, 1981; SEIFERT, 2007). Coniferous woodlands are under strong impact by human activities. Forests of spruce and fir in Bosnia and Herzegovina are primary habitats of *Formica rufa* and *F. polycтена*. Survival of wood ants is closely linked to survival of conifer forests. One of the major threats to the forest is logging (THOR, 1998). Due continuous coniferous woodland deforestation and ecosystem degradation it is important to collect ecological data, information about distribution of wood ants in Bosnia and

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Herzegovina. Besides data on the presence of *Formica rufa* and *F. polyctena* in Bosnia and Herzegovina no additional information on biology and distribution are known. Complex taxonomy of *Formica rufa* and *F. polyctena* is based on number of hairs and cuticle sculpture and does not allow rapid identification (COLLINGWOOD AND AGOSTI, 1986; CZECHOWSKI AND DOUWES, 1996; SOVARI, 2006).

Discrimination of *Formica rufa* and *F. polyctena* is difficult due character overlap (SORVARI, 2006). Intraspecific variation character overlap can be result of hybridization between *Formica rufa* and *F. polyctena*. In the Europe different phenotypes and even hybrids between *Formica rufa* and *F. polyctena* are described (SEIFERT, 1991; SEIFERT, 1992; SEIFERT, 2007). Although the *Formica rufa* and *F. polyctena* species were previously reported for Bosnia and Hercegovina there were no data on the possible existence of intermediary phenotypes or hybrid colonies of *Formica rufa* x *polyctena* (according to SEIFERT, 2007) or morphs described in earlier studies (SEIFER, 1991). To confirm the existence of different phenotypes in Bosnia and Herzegovina we investigated inter and intraspecific variability in *Formica rufa* and *F. polyctena*.

We also evaluated discrimination between *Formica rufa* and *F. polyctena* based on subjective and numerical taxonomic characters. Main anthropogenic pressures were evaluated.

MATERIAL AND METHODS – Materijal i metode rada

Investigated area obtained mountains and woodland complexes of spruce and fir in central parts of Bosnia and Herzegovina. Investigations of Dubo-tica (lat. 44.237°; long. 18.313°) were conducted earlier in 2009. *Formica truncatorum*: 19. 06. 2009; 7 workers. In workers frontal triangle is dull; whool body covered by hairs; second and third antennal scape segments twice as long as broad (Figure 1-2.), identified according to Agosti and Collingwood, 1987.



Figure 1-2: *Formica truncatorum* worker from Dubo-tica lateral view (left) and antennal scape picture show elongated third and second segment in workers (right)

Slike 1-2: Formica truncatorum radilica iz Dubošćice, boćni pogled (lijevo) a slika pipaka pokazuje izdućeni treći i drugi segment kod radilica (desno)

For the *Formica* s. str. sample identification we used taxonomical key (AGOSTI AND COLLINGWOOD, 1987; SEIFERT, 2007).

Ecological research of *Formica rufa* and *F. polyctena* were conducted from 01. May till 30. October 2014. Ecological data on *Formica rufa* Linnaeus, 1761 and *F. polyctena* Förster, 1850 were obtained for the area of mountains Trebevi (lat. 43.821°; long. 18.450°), Ozren (lat. 43.935°; long. 18.425°), emerska (lat. 44.030°; long. 18.317°) and Perun (lat. 44.160°; long. 18.298°).

During field investigations active methods of collecting were used. In order to analyze structural ecological data the field protocol was applied (AGOSTI ET AL 2000). Data in the field protocol included: locality, sample cod, GPS coordinate, altitude, woodland type (coniferous, deciduous, mixed forest), number of trees around discovered anthill. Number of trees was counted in two perpendicular transects 100 m in length with anthill in center, placement of ant colony in (deep wood, wood edge, meadow, clearings in wood made by construction of wood roads), pressures on habitat (fire, road building infrastructure, wood exploitation, expansion of settlements). Dimensions of anthills for *Formica rufa* and *F. polyctena* species were measured: length of longest anthill side (K1), length of shortest anthill side (K2), maximal (R1) and minimal (R2) diameter of colony base. Exposition of an anthill was analyzed.

The protocol was applied on each newly found colony. In laboratory workers were dry mounted on cardboard triangles and reproductive specimens were pinned on entomological needle. Morphometry was performed on Reichert stereo zoom microscope, with micrometer mounted on right ocular. Calibration of ocular was conducted on Reichert. Calibration of microoculare on slide 1 notch = 10 µm. Division of scale in ocular at 100 X magnification was 13,66248 µm and on 50 X magnification 23,529412 µm.

From 01. May till 30. October 2014. we found and sampled 122 nests of *Formica rufa* and three colonies of *Formica polyctena*. Workers and reproductive caste were sampled and stored in 96% ethyl alcohol. Five to ten workers were collected from each colony. We analyzed 97 workers of *Formica rufa* from 32 colonies and 20 workers of *Formica polyctena* from three colonies.

Morphometric analysis included: head with (HW), head length (HL), frontal carina with (HCL), scape length (SL), maximal scape width (SMAX), and length of longest hair on gula (CUHL), length of longest hair on pronotum (PNHL). Unilateral number of hairs on occiput (nCH), gula (nCU) and pronotum (nPN) were counted. Morphometricall indices analyzed in this paper were computed: $CI = HW/HL$, $SCI = SL/SMAX$.

Analyzed morphometric characteristics and indices are defined by SEIFERT(2007). Presence and distribution of hairs on mesopleuron was analyzed. We also analyzed micro sculpture and glossiness of frons in worker caste (COLLINGWOOD, 1979; AGOSTI AND COLLINGWOOD, 1987). Determination of the collected wood antæ

material was based on subjective characteristics (AGOSTI AND COLLINGWOOD, 1987; GOSSWALD, 1981) and morphological indices (Table 1) (SEIFERT, 2007).

All findings of colonies identified as hybrid *Formica rufa x polyctena* or phenotypes of *F. rufa*. In ecological analysis specimens were treated as *Formica rufa*.

Statistical analysis included descriptive statistic and inferential ANOVA, post hoc Newman-Keules test. Differences in frequencies were tested by Kruskal Wallis test. Multivariate analysis included discriminant function. Gradient analysis was performed by PCA analysis. Population density was calculated as transect length defined by minimal and maximal altitude of findings divided by number of colonies.

Table 1: Morphometric indices for identification of wood ants species and hybrid according to (SEIFERT, 2007)

Tabela 1: Morfometrijski pokazatelji korišteni u identifikaciji vrsta i hibrida šumskih mrava prema (SEIFERT, 2007)

<i>Formica rufa</i>	<i>Formica rufa x polyctena</i>	<i>Formica polyctena</i>
nCU = 5.10-11.00	nCU = 0.19-6.60	nCU = 0.10-3.00
CUHL = 155.00-224.00	CUHL = 96.00-197.00	CUHL = 7.00-79.00
nPN = 12.50-45.00	nPN = 5.80-16.00	nPN = 0.1-5.6
PNHL = 61.00-102.00	PNHL = 47.0-83.00	PNHL = 6.00-55.00
nCH = 0.00-3.60	nCH = 0.00-1.20	nCH = 0.00-0.90
SI = SL/SMAX = 10.13±0.29	SI = SL/SMAX = 10.00±0.24	SI = SL/SMAX = 10.00±0.24

RESULTS AND DISCUSSION – *Rezultati rada i diskusija*

First finding of *Formica truncorum* Fabricius, 1804 was obtained earlier in 2009. from faunistic research of Dubo-tica (municipality Vare-). Field investigations in 2014. confirmed presence of *Formica rufa* Linnaeus, 1761, *F. polyctena* Förster, 1850 and *F. pratensis* in Bosnia and Herzegovina. With additional new finding of *Formica truncorum*, a total number of species belonging to *Formica rufa* group in Bosnia and Herzegovina is raised up to four. In Serbia number of *Formica rufa* group species is same as in Bonia (PETROV, 2006). In Croatia and Montenegro *Formica rufa* group is represented by five species (BRA KO, 2006; KARAMAN, 2004).

Analysis based on seta number indicated presence of two different phenotypes of *Formica rufa* in researched area. Typical *Formica rufa* phenotypes were found in colonies with the head width of worker caste higher than 1.8 mm (Table 7). Typical *Formica rufa* has the highest average unilateral seta number on occiput, gula and pronotum (Table 7).

Second *Formica rufa* phenotype is with significantly ($p < 5\%$) narrower head with 1, 7 mm (Tab. 7.). Compared to *Formica rufa* with typical pilosity second *F. rufa* phenotype has fewer hairs on pronotum and gula (Table 7). The fact that ants with smaller head were with less number of hairs is important. There is significant size dependent decline of pilosity in very small workers (SEIFERT, 1991). Juvenile colonies

with smaller worker caste exhibit decline of pilosity and were included in analysis. In analysis only five workers were with head width smaller than 1.4 mm. Correlation between head width and number of seta was positive, but linear regression was not statistically significant at 5% level, $nPN = -16.60 + 0.01806 * HW$, correlation $r = 0.50492$.

Table 2: Frequency table of seta number on occiput (nCH) for *Formica rufa* and *F. rufa* phenotype

Tabela 2: Distribucija frekvencija za broj dlaka na podbratku (nCH) za *Formica rufa* i *F. rufa* fenotip

<i>Formica rufa</i> K-S d=.53703, p<.01; Lilliefors p<.01			<i>Formica rufa</i> phenotype K-S d=.53336, p<.01; Lilliefors p<.01		
Kategory	Count	Percent	Kategory	Count	Percent
-0.5<x<=0.0	44	97.7	-0.5<x<=0.0	49	94.2
0.5<x<=1.0	0	0.0	0.5<x<=1.0	2	3.8
1.5<x<=2.0	1	2.3	1.5<x<=2.0	1	1.9
Missing	0	0.0	Missing	0	0.0

Number of seta on gula show statistically significant difference between *Formica polycтена* and two *Formica rufa* phenotypes (Table 3-4).

Table 3: Multiple Comparisons p values (2-tailed) for number of seta on gula (nCU) Kruskal-Wallis test: $H(2, N=117) = 11.07274$ $p = .0039$, statistically significant differences are written in bold

Tabela 3: Višestruko dvosmjerno poređenje p vrijednosti za broj seta na podbratku (nCU) Kruskal-Wallis test: $H(2, N=117) = 11, 07274$ $p = ,0039$, statistički značajne razlike su podebljane

Species	Species		
	<i>Formica rufa</i>	<i>F. rufa</i> phenotype	<i>F. polycтена</i>
<i>Formica rufa</i>		0.291821	0.006322
<i>Formica rufa</i> phenotype	0.291821		0.035298
<i>Formica polycтена</i>	0.006322	0.035298	

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Table 4: Frequency table for number of seta on gula (nCU) for *Formica rufa* and *F. rufa* phenotype

Tabela 4: Distribucija frekvencija za broj dlaka na podbratku (nCU) za *Formica rufa* i *F. rufa* fenotip

<i>Formica rufa</i> K-S d=.15259, p> .20; Lilliefors p<.05			<i>Formica rufa</i> phenotype K-S d=.18410, p<.10; Lilliefors p<.01		
Category	Count	Percent	Category	Count	Percent
0.0<x<=1.0	3	6.66667	-1.0<x<=0.0	4	7.69231
1.0<x<=2.0	6	13.33333	0.0<x<=1.0	4	7.69231
2.0<x<=3.0	9	20.00000	1.0<x<=2.0	5	9.61538
3.0<x<=4.0	10	22.22222	2.0<x<=3.0	16	30.76923
4.0<x<=5.0	11	24.44444	3.0<x<=4.0	12	23.07692
5.0<x<=6.0	5	11.11111	4.0<x<=5.0	6	11.53846
6.0<x<=7.0	1	2.22222	5.0<x<=6.0	5	9.61538
Missing	0	0.00000	Missing	0	0.00000

Less than 5% of workers of *Formica rufa* were with hairs on occiput and all *F. polycytena* workers were without hairs. Multiple comparisons Kruskal-Wallis test: H (2, N = 117) = .8735411 p = .6461 did not show statistically significant differences in frequencies for number of seta on occiput (nCH) between *Formica rufa*, *F. rufa* phenotype and *Formica polycytena*. (Table 2).

Highest number of seta on pronotum was in workers of *Formica rufa*. Differences in seta number are statistically significant between *Formica rufa*, *F. rufa* phenotype and *F. polycytena* (Table 5-6).

Table 5: Multiple Comparisons p values (2-tailed); number of seta on pronotum (nPN)
Kruskal-Wallis test: H (2, N=117) = 20.58424 p = .0000, statistically significant differences are written in bold

Tabela 5: Višestruko dvosmjerno poređenje p vrijednosti za broj seta na pronotumu (nCU)
Kruskal-Wallis test: H (2, N=117) = 20, 58424 p =,0000, statistički značajne razlike su podebljane

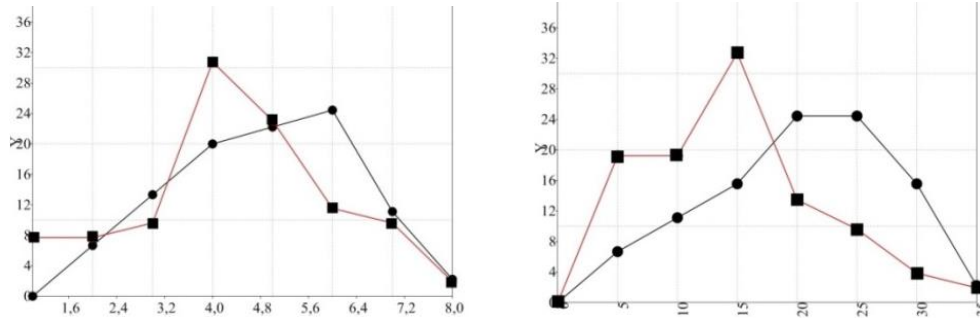
Species	Species		
	<i>Formica rufa</i>	<i>F. rufa</i> phenotype	<i>F. polycytena</i>
<i>Formica rufa</i>		0.001686	0.001286
<i>Formica rufa</i> phenotype	0.001686		0.055738
<i>Formica polycytena</i>	0.001286	0.055738	

Table 6: Frequency table for number of seta on pronotum (nPN) for *Formica rufa* and *F. rufa* phenotype

Tabela 6: Distribucija frekvencija za broj dlaka na pronotumu (nPN) za *Formica rufa* i *F. rufa* fenotip

<i>Formica rufa</i> K-S d=.09456, p> .20; Lilliefors p> .20			<i>Formica rufa</i> phenotype K-S d=.13012, p> .20; Lilliefors p<.05		
Category	Count	Percent	Category	Count	Percent
-5.0<x<=0.0	0	0.00000	-5.0<x<=0.0	0	0.00000
0.0<x<=5.0	3	6.66667	0.0<x<=5.0	10	19.23077
5.0<x<=10.0	5	11.11111	5.0<x<=10.0	10	19.23077
10.0<x<=15.0	7	15.55556	10.0<x<=15.0	17	32.69231
15.0<x<=20.0	11	24.44444	15.0<x<=20.0	7	13.46154
20.0<x<=25.0	11	24.44444	20.0<x<=25.0	5	9.61538
25.0<x<=30.0	7	15.55556	25.0<x<=30.0	2	3.84615
30.0<x<=35.0	1	2.22222	30.0<x<=35.0	1	1.92308
Missing	0	0.00000	Missing	0	0.00000

Morphological analysis of workers showed that 54.6% of analyzed colonies were with intermediary characteristics of *Formica rufa* and *F. polyctena*. In literature maximal established percentage of hybrids was 26.0% (SEIFERT, 2007). Morphometric analysis based on description of hybrid *Formica rufa* x *polyctena* SEIFERT (2007) did not indicate statistically significant difference in length of seta on gula and pronotum between *Formica rufa* and assumed hybrid colonies (Graphs 1-2).



Graph 1-2: Distribution of seta number plotted on y axis; gula (left) and pronotum (right) in *Formica rufa* (dot) and *F. rufa* phenotype (square)

Grafikon 1-2: Distribucija broja seta na y osi; podbradak (lijevo) i pronotum (desno) kod *Formica rufa* (tačka) and *F. rufa* fenotip (kvadrat)

Two colonies from Perun and one colony from avljak show clear characteristics of hybrid *Formica rufa* x *polyctena* (SEIFERT, 2007). Determination of hybrid was based on length of seta on gula, pronotum and number of seta on pronotum. Typical characteristics of *Formica rufa* were found in 42.4% of colonies. Typical *Formica polyctena* characteristics were found in three colonies.

Number and distribution of seta showed intraspecific and intracolony variability. Number of worker caste with intermediary seta characteristics between *Formica rufa* and *F. polycтена* was 44.5 %. Most significant difference between *Formica rufa* and *F. polycтена* was in seta number at gula and pronotum. Average number of seta in colonies of *Formica rufa* was between 0.0 and maximal 0.7. In colonies of *Formica rufa* with intermediary phenotypes maximal average number of seta was 0.5 (Table 7).

Microsculpture and glossiness of frons in worker caste proposed by COLLINGWOOD (1979) and AGOSTI AND COLLINGWOOD (1987) was impractical and for Bosnian wood ants characters were poorly defined. Intensity of shines of the frons in samples shows intracolony variation. Similar data were obtained for seta number and distribution of seta on mesopleuron. Number of seta on mesopleuron also showed intracolony variability. In some colonies workers without hairs on mesopleuron, workers with hairs on posterior side of mesopleuron and with evenly distributed hairs were found. In worker caste seta on mesopleuron were not detected and it was stable character in colonies of *Formica polycтена*.

Statistically significant differences between *Formica rufa* and hybrids of *Formica rufa x polycтена* colonies were detected (Table 7). Length of scape has statistically significant difference between *Formica rufa* and *F. polycтена* (Table 7). Same result was confirmed by scape index (Table 7).

Table 7: Morphometric indices for *Formica rufa*, *Formica rufa* phenotype and *Formica polyctena*: average±standard deviation (SD), minimal (min), maximal (max) value, coefficient of variability (V%), standard error mean (SE). Differences were tested by ANOVA and post-hoc Newman-Keuls test, mean values that share same letter are statistically different at 5%, values that share same letter and (-) are not statistically different

Tabela 7: Pregled variranja odabranih morfometrijskih karaktera za *Formica rufa*, *Formica rufa* fenotip i *Formica polyctena*: aritmetička sredina±standardna devijacija (SD), minimalna (min), maksimalna (max) vrijednost, koeficijent varijabilnosti (V%), standardna greška aritmetičke sredine (SE). Razlike su testirane ANOVA i post-hoc Newman-Keuls testom, aritmetičke sredine koje dijele isto slovo su statistički značajne na nivou od 5%, vrijednosti koje imaju (-) nisu značajne

	<i>Formica rufa</i> N = 45			<i>Formica rufa</i> phenotype N = 52			<i>Formica polyctena</i> N = 20		
	average±SD (min. max)	V%	SE	average±SD (min. max)	V%	SE	average±SD (min. max)	V%	SE
HW	1821.6 ^a ±203.4 (1365.0, 2235.0)	11.2	30.3	1695.0 ^{ab} ±207.0 (1224.0, 2071.0)	12.2	28.7	1637.7 ^{ab} ±91.7 (1505.9, 1788.2)	5.6	20.5
HL	1965.0 ^a ±184.4 (1576.0, 2329.0)	9.4	27.5	1861.8 ^{ab} ±192.9 (1435.0, 2141.0)	10.4	26.8	1794.1 ^{ab} ±93.1 (1623.5, 1952.9)	5.2	20.8
HCL	602.2 ^a ±59.2 (478.0, 724.0)	9.8	8.8	556.0 ^a ±57.3 (424.0, 642.0)	10.3	7.9	539.7 ^{ab} ±51.8 (464.5, 628.5)	9.6	11.6
SL	1763.1 ^a ±166.0 (1341.0, 1953.0)	9.4	24.7	1664.4 ^a ±164.7 (1247.0, 1906.0)	9.9	22.8	1066.0 ^a ±271.1 (874.4, 1788.0)	25.4	60.6
SMAX	216.0 ^a ±18.0 (178.0, 246.0)	8.3	2.7	202.7 ^a ±18.9 (164.0, 232.0)	9.3	2.6	207.7±16.9 (177.6, 232.3)	8.1	3.8
nCH	0.04±0.3 (0.0, 2.0)	670.8	0.0	0.1±0.3 (0.0, 2.0)	434.3	0.05	0.0	0.0	0.0
nCU	3.9±1.5 (1.0, 7.0)	38.8	0.2	3.3±1.6 (0.0, 6.0)	49.6	0.2	0.0	0.0	0.0
CUHL	154.9±27.3 (96.0, 219.0)	17.7	4.1	137.3±49.1 (0.0, 246.0)	35.7	6.8	0.0	0.0	0.0
nPN	17.9±7.4 (2.0, 32.0)	41.5	1.1	12.6±7.0 (2.0, 33.0)	55.5	1.0	0.0	0.0	0.0
PNHL	99.6±16.6 (68.0, 164.0)	16.6	2.5	89.9±16.1 (55.0, 123.0)	17.9	2.2	0.0	0.0	0.0
HW/HL	0.93±0.035 (0.9, 1.0)	3.72	0.005	0.91±0.03 (0.85, 1.02)	3.67	0.00	0.91±0.02 (0.89, 0.95)	1.98	0.00
SL/SMAX	8.17 ^{ab} ±0.45 (7.40, 9.52)	5.55	0.067	8.22 ^{ab} ±0.42 (7.15, 9.36)	5.09	0.06	5.16 ^a ±1.4 (4.38, 8.59)	27.05	0.31

*head with (HW), head length (HL), frontal carina with (HCL), scape length (SL), maximal scape with (SMAX), maximal length of seta on gula (CUHL), maximal length of seta on pronotum (PNHL), unilateral number of hairs on occiput (nCH), unilateral number of hairs on gula (nCU) and unilateral number of hairs on pronotum (nPN).

Six variables were included in multivariate discriminant function analysis model. *Partial Wilks' Lambda* indicates that variable scape length had greatest discriminant power between *Formica rufa*, *F. rufa* phenotype and *F. polyctena* (Table 8). Frontal carina with and scape index did not show statistically significant discriminant power (Table 9).

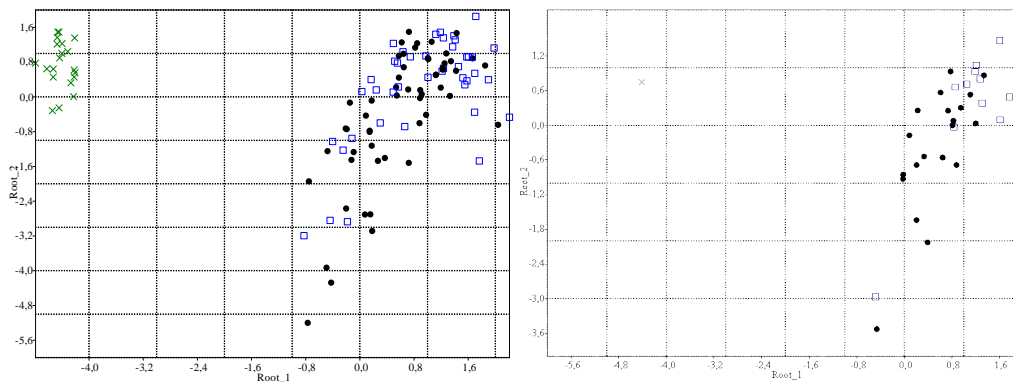
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The first discriminant function is weighted most heavily by the scapus length (SL) and head width (HW). The other two variables also contribute to this function. The second function is marked by head width (HW) and head length (HL) (Table 10; Graph 3-4). The less hairy morph of *Formica rufa* in our investigations is by hair number very close to *F. polycтена*. Other authors reported *Formica polycтена* hairy phenotype from continental Europe suggesting that is hybrid of *F. polycтена* and *F. rufa* (SEIFERT, 1991; SEIFERT, 2007; CZECHOWSKI AND DOUWES, 1996). SORVARI (2006) reported *Formica polycтена* phenotype with more hairs form Finland.

Table 8: Discriminant Function Analysis Summary, number of variables in the model: 6; groups 33; Wilks' Lambda: ,01179 approx. $F(192,475) = 2.7719$ $p < 0.0000$

Tabela 8: Analiza diskriminantne funkcije, broj varijabli u modelu 6; 33 grupe; Wilks' Lambda: ,01179 approx. $F(192,475) = 2.7719$ $p < 0,0000$

	Wilks'	Partial	F-remove	p-value	Toler.	1-Toler.
SL	0.019588	0.602138	1.631224	0.041267	0.092671	0.907329
HW	0.024342	0.484542	2.626266	0.000273	0.001249	0.998751
HCL	0.018109	0.651316	1.321650	0.159664	0.250144	0.749856
SL/SMAX	0.017741	0.664834	1.244582	0.215487	0.150884	0.849116
HL	0.024376	0.483865	2.633395	0.000263	0.001652	0.998348
HW/HL	0.023896	0.493591	2.532858	0.000443	0.009580	0.990420



Graph 3-4: Unstandardized Canonical Scores for workers (left) and Means of Canonical Variables for colonies (right): *Formica rufa* (square), *F. rufa* phenotype (dot) and *F. polycтена* (x)

Grafikon 3-4: Nestandardizirane kanonijske vrijednosti za radnike (lijevo) i srednje vrijednosti kanonijskih varijabli za kolonije (desno): *Formica rufa* (kvadrat), *F. rufa* fenotip (tačka) i *F. polycтена* (x)

Table 9: Chi square test of successive roots, statistically significant roots are in bold
 Tabela 9: Hi-kvadrat test sukcesivnih korijena, statistički značajni korijeni su podebljani

Roots Removed	Eigen-	Canoniel	Wilks'	Chi-Sqr.	df	p-value
0	4.119746	0.897038	0.011795	428.4682	192	0.000000
1	1.522614	0.776908	0.060387	270.8736	155	0.000000
2	1.058620	0.717104	0.152333	181.5826	120	0.000244
3	0.652521	0.628382	0.313596	111.9061	87	0.037328
4	0.478115	0.568738	0.518224	63.4340	56	0.230882
5	0.305491	0.483741	0.765995	25.7249	27	0.533904

Table 10: Standardized Coefficients for Canonical Variables
 Tabela 10: Standardizirani koeficijenti kanonijskih varijabli

	Root 1	Root 2	Root 3	Root 4	Root 5	Root 6
SL	1.24509	0.6208	-0.6844	-0.09393	-2.60778	1.25598
HW	2.11301	-14.2479	22.8875	-0.92105	-3.10736	7.67676
HCL	-0.22987	-0.1541	0.4068	-1.50475	-0.31567	-1.17970
SL/SMAX	-0.02773	-0.7747	0.3257	0.17654	2.14995	-1.12572
HL	-2.07499	12.7865	-19.4089	1.60565	4.68553	-6.03722
HW/HL	-0.75005	5.3270	-7.8290	1.34339	1.33152	-3.25133
Eigenval	4.11975	1.5226	1.0586	0.65252	0.47811	0.30549
Cum.Prop	0.50629	0.6934	0.8235	0.90370	0.96246	1.00000

Ecological data between *Formica rufa* and *F. polyctena* were not comparable due small number of *F. polyctena* findings. Statistically significant difference in altitude between *Formica polyctena* and *F.rufa*, was detected by multiple comparisons p values Kruskal-Wallis test at 5% significance (Table 11). Differences in anthill dimensions between species were not detected at 5% significance level by Newman-Keuls test. Findings of *Formica polyctena* were on lower boundary of *Formica rufa* vertical distribution.

Formica rufa and *F. polyctena* were most common in coniferous forests. Relative number of colonies of *Formica rufa* and its phenotype in coniferous *Abieto-picetum* forest habitat was between 88% and 89%. All colonies of *Formica polyctena* were in *Abieto-picetum* woodlands. *Formica rufa* builds colonies more often near wood roads. Total number of *Formica rufa* colonies near road was 91%, in regard to *Formica rufa* phenotype 61%. Colonies of *Formica polyctena* were not found near roads. Data from LUTERŃEK (1960) indicate that *Formica polyctena* is infrequent, compared to *Formica rufa*. Distribution data from Igman indicate that large and small wood ant are more common in meadows than in the woods (LUTERŃEK, 1960).

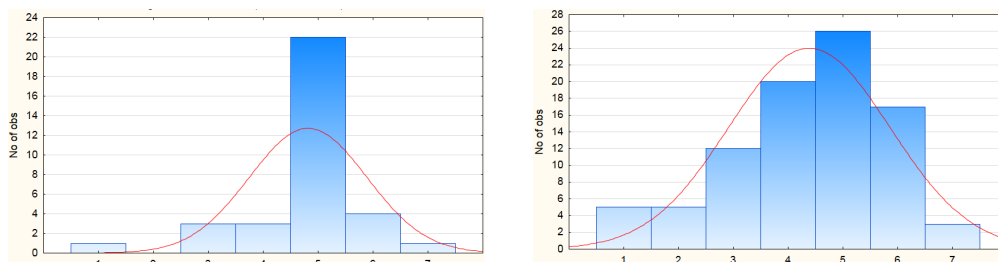
Colonies of *Formica polyctena* were found in deep woodland habitats 34% and 66% in congregation with more than 30 trees. Colonies of *Formica rufa* also show strong association with dense forests. Most colonies 86% of *Formica rufa* were collected in habitats with 20 to 30 trees, similar number of colonies 72% were for *Formica rufa* phenotype (Graph 5-6).

Table 11: Altitude and anthill dimension for *Formica rufa* and *F. polycтена* colonies average±standard deviation (SD), minimal (min), maximal (max) value, coefficient of variability (V%), standard error mean (SE) Differences were tested by ANOVA and post-hoc Newman-Keuls test, mean values that share same letter are statistically different at 5%, values that share same letter and (-) are not statistically different

Tabela 11: Nadmorska visina i dimenzije kolonija za *Formica rufa* i *Formica polycтена*: aritmetička sredina±standardna devijacija (SD), minimalna (min), maksimalna (max) vrijednost, koeficijent varijabilnosti (V%), standardna greška aritmetičke sredine (SE). Razlike su testirane ANOVA i post-hoc Newman-Keuls testom, aritmetičke sredine koje dijele isto slovo su statistički značajne na nivou od 5%, vrijednosti koje imaju (-) nisu značajne

Parameters	<i>Formica rufa</i> N = 122			<i>Formica polycтена</i> N = 3		
	average±SD (min, max)	V%	SE	average±SD (min, max)	V%	SE
Altitude	1291.2 ^a ±82.9 (981.0, 1611.0)	6.4	7.5	972.4 ^a ±1.5 (971.0, 974.0)	0.16	0.88
R1	141.3±60.4 (25.0, 340.0)	42.8	5.5	83±56.9 (20, 130)	68.2	32.8
R2	120.2±60.8 (10.0, 280.0)	50.6	5.5	82±59.7 (15, 130)	73.0	34.4
K1	99.5±56.6 (10.0, 220.0)	56.9	5.1	72±53.0 (15, 120)	73.9	30.6
K2	57.5±30.0 (10.0, 160.0)	52.2	2.7	72±56.2 (10, 120)	78.4	32.4

In order to examine association of wood ant to conifer trees we analyzed number of colonies that were built up a tree. In our research we detected that 56% of *Formica rufa* colonies and 70% of *F. rufa* phenotype were not leaning up the trees. Colonies of *Formica rufa* were most commonly built on south, south-east expositions 82%. All colonies of *Formica polycтена* were built on plane terrain.



Graph 5-6: Distribution of *Formica rufa* (left) and *F. rufa* phenotype (right) number of colonies in regard to density of trees in habitat

Grafikon 5-6: Distribucija nalaza kolonija vrste *Formica rufa* (lijevo) i *F. rufa* fenotipa (desno) u odnosu na gustinu stabala u staništu

Multivariate PCA analysis of ecological parameters indicates that first two principal components describe 52% of variability between *Formica rufa*, *F. rufa* phenotype and *F. polyctena*. In construction of first principal component mostly participate variable: habitat type 0.61, altitude -0.51, exposition -0.50. Second principal component is constructed mostly by: habitat density -0.75, construction of colonies up a tree 0.55, position of colonies in regard to road 0.31.

In investigated area wood ants show significant association with dens wood complexes. In closed woodlands number of colonies is higher and polydomy was observed in *Formica rufa* and *F. polyctena*. Colonies of *Formica rufa* on forest edges and fragmented woodland habitats were single. In deep and not fragmented wood complexes colonies were polydome and with large density. In avljak area, (Mt. Ozren), with fragmented woodland habitats, number of *Formica rufa* colonies in transect was 8/1000 m. Highest density of *Formica rufa* colonies was found on Mt. Perun 30/1000 m. Positive linear correlation between density and number of colonies was detected, but this correlation was not statistically significant at 5% level. Maximal number of *Formica rufa* colonies decline after its maximum was reached in woodland habitats with 25-30 trees in 100 meter transect. There are two possible explanations for colony number decline in woodlands with higher tree density. In closed woodlands lower temperature is correlated with low insolation level. Second reason was relatively small number of sites with dens woodlands since *Formica rufa* colonies were dominantly built near wood roads (70%). In our research we found that clearings in forest and wood roads were more attractive for wood ants probably due higher insolation.

In our investigation we detected that woodland roads and clearings in forest have positive effect on distribution and density of *Formica rufa* colonies. *Formica rufa* colonies were detected by roads that go through dense forests.

CONCLUSIONS – Zaključci

Central Bosnia is inhabited by five species belonging to subgenus *Formica*. In narrow sense *Formica rufa* group in Bosnia and Herzegovina include two species *Formica rufa* Linnaeus, 1761 and *F. polyctena* Förster, 1850.

Analysis of seta number in *Formica rufa* indicates that all samples have low hairiness in compare to central and north European populations. Bosnian wood antsø populations have below average hair number on occiput and pronotum when compared to central and north European populations.

Morphometric analysis of body indicates that *Formica rufa* less hairy phenotype has much more similarity to *Formica rufa* than to *F. polyctena*.

Morphological investigations of reproductive caste should also be conducted in order to solve question of interbreeding between *Formica rufa* and *F. polyctena* in Bosnia and Herzegovina.

Further investigations should be conducted in wider area of Dinaric Alps in Bosnia and Herzegovina in order to sample and confirm presence of clear morphological phenotypes of *Formica rufa*.

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SAŽETAK

Trnjski mravi iz podroda *Formica* imaju važnu ulogu u ekologiji šumskih mrava. Posebno značajni imaju vrste iz grupe *Formica rufa*. Kolonije imaju veliku biomasu, sa promjerom veće od dva metra. Vrste *Formica rufa* i *Formica polyctena* su ekološki vezane za šume smrčine i jele. Biološki podaci o vrstama *Formica rufa* i *F. polyctena* u Bosni i Hercegovini su na nivou faunističkih podataka.

U radu su prezentirani podaci o diverzitetu šumskih mrava u Bosni i Hercegovini. Prvi nalaz vrste *Formica truncorum* Fabricius, 1804 sa područja Dubočice prijavljen je za Bosnu i Hercegovinu. Ukupan broj vrsta iz podroda *Formica* u fauni podignut je na pet. Istraživanjem lokaliteta u centralnoj Bosni utvrđeno je prisustvo vrste *Formica rufa* Linnaeus, 1761 na planinama Trebević, Ozren i Perun. *Formica polyctena* sakupljena je samo na planini Šemerska.

Rad ima za cilj analizu diverziteta podroda *Formica* i populacione strukture vrsta *Formica rufa* i *F. polyctena*. Na osnovu morfometrijskih pokazatelja izvršena je diferencijacija blisko srodnih vrsta *Formica rufa* i *F. polyctena*. Populacija vrste *Formica rufa* podijeljena je prema stepenu dlakavosti na dva fenotipa. Uzorci identificirani kao tipski fenotip *Formica rufa* prema stepenu dlakavosti su na donjoj granici raspona dlakavosti specifičnih za vrstu. Na osnovu intenziteta dlakavosti u populaciji *Formica rufa* se izdvajaju intermedijerni fenotipovi. Uzorci *Formica rufa*

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sa podprosjem brojem dlaka imaju osobine opisanog hibrida *Formica rufa* x *polyctena* ili dlakavog fenotipa *Formica polyctena*.

Diskriminantnom funkcijom uzorci manje dlakavog fenotipa *Formica rufa* nisu izdvojeni u poseban klaster. Na osnovu simpatrii i prostornog rasporeda pronađeni fenotipovi bez geografske agregacije najvjerojatnije je riječ o ekomorfima. Na istraživanom području centralne Bosne nizak stepen urbanizacije i minimalni turistički kapaciteti nisu prepoznati kao osnovni faktori rizika za umske mrave.

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