

## MODELS OF THE POTENTIAL DISTRIBUTION AND HABITAT PREFERENCES OF THE GENUS *PIPIZA* (SYRPHIDAE: DIPTERA) ON THE BALKAN PENINSULA

TIJANA NIKOLIĆ<sup>1</sup>, D. RADIŠIĆ<sup>1</sup>, DUBRAVKA MILIĆ<sup>1</sup>, V. MARKOVIĆ<sup>2</sup>, SONJA TRIFUNOV<sup>1</sup>, SNEŽANA JOVIČIĆ<sup>1</sup>, SMILJKA ŠIMIĆ<sup>1</sup> and A. VUJIĆ<sup>1\*</sup>

<sup>1</sup>Department of Biology and Ecology, Faculty of Science, University of Novi Sad, 21000 Novi Sad, Serbia

<sup>2</sup>Department of Geography, Tourism and Hotel Management, Faculty of Science, University of Novi Sad, 21000 Novi Sad, Serbia

**Abstract** - Seven species of the genus *Pipiza*, collected throughout the southern and western Balkans, were used for the analysis of habitat preferences and potential geographical distribution on the Balkan Peninsula. The analyzed species show a wide and uneven distribution across the delineated geographical-biogeographical regions. The highest number of species noted is from two regions – the Dinaric mountain chain and the Pannonian and subpannonian regions (seven and six). Land cover patch analysis revealed that forests dominate the landscape surroundings of the analyzed species. “Presence-only models” developed by Maxent support the understanding of the distribution and ecology of each analyzed species. The low probability values of current potential distribution correspond to large non-forested and fragmented forest areas, where, on the other hand, relatively high probabilities overlap with areas of deciduous forests across the peninsula. Results confirm species preference to forest landscapes and emphasize the need for local scale analysis. The studies are of importance in developing regional monitoring schemes and conservation strategies.

**Key words:** Hoverflies, *Pipiza*, land cover, Balkan, Maxent, distribution, modeling.

### INTRODUCTION

The monophyletic tribe Pipizini (Diptera, Syrphidae) comprises 6 genera with approximately 63 species in Europe. The genus *Pipiza* is in a broader sense confined to the Holarctic region, whereas in the Palaearctic, according to the catalogue of Palaearctic Diptera (Peck, 1988), 17 species are present. As for the European species belonging to the genus *Pipiza*, a recent taxonomic revision listed by Vujić et al. (2013) reveals 12 European species; *Pipiza accola* Violenkov, 1985; *Pipiza austriaca* Meigen, 1822; *Pipiza carbonaria* Meigen, 1822; *Pipiza fasciata* Meigen, 1822; *Pipiza festiva* Meigen, 1822; *Pipiza laurusi* Vujić & Stahls 2013; *Pipiza luteibarba* Vujić, Radenković &

Polić, 2008; *Pipiza luteitarsis* Zetterstedt, 1843; *Pipiza lugubris* Fabricius, 1775; *Pipiza noctiluca* (Linnaeus, 1758); *Pipiza notata* Meigen, 1822; and *Pipiza quadrimaculata* (Panzer, 1804). Hoverflies as pollinators are important members of ecosystem communities and crucial for the maintenance of the vegetation cover in terrestrial ecosystems (Potts et al., 2010). The analysis of potential pollinator frequencies and species specializations in pollination (both of plants and animals) by Fenster et al. (2004), confirmed that 75% (207 out of 278) of the investigated plant taxa were specialized for a specific functional group of species for pollination. According to these specializations, potential pollinators, necessary to sustain a system's viability, are classified in 9 functional

groups: long-tongued bee, short-tongued bee, other Hymenoptera, Diptera, Coleoptera, Lepidoptera, Hemiptera, Neuroptera and birds (Robertson, 1928). Except for a few groups thoroughly investigated in some parts of Europe (e.g. United Kingdom, Holland; Biesmeijer, 2006), the extended knowledge of pollinators, especially non-*Apis* pollinators, remains deficient (Potts et al., 2011), mainly in the context of their ecology and distribution. According to NRC (2006), environmental changes such as habitat fragmentation and habitat loss influence the functional diversity of pollinators and animal-pollinated plants but interactive effects are not yet fully understood (Schweiger et al., 2011).

The recent revision of the genus *Pipiza* and resolved taxonomic issues by Vujić et al. (2013) highlighted the fact that the ecology of species of the genus *Pipiza* and factors that shaped their distribution are mainly unstudied and scant. Based on this study, 10 species are present on the Balkan Peninsula. The Balkan region is characterized by diverse and complex geographic and bio-geographical structure as a result of its turbulent geological history, variety of morphological and climatic features (Cvijić, 1904; Stanković, 1960; Savić, 2008). Bioregions, for the Balkans as a whole, are characterized by broad, landscape-scale natural features and environmental processes capturing the large-scale geographical patterns across the peninsula (Matvejev 1976; Savić, 2008). The remarkable richness of biodiversity is illustrated by the endemic and relict hoverfly fauna (Šimić et al., 1999). Two species of the genus *Pipiza* from the Balkan Peninsula, *P. luteibarba* and the newly discovered species *P. laurusi*, are endemic, distributed in fragile and endangered ecosystems, and because of this, *P. luteibarba* is regarded as a candidate for the European Red List (Speight, M., pers. comm.).

In recent years, modeling methods using the data on species occurrence and environmental covariates, have been proliferating, greatly facilitating the understanding, as well as prediction of the geographic distribution of species (Vargas et al., 2004; Elith et al., 2006). The results from studies taking the modeling approach are deemed to be of high importance and

find a wide application, for example in conservation planning, monitoring schemes, biodiversity assessments, habitat management, restoration, prediction of the effects of environmental changes on species and ecosystems etc. Predictive modeling of a species geographic distributions with Maxent (Philips et al., 2006) that requires “presence-only” species occurrence data and environmental data to estimate the potential distribution, i.e. prediction of relative suitability (Philips et al., 2006), has been used for a wide range of studies: species richness, estimation of the extent of occurrence, quality of protection of rare species, invasive species, climate change effects on species distribution, endemism hotspots (see Franklin, 2010).

The aim of this paper is to present occurrence data of species of the genus *Pipiza*; to describe landscape-based habitat preference on the CORINE land cover patches, and to determine the potential distribution with SDM techniques. Such information is of great importance for future regional monitoring schemes and conservation strategy.

## MATERIALS AND METHODS

### *Study area*

The Balkan Peninsula covers 490,000 km<sup>2</sup> and is highly variable in terms of habitat conditions. The geographical region on the Balkan Peninsula as defined by Matvejev (1976) that was taken into consideration for the analysis were Pannonian and sub-pannonian hilly regions, Moesian hilly regions, the Mediterranean (Adriatic and Aegean) shoreline, Eastern Alps, Northern Dinarides, Southern Dinarides, Carpathians, Balkan range (Stara Planina) and the Rilo-Rhodopes. The large-scale geographical patterns across the peninsula are characterized by a wide range of habitat conditions. Here, two terrestrial biogeographical regions are confronted: the Mediterranean and Temperate European regions. According to Matvejev (1976), along with complex geographic features portraying assembles of dominant biomes are the submediterranean mainly oak deciduous forests, steppes and forest steppes, oro-Mediterranean

mountains, mountain forests on rocky slopes and gorges, Mediterranean evergreen woodlands and maquis, European mainly deciduous forests, European mainly coniferous forests of boreal type and high mountains rocks, snow patches, tundras and pastures of Alpine and high Nordic types.

The sampling localities spread across the western and southern Balkan area, with focus on mountain forests, forest edges and streams (Table 1). Species distribution across biogeographical regions was tested with a Chi square test (Statsoft 10).

#### *Data source*

The material used in this study was collected over the course of more than 15 years of investigations (1985-2000) of the genus *Pipiza* hoverflies on the Balkan Peninsula. The collection is deposited at the Department of Biology and Ecology, Faculty of Natural Sciences, University of Novi Sad (Serbia). Sampling was done through several visits following the seasonal timescale of the species (spring and summer) and using the standard method (census) for collecting and preparation of hoverflies. According to data availability presented in Table 2, 7 out of 12 European species of the genus *Pipiza* were used in this study; 2 out of 12 European *Pipiza* species are not present on the Balkan Peninsula (*P. accola* and *P. lugubris*).

#### *Land cover patch classification*

The classification of land cover patches was based on the Corine Land Cover (CLC 2000), made in the scale of 1: 100,000 and with a minimal mapping area of 25 ha. The standard CLC nomenclature includes 44 land cover classes, grouped in a three-level hierarchy. A circle 2 km in radius was delineated around each occurrence point, taken to be the full range of the individual specimen and longest dispersal move (according to experts' field experience). For the estimation of each land-use type portion within the delineated circles, all land cover classes were used for the calculation of class area – equals the sum of the areas of all land cover patches (units of equal ha); total area – equals the area of all land cover patches

(units of equal ha) and number of patches – equals the number of land cover patches within each type (class) of patch.

#### *Modeling methods*

Species distribution modeling (SDM) combines data on species occurrence with environmental variables to create a model of species' ecological niche requirements (Franklin et al., 2010), and projecting the model into geographic space presents the species' potential distribution (Philips et al., 2006). The modeling software MAXENT calculates the range of species in order to find the species distribution of maximum entropy – closest to the uniform (Philips et al., 2006; Philips and Dudik, 2008). Calibration (training) data was generated by random selection of 75% occurrence records and 25% for testing. The chosen Maxent default settings were: (maximum number of iterations = 500, convergence threshold =  $10^{-5}$ , regularization multiplier = 1.0, maximum number of background points = 10000). Cross-validation replicates were done for each species. All data points were entered into the Geographic Information System DIVA-GIS 5.2 (Hijmans et al., 2005). Based on the species preferences, by using Worldclim variables, 2.5 arc-minutes resolution (Hijmans et al., 2005) and elevation, the area of species distributions were modeled and projected on the Balkan Peninsula. Covariates were first tested for multicollinearity with VIF (various inflation factors) analysis in R package. Selected covariates for SDM analysis are shown in Table 3.

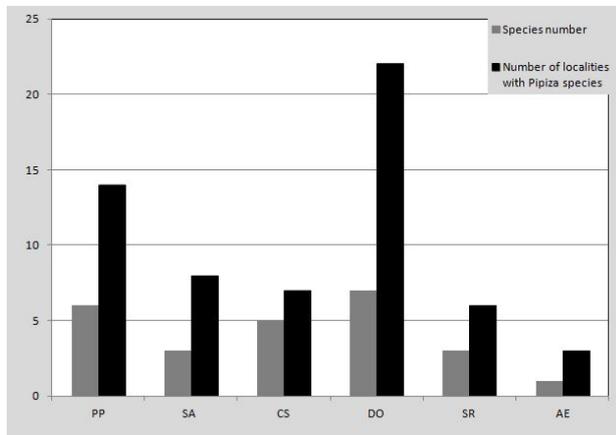
For the evaluation statistics, the "area under the receiver operating curve" (AUC) index was used to assess the model performance. It provides a single measure of overall accuracy and relates true positive proportion and false negative proportion to a wide range of threshold levels (Pearce and Ferrier, 2000). In order to diminish spatial autocorrelation effects we merged a polygon for background data by taking into consideration the environmental and geographical range of the species and research area extent with its available environmental condition. Background data were selected from an area of 100 km in radius

around every occurrence point and then merged to one polygon. This polygon served for background data sampling because it represents geographical and environmental space with the same bias as the occurrence data (Philips et al., 2009). The AUC values ranges from 0.5 (randomness) to 1 (perfect discrimination). The spatial analysis yielded seven maps (one for each species) presenting the potential species distribution on the Balkan Peninsula.

## RESULTS

### Data distribution

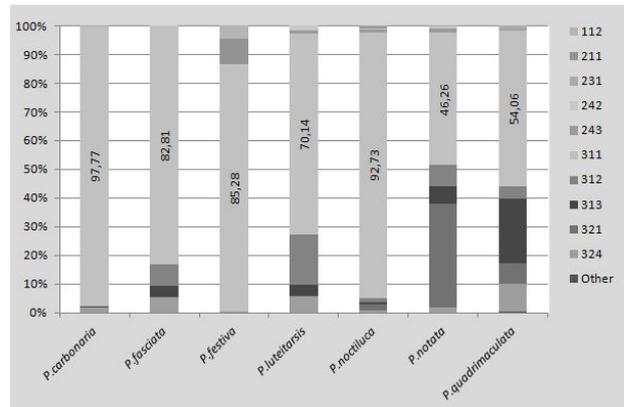
The number of species is unevenly distributed (Chi-Square = 6, 25;  $p = 0, 28$ ) across the geographical-biogeographical regions on the southern and western Balkan Peninsula, with the highest diversity on the Dinaric mountain chain, and Pannonian and subpannonian regions (Fig. 1).



**Fig. 1.** Sample distribution of *Pipiza* species throughout the geographical-biogeographical regions of Balkan defined by Matvejev (1969): PP - Pannonian and subpannonian region, SA - Eastern Alps, CS - Carpathians, DO – North and South Dinaric mountains, SR - Stara planina (Balkan range) Rilo-Rhodopes-Moesian hilly areas, AE - Mediterranean (Adriatic and Aegean).

### Land cover patch analysis

Results of land cover patch analysis are summarized for seven analyzed species of the genus *Pipiza* in Fig. 2.



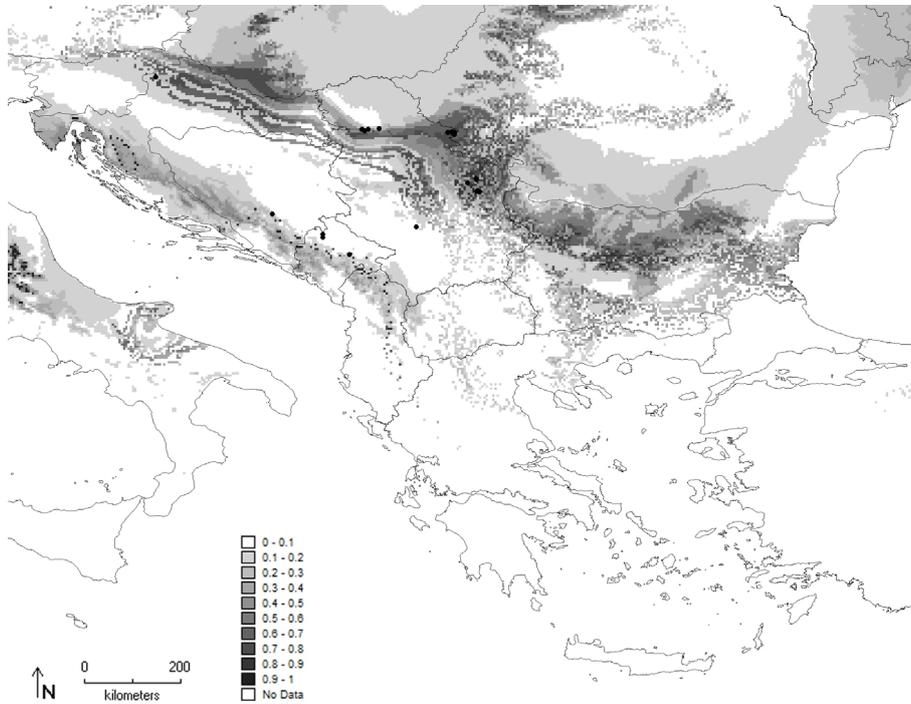
**Fig. 2.** Share of different land cover class in *Pipiza* species occurrence points surrounding, with percentage of deciduous forests. Only class with a share of >1% of the total surface of any species occurrence points surrounding are listed: 112 - Discontinuous urban fabric, 211 - Non-irrigated arable land, 231 - Pastures, 242 - Complex cultivation patterns, 243 - Land principally occupied by agriculture, with significant areas of natural vegetation, 311 - Broad-leaved (deciduous) forest, 312 - Coniferous forest, 313 - Mixed forest, 321 - Natural grasslands, 324 - Transitional woodland-shrub, Other - Other.

*Pipiza carbonaria.* Landscape around the occurrence points is strongly dominated by deciduous forests, (covering 98% of the analyzed surrounding surface) and transitional woodland-shrub that covers slightly more than 1%.

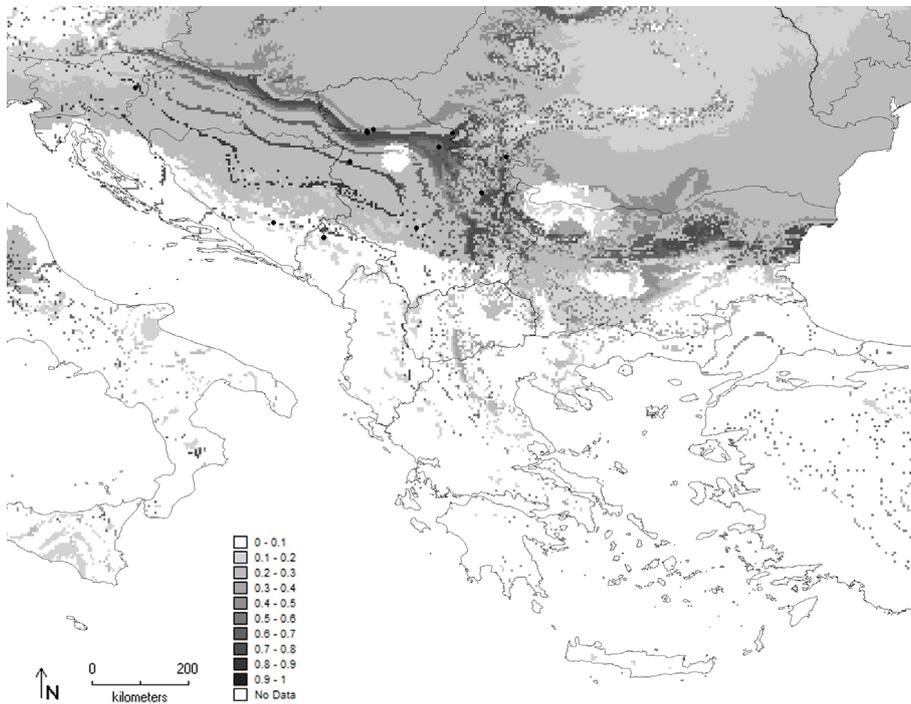
*Pipiza fasciata.* Deciduous forests are the dominant land cover type in the surrounding of the occurrence points, covering 83%, followed by coniferous forests (8%), transitional woodland-shrub (5%) and mixed forests (2%).

*Pipiza festiva.* Deciduous forests cover the largest part of the area surrounding the occurrence points (85%). Open and semi-open patches of land cover, non-irrigated arable land, discontinuous urban fabric and complex cultivation pattern are also well represented (9%, 5% and 1%, respectively).

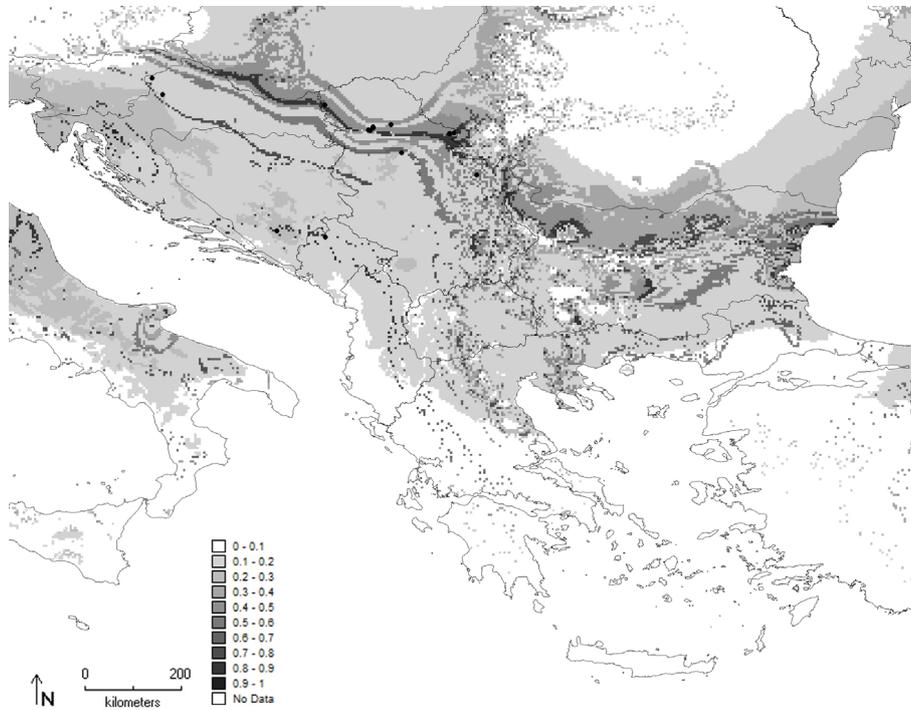
*Pipiza luteitarsis.* The surrounding area of the occurrence points is dominated by deciduous forests (70%), with a significant presence of coniferous and mixed forests (17% and 4%, respectively), along with transitional woodland-shrub (6%).



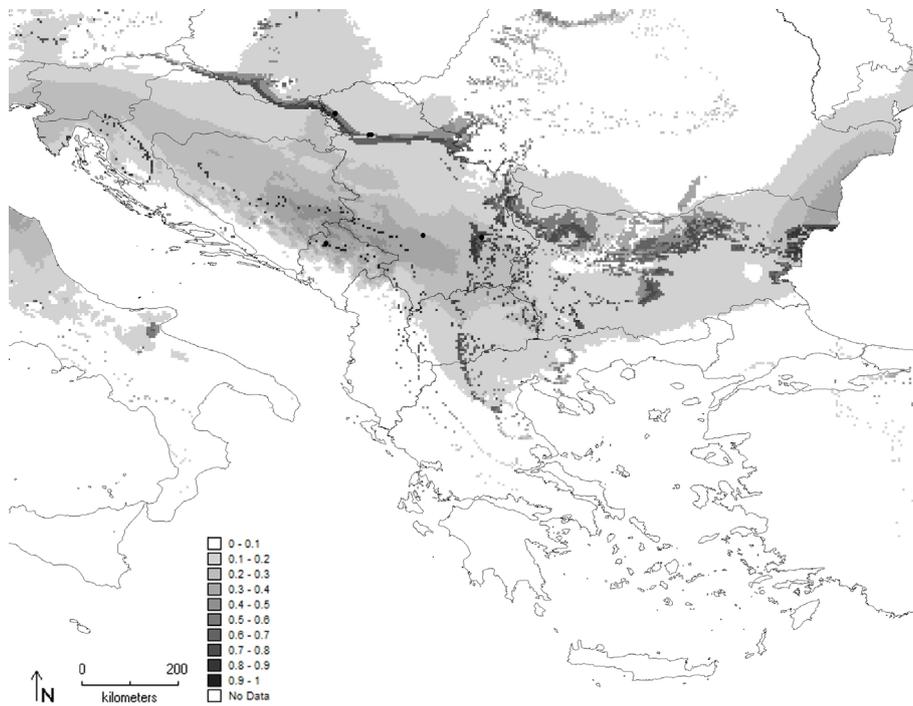
**Fig. 3.** Maximum entropy model developed for *P. carbonaria* on the Balkan Peninsula. Different shades of gray represent the percentage of the probability of occurrence.



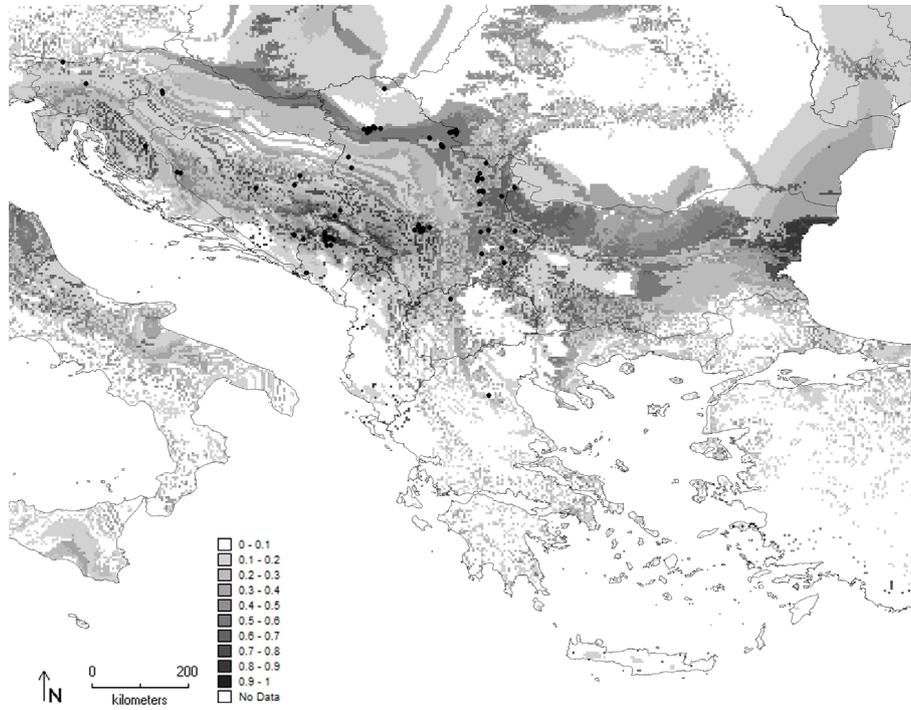
**Fig. 4.** Maximum entropy model developed for *P. fasciata* on the Balkan Peninsula. Different shades of gray represent the percentage of the probability of occurrence.



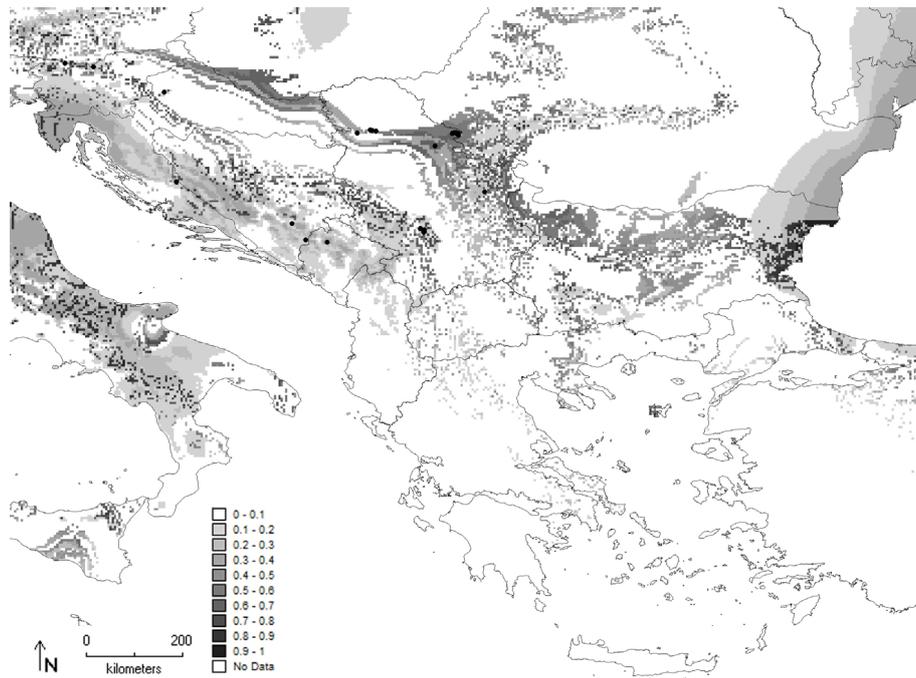
**Fig. 5.** Maximum entropy model developed for *P. festiva* on the Balkan Peninsula. Different shades of gray represent the percentage of the probability of occurrence.



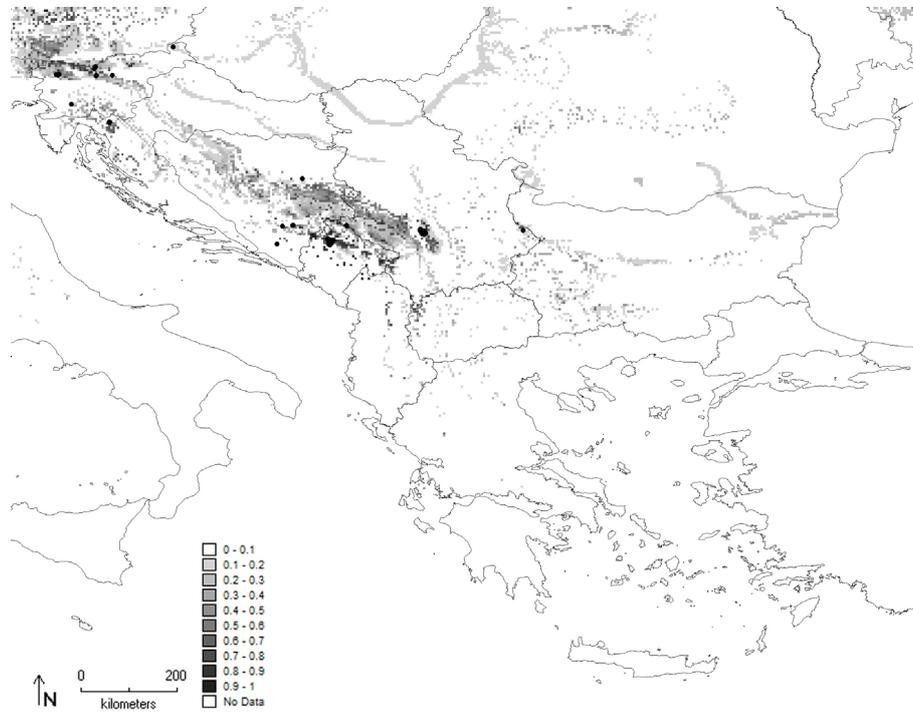
**Fig. 6.** Maximum entropy model developed for *P. luteitarsis* on the Balkan Peninsula. Different shades of gray represent the percentage of the probability of occurrence.



**Fig. 7.** Maximum entropy model developed for *P. noctiluca* on the Balkan Peninsula. Different shades of gray represent the percentage of the probability of occurrence.



**Fig. 8.** Maximum entropy model developed for *P. notata* on the Balkan Peninsula. Different shades of gray represent the percentage of the probability of occurrence.



**Fig. 9.** Maximum entropy model developed for *P. quadrimaculata* on the Balkan Peninsula. Different shades of gray represent the percentage of the probability of occurrence.

*Pipiza noctiluca*. The surroundings of the occurrence points are highly dominated by deciduous forests (93%). Furthermore, another 13 types of land cover classes were present, showing a wide range of habitats within the landscape matrix occupied by this species.

*Pipiza notata*. Although area surrounding the occurrence points was dominated by deciduous forest (46%), the percentage of other land cover types was also significant and slightly higher than in cases of other species. Natural grasslands, followed by coniferous and mixed forests, transitional woodland-shrub, and a few types of mosaic cultivated landscape, covered a significant portion of the surrounding area (36%, 7%, 6%, 2% and 3% respectively).

*Pipiza quadrimaculata*. The occurrence points in the surrounding area are dominated by deciduous forests (54%), followed by mixed forests (23%). Percentage of area under transitional woodland-shrub

(10%), natural grassland (7%), coniferous forests (4%) and pastures (1%) is also significant.

#### *Distribution modeling*

The most important variable for *Pipiza* species was elevation (alt), and the jackknife tests showed that eliminating it from the analyses dramatically lowers the predictive power of the models. Temperature and precipitation variables followed by their importance for each species of the genus *Pipiza*, respectively, in slightly different combinations. The remaining climatic variables were only marginally important and removing them did not severely affect the models' performance. The contribution of covariates used for the analysis of distribution of each species is presented in Table 4.

Training AUC was 0.920 for *P. quadrimaculata*; 0.871 for *P. notata*; 0.847 for *P. carbonaria*; 0.820 for *P. luteitarsis*; 0.808 for *P. faciata*; 0.800 for *P. festiva*;

**Table 1.** Sampling localities and number of specimen within bio-geographical regions

	Pannonian and Subpannonian	Eastern Alps	Carpathians	North and South Dinaric mountains	Stara planina (Balkan range), Rilo-Rhodopes, Moesian hilly areas	Mediterranean (Adriatic and Aegean)
<i>P. carbonaria</i>	Localities: 2 Specimen: 22		Localities: 4 Specimen: 17	Localities: 5 Specimen: 6		
<i>P. fasciata</i>	Localities: 5 Specimen: 10		Localities: 3 Specimen: 6	Localities: 3 Specimen: 7		
<i>P. festiva</i>	Localities: 7 Specimen: 19		Localities: 1 Specimen: 1	Localities: 3 Specimen: 4		
<i>P. luteitarsis</i>	Localities: 3 Specimen: 7			Localities: 2 Specimen: 18	Localities: 1 Specimen: 6	
<i>P. noctiluca</i>	Localities: 9 Specimen: 83	Localities: 1 Specimen: 4	Localities: 4 Specimen: 13	Localities: 13 Specimen: 68	Localities: 6 Specimen: 8	Localities: 3 Specimen: 7
<i>P. notata</i>	Localities: 3 Specimen: 27	Localities: 2 Specimen: 3	Localities: 1 Specimen: 1	Localities: 5 Specimen: 23		
<i>P. quadrimaculata</i>		Localities: 7 Specimen: 14		Localities: 8 Specimen: 209	Localities: 1 Specimen: 1	
Total number of specimens	168	21	38	335	15	10
Total number of localities	14	8	7	22	6	3
Total number of species	6	3	5	7	3	1

and 0.795 for *P. noctiluca*. The geographical distribution of the Maxent-predicted suitability for the seven species in 2.5 arc minutes across the Balkan Peninsula are described in more detail below and are presented in Fig. 3-9.

#### *Geographical distribution of species across the Balkan Peninsula : Pipiza carbonaria*

The obtained distribution model projects the highest presence probabilities for borders of the Pannonian plain, Pannonian mountains, Carpathian foothills, Mt. Stara planina (Balkan range), and some small isolated patches of the Dinaric mountain chain. The

lowest presence probabilities are projected for most of the Pannonian plain, eastern parts of the Dinaric mountain chain, most of the FYR Macedonia, as well as the Mediterranean part of the Balkans (Fig. 3).

#### *Pipiza fasciata*

The highest presence probabilities are projected for the Pannonian mountains, the Danube and Drava river valleys, the eastern borders of the Pannonian plain, Carpathian foothills, mountains of southeastern Serbia, Mt. Stara planina (Balkan range), Strandža Mountain, and parts of the Dinaric mountain chain. The lowest presence probabilities are projected for

**Table 2.** Species modeled for the analysis

Speciment	Number
<i>P. carbonaria</i>	47
<i>P. fasciata</i>	27
<i>P. festiva</i>	25
<i>P. luteitarsis</i>	31
<i>P. noctiluca</i>	172
<i>P. notata</i>	65
<i>P. quadrimaculata</i>	220

parts of the Pannonian plain, the Danube valley in the eastern part of the Djerdap gorge, the western part of the Dinaric mountain chain and the entire southern and Mediterranean Balkan region, showing the southern border of the species range (Fig. 4).

#### *Pipiza festiva*

The highest presence probabilities are projected for the Pannonian mountains, western Pannonian borders, the Sava, Danube and Morava river valleys, smaller patches within the Dinaric mountain chain, the Carpathian foothills, the Rilo-Rhodopes, Mts. Strandža and Stara Planina (northern Balkan foothills). The lowest probabilities of presence are projected for the Carpathian mountain chain, a large part of the Dinaric mountain chain, the highest parts of Rilo-Rhodopes and Mt. Stara planina (Balkan

range), as well as southern parts of the Mediterranean Balkan, showing the southern borders of the species range (Fig. 5).

#### *Pipiza luteitarsis*

The highest probabilities of presence are projected for the Pannonian mountains, parts of the Danube and Drava river valleys, hilly mountains in eastern and central Serbia, parts of Mts. Stara planina (Balkan range), Rilo-Rhodopes, Strandža, Galičica, Kožuf and the Dinaric mountain chain. The lowest presence probabilities are projected for the whole Carpathian region, parts of the Pannonian plain and the whole Mediterranean and southern Balkan region (Fig. 6).

#### *Pipiza noctiluca*

The highest presence probabilities are projected for the Pannonian mountains, the Danube and Drava river valleys, hilly mountains of eastern Serbia, parts of the Rilo-Rhodopes, Mts. Stara planina (Balkan range), Strandža, Galičica, Kožuf and the Dinaric mountain chain. The lowest presence probabilities are projected for parts of the Pannonian plain, higher parts of the Carpathian and Rila-Rhodopes mountains, as well as a large part of the Mediterranean Balkan region (Fig. 7).

**Table 3.** Selected covariats for the SDM analysis

	<i>P. carbonaria</i>	<i>P. fasciata</i>	<i>P. festiva</i>	<i>P. luteitarsis</i>	<i>P. noctiluca</i>	<i>P. notata</i>	<i>P. quadrimaculata</i>
Bio 2*	x		x		x	x	
Bio 6*		x	x		x		x
Bio 8*							x
Bio 9*		x					x
Bio 15*	x	x	x	x	x	x	
Bio 18*	x	x	x	x	x	x	x
Elevation	x	x	x	x	x	x	x

\* Bio 2 - Mean Diurnal Range; Bio 6 - Min Temperature of Coldest Month; Bio 8 - Mean Temperature of Wettest Quarter; Bio 9 - Mean Temperature of Driest Quarter; Bio 15 - Precipitation Seasonality; Bio 18 - Precipitation of Warmest Quarter.

**Table 4.** Covariates used for distribution modeling

Species	Covariates	Percent contribution	Permutation importance
<i>P. carbonaria</i>	alt	57.1	66.9
	bio 18	25.2	14.6
	bio 15	16.2	15.5
	bio2	1.5	2.9
<i>P. faciata</i>	alt	75.5	71.7
	bio 9	23.7	28.3
	bio 6	0.6	0
	bio 18	0.2	0
<i>P. festiva</i>	alt	93	88.5
	bio 6	0.6	0
	bio 18	0.2	0
<i>P. luteitarsis</i>	alt	75.5	83.1
	bio 15	24.5	16.9
<i>P. noctiluca</i>	alt	75.3	72
	bio 15	19.3	13.6
	bio 2	3	10.9
	bio 6	1.6	0
	bio 18	0.9	3.5
<i>P. notata</i>	alt	83.2	75.6
	bio 2	14.2	24.4
	bio 15	2.6	0
<i>P. quadrimaculata</i>	alt	48.5	76.6
	bio 15	25.5	13.7
	bio 6	20.9	6.8
	bio 9	4.9	1.7
	bio 8	0.1	1.2

*P. noctiluca* is the only species of the *Pipiza* genus found in a few different localities in the Mediterranean region of the Balkan Peninsula. Its potential distribution significantly spreads across the Mediterranean Balkan region compared to other species of *Pipiza*.

#### *Pipiza notata*

The highest probability presence is projected for the eastern border of the Pannonian plain, the Danube and Drava river valleys, the Carpathian foothills, parts of the Dinaric mountain chain, Mts. Stara planina (Balkan range), Rilo-Rhodopes and Strandža. The

lowest probabilities are projected for a large part of the Pannonian plain, the eastern Dinaric mountain chain and western borders of the Pannonian plain, Carpathians, a larger part of Bulgaria and most of the southern and Mediterranean Balkan region. The projected distribution probably illustrates the southern border of species range (Fig. 8).

#### *Pipiza quadrimaculata*

The highest presence probabilities are projected for the southern and southeastern Dinaric mountain chain, the Alpine region, a small part of Mt. Stara

planina (Balkan range) and the Rilo-Rhodopes, Mt. Šar planina and the highest mountain areas of Greece and FYR Macedonia. The lowest presence probabilities are projected for a large part of the hilly regions, foothills and lowland area on the Balkan Peninsula (Fig. 9).

## DISCUSSION

The presented results show that the *Pipiza* genus is widely and unevenly distributed throughout the southern and western Balkan region. For most species of the genus (except *P. noctiluca*), the Balkan Peninsula represents the southern border of its range (Speight, 2012). Research localities include a number of ecological variations, characteristic for the Balkans (Adamović 1909; Matvejev, 1976; Stevanović and Stevanović, 1995; Stevanović et al., 1995), so most could be considered as a full environmental range (in terms of climate, topography and habitat types) of *Pipiza* species in southern and western Balkans.

The distribution of *Pipiza* species in the western and southern Balkans is mostly associated with the distribution of European, mainly deciduous, forests. The results confirm this to a great degree with most of the analyzed species occurring in the submediterranean zone of deciduous forests and mountain coniferous and mixed forests. Only one species (*P. noctiluca*) is widely distributed and common across the Mediterranean part of the researched area. High mountains with alpine ecosystems have a low diversity of the species, with only one species regularly present above the forest zone (*P. quadrimaculata*) (Speight, 2012). In contrast, six species were recorded in the Pannonian and subpannonian mountains (Fruška gora and Vršacke planine), and four species in the lowland forests of the Pannonian biogeographical region. The Pannonian mountains (Fruška gora and Vršacke planine) are covered by diverse forests, including oak, beech, hornbeam and lime communities (e.g. Janković and Mišić, 1980; Sučević, 1962; Butorac, 1992), and, obviously, represent a suitable habitat for most *Pipiza* species, and could be considered as the center of *Pipiza* species diversity. Fruška gora and Vršacke planine are also well-documented

centers of hoverfly diversity in the Pannonian part of Serbia (Vujić and Glumac 1992, Vujić and Šimić 1994, Nedeljković et al., 2008, Nedeljković et al., 2009).

Land cover patch analysis revealed that forests dominate in the landscapes surrounding the occurrence points of all analyzed species. Besides forests, *Pipiza* species occupy on forest edges, bushes, near-water localities, orchards, gardens and plantations (Speight, 2012), important in the life cycle of hoverflies (breeding, feeding sites, sun basking, etc.).

Results show that species of the genus *Pipiza* on the Balkan Peninsula generally depend on forest landscapes with natural grasslands, arable land, orchards, streams, etc.

*Pipiza carbonaria* is a mainly forest and forest-edge species, with a preference for oak forests (Speight, 2012), which is also presented in our analysis. Oak forests are widely distributed in the western and southern Balkans (e.g. Stevanović et al., 1995; Matvejev, 1961).

*Pipiza fasciata* mostly occupies diverse forests dominated by oak, beech and spruce (Speight, 2012). The analysis revealed that in the western and southern Balkan region this species occurs mainly in deciduous forests, similar to its representatives in the central and northern European range (Speight, 2012).

*Pipiza festiva* is generally a lowland- and floodplain-forest species, also occupying mosaic landscapes (Speight, 2012). The results confirm species preference for floodplain forests, as well as for other lowland forest types. The presence of open and semi-open land cover patches may be a consequence of the severe fragmentation of lowland forests in the western and southern Balkans (Stevanović, 1995) or even illustrate a certain preference of the species to suitable mosaic habitats.

*Pipiza luteitarsis* occupies similar types of habitat as its representatives in other parts of its European range, where the specimens are most often found in

beech forests and acidophilous oak forests, as well as in old and overgrown parks and gardens (Speight, 2012). A large portion of coniferous and mixed forests, not a common habitat for *P. luteitarsis* in Europe, around the occurrence points can be explained by the fact that the elevation zone of beech and coniferous forest in Balkan mountains is often very narrow and with wide transition zones between them (Matvejev, 1961).

*Pipiza noctiluca* could be considered a typical deciduous forest species in the western and southern Balkan region. It occurs in a wide variety of habitats, from diverse forests to plantations of conifer and deciduous trees, orchards, gardens, hedges and water edges (Speight, 2012). Most of these habitats appear in the surrounding of the occurrence points, but in a somewhat smaller percentage than expected. This may be explained by the slightly different habitat preferences of the species in the western and southern Balkan region.

Field observations usually confirm that *P. notata* and *P. noctiluca* often occur at the same localities and, generally, in similar habitats. The results of this study, however, suggest greater differences in habitat preferences of the two species in the western and southern Balkan region. In the case of this study, however, the land cover analysis showed that populations of *P. notata* occupy a wider range of landscapes dominated by deciduous forests, and to a lesser extent the types of landscapes occupied by *P. noctiluca*. Hence, the results suggest a greater difference in the habitat preferences of the two species *P. notata* and *P. noctiluca* in the western and southern Balkan region.

Mountain coniferous and mixed forests, especially moist beech and spruce forests are a typical habitat of the species *P. quadrimaculata* (Speight, 2012). The results confirm that in the western and southern Balkan region, *P. quadrimaculata* is also a typical mountain species occurring in various types of mountain forests, as well as in other habitat types common for the mountain zone above the forest line. The relatively small percentage of coniferous forests and at the same time much higher percentage of deciduous

forests in the surrounding of the occurrence points could be explained by the narrow, often depleted or even completely destroyed zone of coniferous forests in Balkan mountains (Matvejev, 1961); beech forests often represent the highest forest zone.

*Pipiza* species are absent in unforested areas or areas without larger forest areas, as is the case in a large part of the Pannonian plain, as well as in severely fragmented deciduous forests. On the other hand, most specimens were collected on few well-researched areas, where all or all but one species were found: Fruška gora, Vršачke planine, Kopaonik and Durmitor. These sites contain large, continuous, well-preserved and complex deciduous forest landscapes (e.g. Mišić and Popović, 1954; Sučević, 1962; Janković and Mišić, 1980; Lakušić et al., 1984) and are legally protected as national parks or under other protected area categories.

The highest AUC values were obtained for *P. quadrimaculata*, the species with the highest number of occurrence points and quite specific ecological preferences (e.g., altitudes), connoting high, reliable predictive capacity gain (e.g. AUC > 0.75 is considered as acceptable). The lowest AUC value for *P. noctiluca* was probably due to the highest spatial autocorrelation of sampling points, which was not resolved with the bias grid file used. This can also be explained by the fact that the model calculation for generalists, occurring in a less restricted range of ecological conditions than specialists do, tends to provide less accuracy (Elith et al., 2006).

Among the covariates, altitude had the greatest contribution in developing models of distribution of all analyzed species (Table 5). Altitude influences the whole range of ecological conditions, among them vegetation cover (Huggett, 2004), which influences hoverfly distribution patterns. Although it is sometimes excluded from analyses because of its strong correlation with climate variables (e.g. Telleria et al., 2012), more often it is recognized as one of the most significant predicting covariates (e.g. Bosso et al., *Tin press*; Hu et al., 2010). On the Balkan Peninsula, altitude defines vegetation

zones (Matvejev, 1976), revealed by the divergent forest types inhabited by different *Pipiza* species (Speight 2012). The existing correlation between the distribution of insect species and distribution of elevations with specific forest types has already been shown in previous research (e.g. Bosso et al., in press). Climatic covariates used for the analysis did not show any universal pattern of contribution to the models of potential distribution of different *Pipiza* species (Table 5).

According to the potential distribution models, the deciduous forests of the subpannonian part of the Balkan Peninsula, as well as of the Carpathian foothills in the east of Serbia, should be inhabited by most of the *Pipiza* species. For these areas, the distribution models predict the presence with high probability values. The original vegetation of these areas is primarily oak forest (Matvejev, 1976). The forested areas of subpannonian hills are confirmed as highly suitable habitats for genus *Pipiza*, and were previously recognized as localities with a high diversity of the genus *Cheilosia*, which has similar habitat preferences to the genus *Pipiza* (Vujić, 1996).

Although all of the species from the genus *Pipiza* have been found in the Dinaric mountain chain, the current distribution model predicts moderately low probabilities of presence of most of the species in the larger part of this area (except for mountain species of *P. quadrimaculata* and widely distributed *P. noctiluca*). The low probabilities of presence were not expected because of the well-known fact that the Dinaric mountain chain is occupied by well-preserved temperate forests ([www.worldwildlife.org/biomes](http://www.worldwildlife.org/biomes)). Additionally, many data on *Pipiza* species distribution originate from the mountains of the Dinaric chain (e.g., Durmitor). Finally, the Dinaric mountain chain is known for its greatest species richness of *Cheilosia* (Vujić, 1996).

For most species (*P. carbonaria*, *P. fasciata*, *P. festiva*, *P. luteitarsis*, *P. notata*) the models showed high presence probabilities in small and very isolated patches in different parts of the Dinaric mountain chain, which could mean that *Pipiza* species occur

only in very specific parts of the area with unique habitat features, such as canyons and valleys with warmer microclimates and with presence of forests typical for lower altitudes. In order to gain insight into the ecology and distribution of *Pipiza* species, the climatic and topographic variables necessary for the analysis at a regional scale would be missed at a local scale (Lomba et al., 2010). On the other hand, further detailed local scale research of hoverflies population viability should be focused on Dinaric mountain chain forests, especially on smaller patches with specific environmental conditions.

It is clear that members of the *Pipiza* genus are typical forest-landscape species; nonetheless, their ecology is largely unexamined. More sophisticated analysis of habitats, plant communities and their spatial relations in ecosystems inhabited by the *Pipiza* genus would be needed for a comprehensive understanding of the ecological requirements of this group. Especially important in the research of the ecology of *Pipiza* species is the information on the plant species they feed on. *Pipiza* species are typical pollinators of flowers (e.g. *Stellaria* sp.; *Smyrniium perfoliatum*), so that obtaining knowledge about their role in ecosystems as well as of their importance for a particular plant species is very desirable. Finally, taking into account the diversity of ecosystems and plant communities, the Balkan Peninsula could be a very important area for future ecological research. Such information could also be of importance in developing future regional monitoring schemes and conservation strategies.

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