SEEFOR SOUTH-EAST EUROPEAN FORESTRY

OPEN ACCESS
ISSN 1847-6481
eISSN 1849-0891

ORIGINAL SCIENTIFIC PAPER

DOI: https://doi.org/10.15177/seefor.23-11

Occurrence of Bees and Bumblebees in Bark Beetle Slit Traps from Spruce and Fir Woodlands of Central Dinaric Alps

Adi Vesnić[1,*], Dejan Kulijer[2], Osman Mujezinović[3], Damir Prljača[3], Mirza Dautbašić[3], Sead Ivojević[3]

(1) University of Sarajevo, Faculty of Science and Mathematics, Department of Biology, Zmaja od Bosne 33-35, BA-71000 Sarajevo, Bosnia and Herzegovina; **(2)** Zemaljski muzej Bosne i Hercegovine, Zmaja od Bosne 3, BA-71000 Sarajevo, Bosnia and Herzegovina; **(3)** University of Sarajevo, Faculty of Forestry, Zagrebačka 20, BA-71000 Sarajevo, Bosnia and Herzegovina

*** Correspondence:** e-mail: vesnicadi@gmail.com

Citation: Vesnić A, Kulijer D, Mujezinović O, Prljača D, Dautbašić M, Ivojević S, 2023. Occurrence of Bees and Bumblebees in Bark Beetle Slit Traps from Spruce and Fir Woodlands of Central Dinaric Alps. *South-east Eur for* 14(1): 83-91. https://doi.org/10.15177/seefor.23-11.

Received: 9 Mar 2023; **Revised:** 5 Jun 2023; **Accepted:** 6 Jun 2023; **Published online:** 21 Jun 2023

ABSTRACT

The paper analysed bees by-catch collected in 259 bark beetle slit traps, from eleven localities in Bosnia and Herzegovina. Sampling was carried out in spruce and fir forests in 2020 and 2021. As a by-catch from bark beetle slit traps 84 bee individuals from four families and 13 genera were collected. In the bark beetle slit traps sample, out of 29 bee taxa, 22 species were identified at the species level and eight specimens were left at the genus/subgenus level. The most dominant genera were *Megachile* with 34 specimens and *Osmia* represented by 20 specimens in the total sample. The research identified 14 bee species new to the fauna of Bosnia and Herzegovina. The bee species collected in the bark beetle slit-traps were dominated by nesters in cavities, above the ground-nesting bees.

Keywords: conservation; pollinators; by-catch; forest; management

INTRODUCTION

In Europe, bees represent the main group of pollinators (Drossart and Gérard 2020) and in the European Union pollination has an estimated economic value of €15 billion per year (Nieto et al. 2014). The number of bee species in the wild has declined globally, the decrease occurred in the last 10-15 years, with roughly 25 per cent fewer species recorded (Potts et al. 2010, Zattara and Aisen 2021). The loss of bee diversity has intensified efforts to develop methods of standardized sampling and the assessment of bee diversity. The three most commonly used trapping methods for collecting bees for biodiversity studies are bowl traps, vane traps, and Malaise traps. Methods of passive bee sampling with traps and statistical models for the purpose of monitoring are still being developed and attempts are being made to understand the scope of bee diversity that is included through sampling with coloured pan traps (McCravy 2018). Bees also find their way into traps that use both visual and olfactory cues to attract pest insects. Researchers work to improve pest monitoring tools to increase target captures and reduce bee by-catch. The bee by-catch composition analysis can help assess biodiversity, determine population fluctuations and range expansions, support monitoring efforts, and identify patterns and processes of broader ecological interest (Spears et al. 2021). Forestry implements traps to control bark beetles, ambrosia beetles, wood-boring insects, and wood wasps, thereby minimizing their populations. Additionally, traps in forestry are employed to identify and monitor the presence of pests and invasive insects. Introduced in the late 1970s, pheromone traps were implemented as a replacement for trap trees that had been utilized for over two centuries, serving as a protective measure against the spruce bark beetle (Zahradnik 2015).

Standardised bark beetle slit traps used for the mass trapping of bark beetles can be used with or without an attractant. Bark beetle slit traps are considered to have relatively few wider ecosystem effects on the woodland environment, but this is rarely tested in field conditions. In Bosnia and Herzegovina, monitoring of wild bees by standardized sampling has not been performed and data on the composition of solitary bee and bumblebee fauna from traps are unknown.

The importance of by-catch bees in traps for monitoring of pests has already been confirmed and data were used for biodiversity assessment (Buchholz et al. 2011, Spears and

Ramirez 2015). By-catch from lepidopteran traps and pitfall traps were used to determine the abundance and diversity of bees (Hatten et al. 2013, Hung et al. 2015, Parys et al. 2021).

Considering the importance of solitary bees and population decline trends, data on collected species from non-target catches are a significant source of data on the distribution and diversity of bees, especially if one takes into account the standardized collection method and long-term monitoring of bark beetles in forestry. This study aimed to determine the composition of honey bee, solitary bees and bumblebees that occur in the bark beetle slit traps in the spruce and fir forests of central Bosnia and Herzegovina.

MATERIALS AND METHODS

Control and monitoring of bark beetles are carried out by the University of Sarajevo - Faculty of Forestry, Plant Protection Laboratory. Collected bees were separated from the sample within a bark beetle monitoring program. The by-catch was processed at the Faculty of Science, Department of Biology, where taxonomic analysis of the bees was carried out. Bees from the by-catch were washed, dried and placed on entomological pins. The identification was carried out using stereo zoom microscope with 90X magnification and taxonomic keys (Friese 1895a, 1985b, 1896, 1897, Brohmer et al. 1930, Warncke 1968, Mauss 1994, Amiet et al. 2001, 2004; 2007, 2010, 2014, 2017, Michez et al. 2019, Rasmont et al. 2021). The current systematic and species status follows Kuhlman et al. (2023).

The samples were collected from 259 bark beetle slit traps with attractants; Pheroprax® (ipsdienol, cis-verbenol, 2-methylbut-3-en-2-ol) and Gallowit® (ipsdienol CAS 1443441-4,ipsenol CAS 60894-96-4, DMWK CAS 115-18-4, cis-verbenol CAS 18881-04-4, α-pinene CAS 80-56-8, ethanol CAS 64-17-5). On the sampling sites we use "Theysohn" (producer THEYSOHN Kunststoff GmbH, Germany) type pheromone traps. All traps had the same set of baitpheromones, baited-traps were set approximately 20m from the forest edge, the distance between baited traps was approximately 20 m apart and bark beetle slit traps were placed 1.5 m above the ground.

The sampling was carried out from May to June 2020 and May to September 2021. The pheromone-baited traps were emptied weekly.

Study Sites

Sampling was performed at 11 monitoring sites in central Bosnia and Herzegovina (Figure 1, Table 1).

The monitoring sites are located on Mt. Bjelašnica, Mt. Igman, Mt. Ozren, Mt. Trebević, and Mt. Zvijezda. The traps were used for annual bark beetle control and monitoring. All selected sampling sites were within *Picea abies* (L.) Karst. and *Abies alba* Mill. forests in the Dinaric, Pre-Alpine region (Table 1). Local habitat parameters were not estimated on the field due to a lack of field protocol. Values of climatic parameters for each sampling site were extracted from WorldClim raster for each locality (Fick et al. 2017). The parameters used for obtaining bioclimatic data were extracted from WorldClim raster with a spatial resolution of 1 km^2: Annual Mean Temperature - bio1, Mean Temperature of Warmest Quarter - bio10, Mean Temperature of Coldest Quarter - bio11, Annual Precipitation - bio12 (Fick et al. 2017).

Landscape Pattern Analysis

Land cover maps of the study area were generated from Corrine Land Cover maps with 100X100 meters resolution. The classification of the study region was made according to CLC classification. From the CLC map, 11 forest patches were selected. The centre of each CLC patch coincides with the centroid of traps in the investigated localities, calculated using a centroid point layer in QGIS. The forest patch had a diameter of 1600 meters and an area of 2.0 km^2. Landscape pattern analysis was conducted with QGIS raster to calculate forest cover and landscape heterogeneity using the Shannon diversity index.

The Shannon diversity index considers the number of different types of environments and their proportion in each landscape (Table 2.). If two landscapes are covered by exactly the same types of habitats, that with the highest Shannon-Weaver value will be the one with the highest category evenness (McGarigal et al. 2012).

Data Processing

For each sampling site, we estimated two bee community level variables: richness (number of species), and

Table 1. The position of monitoring sites; coordinates are centroids for bark beetle slit raps used for forest pest control and management

Locality	Lat.	Lon.	Meters
1. Bijambare	44.082868	18.511551	980
2. Gornjebosansko, Gornja Ljubina	43.973329	18.381129	612
3. Trnovo, Hojta-Presjenica	43.674577	18.334640	938
4. Gornjebosansko, Kaljina-Bioštica	44.061094	18.534055	1030
5. Igman	43.752618	18.267648	1240
6. Igmansko, Hadžići Zujevina	43.726973	18.082502	944
7. Skakavac, Vogošća-Bulozi; Vučja Luka	43.939597	18.453573	1409
8. Trebević	43.834989	18.452661	1086
9. Trnovo, Crna Rijeka-Željeznica	43.659614	18.381594	1121
10. Trnovo, Gornja Rakitnica	43.655270	18.286679	1220
11. Gornjebosansko, Gornja Misoča	43.958932	18.308820	757

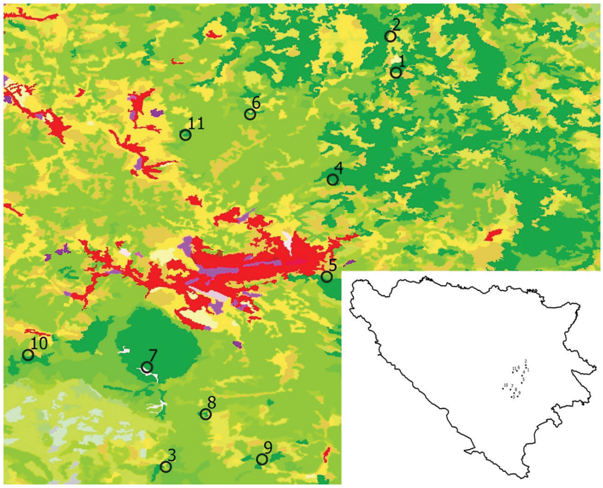


Figure 1. Position of monitoring sites for bark beetle slit traps on Corine Land Cover, circles represent forest patches 2 km2 with the associated localities that are numbered, the sampling sites are marked on a blind map of Bosnia and Herzegovina; 1 – Bijambare, 2 - Gornjebosansko, Gornja Ljubina, 3 – Trnovo, Hojta-Presjenica, 4 – Gornjebosansko, Kaljina-Bioštica, 5 – Igman, 6 – Igmansko, Hadžići Zujevina, 7 – Skakavac, Vogošća-Bulozi, Vučja Luka, 8 – Trebević, 9 – Trnovo, Crna Rijeka-Željeznica, 10 – Trnovo, Gornja Rakitnica, 11 – Gornjebosansko, Gornja Misoča.

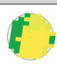
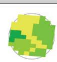
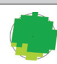
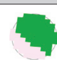
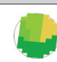
abundance (total bee amount), from which we calculate the Shannon diversity index. The frequency of bee species in the investigated locality was analysed as an indicator of the diversity and composition of bee communities. Based on the data, the similarity between the samples was compared using Beta Diversity and Pairwise comparison Whittaker. The diversity indexes by sampling locality and the number of bees collected in the traps were used to calculate: Taxa_S, Individuals, Dominance_D, Simpson_1-D, Shannon_H, Margalef, Fisher_alpha, Berger-Parker, chao1. The correlation between altitude, the number of individuals and the number of species was tested using linear correlation. Ordinary Least Squares Regression was used for the correlation between the number of bees and the number of traps per locality.

RESULTS AND DISCUSSION

The relative abundance of spruce and fir forests according to CLC analysis within an area of 2 km^2 varies in the range of 0.07-0.88, median=0.31 (Table 2).

The mean values for 11 sampling sites were calculated using data obtained from WorldClim rasters mean±standard deviation (min, max): Average Annual Mean

Table 2. The number of different land cover types, CLC category proportion in each sampling locality and Shannon-H value for each sampling locality.

	Locality										
CLC category	**L1**	**L2**	**L3**	**L4**	**L5**	**L6**	**L7**	**L8**	**L9**	**L10**	**L11**
Mapped 1.6 km radius landscapes											
142 Sport and leisure facilities	0.00	0.00	0.00	0.00	0.00	0.31	0.00	0.00	0.00	0.00	0.00
231 Pastures	0.24	0.36	0.00	0.00	0.14	0.00	0.25	0.00	0.00	0.00	0.00
242 Complex cultivation patterns	0.49	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
243 Annual crops associated with permanent crops	0.00	0.00	0.00	0.13	0.00	0.00	0.00	0.00	0.21	0.00	0.00
311 Broad-leaved forest	0.00	0.16	0.00	0.17	0.29	0.00	0.51	0.93	0.26	0.53	0.00
312 Coniferous forest	0.27	0.08	0.85	0.31	0.21	0.69	0.24	0.07	0.39	0.47	0.88
313 Mixed forest	0.00	0.40	0.00	0.39	0.082	0.00	0.00	0.00	0.14	0.00	0.00
324 Transitional woodland shrub	0.00	0.00	0.15	0.00	0.29	0.00	0.00	0.00	0.00	0.00	0.12
Number of categories	3	4	2	4	5	2	3	2	4	2	2
Shannon-H	1.04	1.24	0.42	1.29	1.52	0.62	1.03	0.25	1.32	0.69	0.37

Temperature °C = 7.32±1.01 (5.65, 9.15), Mean Temperature of Warmest Quarter °C = 15.65±1.15 (13.77, 17.78), Mean Temperature of Coldest Quarter °C = -1.17±0.77 (-2.41, 0.23) and Annual Precipitation mm·m^{-2} = 1078,83±30.08 (1035, 1115).

The solitary bees and bumblebees collected in the by-catch sample from the bark beetle slit-traps were represented by 84 bees. In 2020, 19 bees were collected from 18 bark beetle slit traps and in 2021, 65 bees were collected from 39 slit traps.

The minimum number of bees in the bark beetle slit traps was collected in May 2021, the bees were most numerous in July 2020 - 10 bees and in July 2021 - 23 bees. The number of bees in traps decreases in August and September (Table 3). The maximum number of individuals from the genus *Osmia* was collected in the traps in July and June, while the genus *Megachile* was most dominant in July and August (Table 3.).

The sampled bees collected in bark beetle slit traps belong to 13 genera (Table 3). The prevailing bee genera was *Megachile* represented by 34 individuals, *Osmia* represented by 20 bees and *Apis* - 10 individuals (Table 3). The genus *Megachile*, *Osmia* and *Apis* in the sample comprise 76% of the total sample. *Apis mellifera* was represented in 73% of the sampling localities. In the total sample, 49 bees were females and 35 were males. The ratio of males to females in the genus *Megachile* was in favor of males, while in the genus *Osmia* females were dominant (Table 4).

Three localities stand out regarding the number of collected specimens: locality 5 Igman (16), locality 7 Skakavac, Vogošća-Bulozi, Vučja Luka (15) and locality 10 Trnovo, Gornja Rakitnica (17). The aforementioned localities account for 57.14% of the collected bees in bark beetle slit traps (Table 5). The localities with the largest number of collected bees are the ones with the highest species diversity, which is locality 7 Skakavac, Vogošća-Bulozi, Vučja Luka (Table 4).

Genus *Osmia* was represented by eight species and two bees which were identified at the genus level. The genus *Megachile* was represented by seven species and one bee was identified at the genus level. The lowest number of identified individuals at the species level from the slit traps was in the genus *Bombus*. Due to the damage of the individuals in the bark beetle slit-traps, only one bumblebee was identified at the species level (Table 5.).

Diversity indices show the localities which are richest in diversity are: 5 Igman, 7 Skakavac-Vogošća-Bulozi-Vučja Luka, and 10 Trnovo-Gornja Rakitnica (Table 6.).

The relationship between altitude, the number of individuals and the number of bee species has a positive correlation r=0.61; p=0.037. Ordinary Least Squares Regression showed a statistically significant correlation between the number of individuals and the number of traps per locality: t=2.77, p=0.02, r=0.64, r^2=0.41. The number of collected individuals and the number of traps per locality is different; the largest number of traps is in the Igman locality with 93 traps, and in the Trnovo, Crna Rijeka-Željeznica locality two traps were present (Table 7).

From 259 bark beetle slit traps, we collected 84 bees belonging to 26 species. The number of ground-nesting solitary bees and bumblebee species was seven. Overground cavity-nesting bees and dead wood nesters were represented by 18 species and *Apis mellifera* was a eusocial cavity-nesting bee. The number of dead wood nesting bees and over-ground cavity nesters (78) was greater than the number of ground-nesting bees in the by-catch sample. We also collected parasitic bees: *Coelioxys conica*, *Sphecodes majalis* and *Stelis punctulatissima*. Megachilidae were the most abundant taxonomic group represented by 17 bees identified to the species level. The relationship between Megachilidae and bark beetle slit traps placed over the ground is based on the biology of a group that nests in cavities above ground, most often in pre-existing abandoned tunnels of saproxylic insects. The data regarding collected bees is significant from the aspect of understanding the diversity of local bee fauna. The checklist for bee fauna for Bosnia and Herzegovina lists 125

Table 3. Variation in the number of collected bees in bark beetle slit traps during the sampling period July-August 2020 and May-September 2021, dates are in year/month format.

Family	Genus	2020/07	2020/08	2021/05	2021/06	2021/07	2021/08	2021/09	Total
Andrenidae	*Andrena*	0	0	0	0	0	2	0	**2**
Apidae	*Apis*	0	2	0	4	3	1	0	**10**
Apidae	*Bombus*	3	3	0	0	1	0	0	**7**
Apidae	*Eucera*	0	0	0	0	1	0	0	**1**
Halictidae	*Dufourea*	0	0	0	1	0	0	0	**1**
Halictidae	*Halictus*	0	0	0	0	0	0	1	**1**
Halictidae	*Sphecodes*	0	0	0	1	0	0	0	**1**
Megachilidae	*Anthidium*	1	1	1	0	0	1	0	**4**
Megachilidae	*Coelioxys*	1	0	0	0	0	0	0	**1**
Megachilidae	*Hoplosmia*	0	0	0	0	1	0	0	**1**
Megachilidae	*Megachile*	3	2	0	3	10	10	6	**34**
Megachilidae	*Osmia*	1	1	1	7	7	1	2	**20**
Megachilidae	*Stelis*	1	0	0	0	0	0	0	**1**
Total		**10**	**9**	**2**	**16**	**23**	**13**	**9**	

Table 4. The number of collected bee specimens in bark beetle slit-traps by genus and gender.

Genus	Number of specimens	Males	Females
1. *Andrena*	2		2
2. *Apis*	10	2	8
3. *Bombus*	7		7
4. *Eucera*	1		1
5. *Dufourea*	1	1	
6. *Halictus*	1	1	
7. *Sphecodes*	1	1	
8. *Anthidium*	4	1	3
9. *Coelioxys*	1	1	
10. *Hoplosmia*	1	1	
11. *Megachile*	34	20	14
12. *Osmia*	20	6	14
13. *Stelis*	1	1	
Number of specimens	**84**	**35**	**49**

species (Apfelbeck 1896). Comparison with a bee checklist of Serbia (Mudri-Stojnić et al. 2021) with 706 species, indicates a significant difference in species diversity. Of the total 22 identified bee species in the study, up to date, 14 species have not been recorded for Bosnia and Herzegovina according to Apfelbeck checklist: *Andrena tscheki*, *Bombus sylvestris*, *Coelioxys conica*, *Megachile centuncularis*, *M. genalis*, *M. pildens*, *M. pilicrus*, *Osmia bicornis*, *O. claviventris*, *O. latreillei*, *O. leaiana*, *O. mustelina*, *Sphecodes majalis*, *Stelis punctulatissima*.

The relationship between altitude, the number of individuals and the number of bee species has a positive correlation r=0.61; p=0.037. Multivariate linear regression analysis correlated habitat heterogeneity with the number of bee species, the number of collected bees and Shannon – H diversity index for each investigated locality (Table 8). Linear regression analysis indicated a negative correlation between habitat heterogeneity and the number of bee species; habitat heterogeneity and the number of bees. The positive correlation was found between habitat heterogeneity and Shanon – H for bee diversity, and the correlations had no statistical significance.

The spruce and fir forests dying due to bark beetle infestation changes the forest structure and has a positive effect on the diversity of pollinators. Bark beetle infestation leads to the death of trees and loss of cover in the tree floor, a greater amount of light can stimulate the growth of herbaceous plants. Bees are positively associated with disturbed forest habitats and forest low tree cover with high floral richness, while abundant dead wood creates suitable conditions for bees (Moretti et al. 2009, Williams et al. 2010, Spears and Ramirez 2015). In addition to the aforementioned loss of leaf mass, measures to control bark beetles are reduced to bare cutting and cleaning of infested areas, which opens up forest habitats. The bee species richness in the forests increases with flower richness and clear-cut size (Taki et al. 2007, Watson et al. 2011, Schüepp et al. 2011). The landscapes with more forests and environmental heterogeneity can provide more resources for bees through resource complementation processes, maintaining their diversity in the landscape. The presence of forest patches close to open areas is of utmost importance for the conservation of bees and pollination services (Rubene et al. 2015). Data related to the wild bees by-catch composition in forest pest management traps, such as bark beetle slit traps in Bosnia and Herzegovina, have not been studied. The absence of long-term bee monitoring can most likely be compensated by the analysis of the composition of the bee fauna in the traps for e.g., bark beetle, as by-catch. By-catches, also, may cause a variety of adverse consequences on populations, food webs and conservation efforts (Revill et al. 2005).

Integrated Pest and Pollinator Management has been proposed as a new framework to further improve the compatibility of pest management practices with pollinator conservation strategies (Biddinger and Rajotte 2015). Considering that integrated pest management and the inclusion of beneficial insects leads to a higher number of insect groups requiring taxonomic identification, the need for collaboration with additional taxonomists for the identification of materials collected from traps becomes crucial. Due to the intricate nature of the task, the challenges highlight the importance of teamwork and synchronized efforts among multiple teams, as well as the regular exchange of materials with expert taxonomists (Spears et al. 2021).

Non-targeted catch has been used to facilitate taxonomic research and describe new species, identify novel invasive alien species, enhance stakeholder knowledge and conduct surveys of non-target insects. The significant presence of *Megachile* and *Osmia* solitary bee species in the sample indicates the need for additional investigation

Table 5. The number of collected bees in traps by locality and nest preference: ground nester (GN), cavity nester over ground (CN), preexisting holes wood nester, or over ground wood nester (WN).

	Bijambare	Gornjebosansko, Gornja Ljubina	Trnovo, Hojta-Presjenica	Gornjebosansko, Kaljina-Bioštica	Igman	Igmansko, Hadžići Zujevina	Skakavac, Vogošća-Bulozi; Vučja Luka	Trebević	Trnovo, Crna Rijeka-Željeznica	Trnovo, Gornja Rakitnica	Gornjebosansko, Gornja Misoča	Number of specimens
1. Andrena sp. (GN)	0	1	0	0	0	0	0	0	0	0	0	1
2. *Andrena tscheki* (GN)	0	1	0	0	0	0	0	0	0	0	0	1
3. *Anthidium manicatum* (CN)	0	0	1	0	2	0	1	0	0	0	0	4
4. *Apis mellifera* (CN)	2	1	0	2	1	0	1	1	0	1	1	10
5. *Bombus* sp. (GN)	0	0	0	0	4	1	1	0	0	0	0	6
6. *Bombus sylvestris* (GN)	1	0	0	0	0	0	0	0	0	0	0	1
7. *Dufourea* sp. (GN)	0	0	0	0	0	1	0	0	0	0	0	1
8. *Eucera longicornis* (GN)	0	0	0	0	0	0	1	0	0	0	0	1
9. *Halictus* sp. (GN)	0	0	0	0	0	0	0	0	0	1	0	1
10. *Coelioxys conica* (WN)	0	0	0	0	1	1	0	1	0	0	0	3
11. *Megachile centuncularis* (WN)	0	0	1	0	1	0	1	1	0	2	0	6
12. *Megachile genalis* (WN)	0	0	0	0	1	0	0	1	0	2	0	4
13. *Megachile ligniseca* (WN)	0	0	0	0	0	0	1	0	0	0	0	1
14. *Megachile pildens* (WN)	0	0	1	0	0	0	0	1	0	0	0	2
15. *Megachile pilicrus* (WN)	0	0	0	0	1	0	1	0	0	0	0	2
16. *Megachile* sp.	1	0	2	0	0	0	3	0	0	2	1	9
17. *Megachile willughbiella* (WN)	2	0	0	0	0	0	1	1	0	4	0	8
18. *Osmia caerulescens* (WN)	0	0	0	0	0	0	0	0	0	0	1	1
19. *Osmia aurulenta* (WN)	0	0	0	1	0	0	0	0	0	0	0	1
20. *Osmia bicornis* (WN)	0	0	0	0	1	0	1	2	0	0	0	4
21. *Osmia claviventris* (WN)	1	0	0	0	0	0	0	0	1	0	0	2
22. *Osmia cornuta* (WN)	0	0	0	0	1	0	2	0	0	0	0	3
23. *Osmia latreillei* (WN)	0	0	0	0	0	0	0	0	0	1	0	1
24. *Osmia leaiana* (WN)	0	0	0	0	0	0	0	0	0	1	0	1
25. *Osmia mustelina* (CN)	0	0	0	0	0	0	1	0	0	0	0	1
26. *Osmia* sp.	0	0	0	0	3	0	0	0	0	3	0	6
27. *Hoplosmia* sp.	0	0	0	0	0	0	0	0	0	0	1	1
28. Sphecodes majalis (GN)	1	0	0	0	0	0	0	0	0	0	0	1
29. *Stelis punctulatissima* (WN)	0	0	0	0	0	1	0	0	0	0	0	1
Number of bees	**8**	**3**	**5**	**3**	**16**	**4**	**15**	**8**	**1**	**17**	**4**	**84**

into the effectiveness of bark beetle slit traps for monitoring these genera in the Dinaric Alps.

Further research is needed to verify the species diversity of the genera *Megachile* and *Osmia* in pest monitoring traps compared to traps used in bee biodiversity research, such as pan traps. Establishing a correlation in the species diversity of the aforementioned genera enables the introduction of an integrative approach to the control of pests and bee monitoring using bark beetle slit traps. Collecting data from forest pest management traps is the first step towards better knowledge of the distribution of solitary bees and bumblebees. Taking into account the standard sizes of bark beetle slit traps and a larger number of traps, it is most likely possible to monitor bees and determine the correlation between the forest habitat heterogeneity and community and the diversity of bees.

CONCLUSIONS

Solitary bees (79.8%), bumblebees (8.4%) and honey bees (11.8%) were detected as by catches in bark beetle slit traps used for the control and monitoring of bark beetles. The sample of bees from traps is dominated by species nesting in existing tree cavities: *Osmia* 8/22 (36%) and *Megachile* 6/22 (27%). A positive correlation was established between the number of collected bees and the number of traps per locality. Slit traps for the control of bark beetles are important as a source of information about the bee fauna when there is no long-term research on bee fauna of Bosnia and Herzegovina.

The presence of 14 new species of bees was determined which were not previously recorded for the fauna of Bosnia and Herzegovina. The data on the connection between habitat structure and the number of bee species are contrived and

Table 6. Overview of the diversity indices by locality based on the number of bees collected in the traps.

	Bijambare	Gornjebosansko, Gornja Ljubina	Trnovo, Hojta-Presjenica	Gornjebosansko, Kaljina-Bioštica	Igman	Igmansko, Hadžići Zujevina	Skakavac, Vogošća-Bulozi; Vučja Luka	Trebević	Trnovo, Crna Rijeka-Željeznica	Trnovo, Gornja Rakitnica	Gornjebosansko, Gornja Misoča
Taxa_S	6	3	4	2	10	4	12	7	1	9	4
Individuals	8	3	5	3	16	4	15	8	1	17	4
Dominance_D	0.19	0.33	0.28	0.56	0.14	0.25	0.10	0.16	1.00	0.14	0.25
Simpson_1-D	0.81	0.67	0.72	0.44	0.86	0.75	0.90	0.84	0.00	0.86	0.75
Shannon_H	1.73	1.10	1.33	0.64	2.13	1.39	2.40	1.91	0.00	2.07	1.39
Margalef	2.40	1.82	1.86	0.91	3.25	2.16	4.06	2.89	0.00	2.82	2.16
Fisher_alpha	10.91	0.00	9.28	2.62	11.41	0.00	27.85	26.78	0.00	7.75	0.00
Berger-Parker	0.25	0.33	0.40	0.67	0.25	0.25	0.20	0.25	1.00	0.24	0.25
chao1	12.56	6.50	9.13	3.46	34.48	10.40	61.00	25.05	2.34	12.55	10.25

Table 7. The number of collected individuals and the number of traps per locality; the ratio of the number of collected bees and the number of traps.

Locality	Number of bees	Number of traps	Number of bees/traps
Trnovo, Crna Rijeka-Željeznica	1	2	0.5
Trnovo, Hojta-Presjenica	5	6	0.8
Gornjebosansko, Gornja Misoča	4	8	0.5
Igmansko, Hadžići Zujevina	4	9	0.4
Skakavac, Vučja Luka, Vogošća-Bulozi	15	28	0.7
Trebević	8	17	0.5
Bijambare	8	21	0.4
Gornjebosansko, Gornja Ljubina	3	22	0.1
Trnovo, Gornja Rakitnica	17	25	0.7
Gornjebosansko, Kaljina-Bioštica	3	28	0.1
Igman	16	93	0.2
Total	**84**	**259**	

Table 8. Multivariate linear regression analysis between habitat heterogeneity vs the number of bee species, the number of collected bees and Shannon - H for bee diversity.

Variable	Slope	Error	Intercept	Error	r	p
Number of bee species	-0.43	2.67	6.02	2.62	-0.05	0.87
Number of bees	-1.15	4.37	8.66	4.30	-0.09	0.80
Bee diversity indicated by Shannon – H	0.39	0.52	1.11	0.51	0.24	0.47

do not correspond to earlier assumptions about the positive connection between the heterogeneity of forest habitats and the number of insects and bees. This study shows that bark beetle slit traps can be used for monitoring of *Megachile* and *Osmia* genera within woodland communities.

Author Contributions

OM, AV, MD and SI conceived and designed the research, DP collected sample for analysis, DK carried out the sample separation, AV performed taxonomic analysis, DP and AV processed the data and performed the statistical analysis, OM, AV, MD and SI secured the research funding, supervised the research and helped to draft the manuscript, AV, DK, OM and DP wrote the manuscript.

Funding

This research had no funding support.

Conflicts of Interest

The authors declare no conflict of interest.

REFERENCES

Amiet F, Herrmann M, Müller A, Neumeyer R, 2001. Apidae 3 - Halictus, Lasioglossum. Fauna Helvetica 6. Apidae 3: Halictus, Lasioglossum. Fauna Helvetica 6, Centre suisse de cartographie de la faune.

Amiet F, Herrmann M, Müller A, & Neumeyer R, 2004. *Apidae 4 - Anthidium, Chelostoma, Coelioxys, Dioxys, Heriades, Lithurgus, Megachile, Osmia, Stelis.* Fauna Helvetica 9, Centre Suisse de cartographie de la faune.

Amiet F, Herrmann M, Müller A, Neumeyer R, 2007. Apidae 5 - Ammobates, Ammobatoides, Anthophora, Biastes, Ceratina, Dasypoda, Epeoloides, Epeolus, Eucera, Macropis, Melecta, Melitta, Nomada, Pasites, Tetralonia, Thyreus, Xylocopa. Fauna Helvetica 20, Centre suisse de cartographie de la faune & SEG, Neuchâtel.

Amiet F, Herrmann M, Müller A, Neumeyer R, 2010. Apidae 6 - Andrena, Melitturga, Panurginus, Panurgus. Fauna Helvetica 26 Centre suisse de cartographie de la faune & SEG, Neuchâtel.

Amiet F, Müller A, Neumeyer R, 2014. Apidae 2 - Colletes, Dufourea, Hylaeus, Nomia, Nomioides, Rhophitoides, Rophites, Sphecodes, Systropha.–Fauna Helvetica 4, Centre suisse de cartographie de la faune & SEG, Neuchâtel.

Amiet F, Muller A, Praz C, 2017. *Apidae 1 - Allgemeiner Teil, Gattungen Apis, Bombus.* Fauna Helvetica 29, Centre suisse de cartographie de la faune & SEG, Neuchâtel.

Apfelbeck V, 1896. Balkanske Apide (pčele). *Glasnik zemaljskog muzeja u Bosni I Hercegovini* 8: 329-342.

Biddinger DJ, Rajotte EG, 2015. Integrated pest and pollinator management—adding a new dimension to an accepted paradigm. *Curr Opin Insect Sci* 10: 204-209. https://doi.org/10.1016/j.cois.2015.05.012.

Brohmer P, Ehrmann P, Ulmer G, 1930. Hymenoptera. *Die Tierwelt Mitteleuropas* 5, Teil 2, (H. Hedicke).

Buchholz S, Kreuels M, Kronshage A, Terlutter H, Finch OD, 2011. Bycatches of ecological field studies: Bothersome or valuable? *Methods Ecol Evol* 2(1): 99-102. https://doi.org/10.1111/j.2041-210X.2010.00051.x.

Drossart M, Gérard M, 2020. Beyond the decline of wild bees: Optimizing conservation measures and bringing together the actors. *Insects* 11(9): 649. https://doi.org/10.3390/insects11090649.

Fick SE, Hijmans RJ, 2017. WorldClim 2: new 1-km spatial resolution climate surfaces for global land areas. *Int J Climatol* 37(12): 4302-4315. https://doi.org/10.1002/joc.5086.

Friese H, 1895a. Die Bienen Europa's (Apidae europaeae) nach ihnren Gattungen, Arten und Variaten auf vergleichend morphologisc-biologischer Grundlage. Theil I. Schmarotzerbienen. Friedlander & Sohn, Berlin, Germany.

Friese H, 1895b. Die Bienen Europa's (Apidae europaeae) nach ihnren Gattungen, Arten und Variaten auf vergleichend morphologisc-biologischer Grundlage. Theil IV. Solitare Apiden: subfam. Panurginae, Melittinae, Xylocopinae. Friedlander & Sohn, Berlin, Germany.

Friese H, 1896. Die Bienen Europa's (Apidae europaeae) nach ihnren Gattungen, Arten und Variaten auf vergleichend morphologisc-biologischer Grundlage. Theil II, Solitare Apiden. Genus Eucera. Friedlander & Sohn, Berlin, Germany.

Friese H, 1897. Die Bienen Europa's (Apidae europaeae). Theil III. Solitäre Apiden. Genus Podalirius. Friedländer & Sohn, Berlin, Germany.

Hatten TD, Looney C, Strange JP, Bosque-Pérez, NA, Jetton R, 2013. Bumble bee fauna of Palouse Prairie: Survey of native bee pollinators in a fragmented ecosystem. *J Insect Sci* 13(1): 26. https://doi.org/10.1673/031.013.2601.

Hung KLJ, Ascher JS, Gibbs J, Irwin RE, Bolger DT, 2015. Effects of fragmentation on a distinctive coastal sage scrub bee fauna revealed through incidental captures by pitfall traps. *J Insect Conserv* 19(1): 175–179. https://doi.org/10.1007/s10841-015-9763-8.

Kuhlmann M, 2023. Checklist of the Western Palaearctic Bees (Hymenoptera: Apoidea: Anthophila). Available online: http://westpalbees.myspecies.info (31 May 2023).

Mauss V, 1994. Bestimmungsschlüssel für Hummeln. 6. Auflage DJN (Hrsg.) Hamburg, Germany.

McCravy KW, 2018. A review of sampling and monitoring methods for beneficial arthropods in agroecosystems. *Insects* 9(4): 170. https://doi.org/10.3390/insects9040170.

McGarigal K, Cushman SA, Ene E, 2012. FRAGSTATS v4: spatial pattern analysis program for categorical and continuous maps. Computer software program produced by the authors at the University of Massachusetts, Amherst.

Michez D, Rasmont P, Terzo M, Vereecken N, 2019. Bees of Europe. Hymenoptera of Europe 1. N.A.P. Editions, 548 p.

Mudri-Stojnić S, Andrić A, Markov-Ristić Z, Đukić A, Vujić A, 2021. Contribution to the knowledge of the bee fauna (Hymenoptera, Apoidea, Anthophila) in Serbia. *ZooKeys* 1053: 43-105. https://doi.org/10.3897/zookeys.1053.67288.

Moretti M, De Bello F, Roberts SP, Potts SG, 2009. Taxonomical vs. functional responses of bee communities to fire in two contrasting climatic regions. *J Anim Ecol* 78(1): 98-108. https://doi.org/10.1111/j.1365-2656.2008.01462.x.

Nieto A, Roberts SPM, Kemp J, Rasmont P, Kuhlmann M, García Criado M, Biesmeijer JC, Bogusch P, Dathe HH, De la Rúa P, De Meulemeester T, Dehon M, Dewulf A, Ortiz-Sánchez FJ, Lhomme P, Pauly A, Potts SG, Praz C, Quaranta M, Radchenko VG, Scheuchl E, Smit J, Straka J, Terzo M, Tomozii B, Window J, Michez D, 2014. European Red List of bees. Belgium, Luxembourg, Publication Office of the European Union, 84 pp. Available online: https://ec.europa.eu/environment/nature/conservation/species/redlist/downloads/European_bees.pdf (22 December 2022).

Parys KA, Elkins BH, Little NS, Allen KC, Crow W, Cook D, Wright KW, Zhu YC, Griswold T, 2021. Landscape effects on native bees (Hymenoptera: Anthophila) captured in pheromone traps for Noctuid Crop Pests (Lepidoptera: Noctuidae). *Environ Entomol* 50(4): 860-867. https://doi.org/10.1093/ee/nvab040.

Potts SG, Biesmeijer JC, Kremen C, Neumann P, Schweiger O, Kunin WE, 2010. Global pollinator declines: trends, impacts and drivers. *Trends Ecol Evol* 25(6): 345-353. https://doi.org/10.1016/j.tree.2010.01.007.

Rasmont P, Ghisbain G, Terzo M, 2021. Bumblebees of Europe. Hymenoptera of Europe 3, NAP Editions.

Revill AS, Dulvy NK, Holst R, 2005. The survival of discarded lesser-spotted dogfish (*Scyliorhinus canicula*) in the Western English Channel beam trawl fishery. *Fish Res* 71(1): 121-124. https://doi.org/10.1016/j.fishres.2004.07.006.

Rubene D, Schroeder M, Ranius T, 2015. Diversity patterns of wild bees and wasps in managed boreal forests: Effects of spatial structure, local habitat and surrounding landscape. *Biol Conserv* 184: 201-208. https://doi.org/10.1016/j.biocon.2015.01.029.

Schüepp C, Herrmann JD, Herzog F, Schmidt-Entling MH, 2011. Differential effects of habitat isolation and landscape composition on wasps, bees, and their enemies. *Oecologia* 165: 713-721. https://doi.org/10.1007/s00442-010-1746-6.

Spears LR, Ramirez RA, 2015. Learning to love leftovers: Using by-catch to expand our knowledge in entomology. *Am Entomol* 61(3): 168-173. https://doi.org/10.1093/ae/tmv046.

Spears LR, Christman ME, Koch JB, Looney C, Ramirez RA, 2021. A review of bee captures in pest monitoring traps and future directions for research and collaboration. *J Integr Pest Manag* 12(1): 49. https://doi.org/10.1093/jipm/pmab041.

Taki H, Kevan PG, & Ascher JS, 2007. Landscape effects of forest loss in a pollination system. *Landscape Ecol* 22: 1575-1587. https://doi.org/10.1007/s10980-007-9153-z.

Warncke K, 1968. Die Untergattungen der westpalaarktischen Bienengattung Andrena F. *Memorias e Estudos Muséu Zoologico da Universidade de Coimbra* 307: 1-110.

Watson JC, Wolf AT, Ascher JS, 2011. Forested landscapes promote richness and abundance of native bees (Hymenoptera: Apoidea: Anthophila) in Wisconsin apple orchards. *Environ Entomol* 40(3): 621-632. https://doi.org/10.1603/EN10231.

Williams NM, Crone EE, Roulston TH, Minckley RL, Packer L, Potts SG, 2010. Ecological and life-history traits predict bee species responses to environmental disturbances. *Biol Conserv* 143(10): 2280-2291. https://doi.org/10.1016/j.biocon.2010.03.024.

Zahradník P, Zahradníková M, 2015. The efficacy of a new pheromone trap setup design, aimed for trapping *Ips typographus* (Coleoptera, Curculionidae, Scolytinae). *Šumar List* 139(3-4): 185-186.

Zattara EE, Aizen MA, 2021. Worldwide occurrence records suggest a global decline in bee species richness. *One Earth* 4(1): 114-123. https://doi.org/10.1016/j.oneear.2020.12.005.