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Prime Hoverfly (Insecta: Diptera: Syrphidae) Areas (PHA) as a conservation tool in Serbia

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ABSTRACT

Hoverflies are a valuable group of species in need of conservation and monitoring, due to their large contribution to pollination, biological control, and role as indicators of ecosystem change. Though hoverflies are a well-known group of insects, there has been little documentation of their current conservation status. Using long-term hoverfly monitoring data, this study reports on their prevalence in Serbia and presents priority areas for their conservation. An expert-generated, criteria-driven approach was used to identify core areas for conservation of hoverflies, named Prime Hoverfly Areas (PHA); 34% of the identified area lies outside of a national protection area (NPA) network. A systematic conservation approach (gap and irreplaceability analysis) was then applied to evaluate: 1) sufficiency of the NPA for hoverfly conservation, and 2) degree of improvement in hoverfly conservation conferred by the expert-generated PHA network. The networks were evaluated for the achievement of predefined representation targets for each of the 155 hoverfly species identified as important for conservation. We found that the NPA network is insufficient, as it does not cover the ranges of 18% of considered species. The area of the proposed PHA outside of the NPA is small (1.36% of the national territory), but its protection would greatly improve hoverfly conservation by increasing the inclusion of hoverfly habitats for previously unprotected species and by including hoverfly biodiversity hot spots. The suggested PHA network was then compared to a similarly designed habitat network aimed to conserve butterflies. There was partial overlap between the two networks, highlighting the importance of considering multiple groups in planning comprehensive conservation strategies for pollinators.

1. Introduction

Establishing protected areas (PAs) is one of the oldest and most common biodiversity conservation strategies (Groom et al., 2006; Primack, 2008; Soulé, 1991). Over the last few decades, global efforts to increase the amount of land under legal protection have met with some success (Cabeza, 2013; Zimmerer et al., 2004). However, the contribution of PAs to the conservation of biodiversity has been questioned for several reasons. First, biodiversity is decreasing (Butchart et al., 2010) while management of protected areas remains highly variable (Naughton-Treves et al., 2005). Second, the habitats of various species do not always overlap with protected areas, especially for lesser known (or less charismatic) organisms, such as various groups of invertebrates (e.g. Bosso et al., 2012; Cardoso et al., 2011; D'Amen et al., 2013; Hernández-Manrique et al., 2012; Verovnik et al., 2011). This problem is compounded by the fact that biodiversity conservation aims within nature conservation policy initiatives are often focused on a very small number of species, with insufficient coverage of taxonomic and functional species groups. For example, in legal instruments such as the species protection Annexes of the EU Habitats Directive, major pollinator groups (bees and hoverflies) are absent. Finally, many protected areas were created for anthrocentric reasons (e.g. aesthetic, cultural, religious) rather than for improved biodiversity conservation (Oldfield et al., 2004).

To strengthen the conservation of underrepresented organisms and to encourage better designation of protected area networks, detailed inventory programmes have been initiated throughout the world that reveal new spaces in need of protection, including key biodiversity areas (Eken et al., 2004). Identification of important habitat areas has been completed for various species groups, using many different approaches and criteria for site choice. Generally, these methods for protected area identification can be labelled either 'scoring-based approaches' or 'complementarity approaches' (Zeydanlı et al., 2012). The most commonly applied protected area selection methodology is based on the concept of Important Bird Areas (IBA), where the selection of sites is criteria-driven, using a scoring-based approach. This approach has since been extended to other taxa, identifying important areas for species

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conservation, including Important Plant Areas (IPA) (Anderson, 2002) and Prime Butterfly Areas (PBA) in Europe (van Swaay and Warren, 2003, 2006). However, to date, the majority of protected area identification and establishment efforts have focused on well-researched charismatic species, while many other groups remain underrepresented. In order to increase representation of previously unconsidered but ecologically important species within established PA methodology, in the present study we use long-term monitoring data to propose priority areas for hoverfly conservation in Serbia.

Hoverflies are an important pollinator group (Inouye et al., 2015; Larson et al., 2001; Rader et al., 2015; Ssymank et al., 2009, 2008) and excellent ecosystem indicators, with a high number of different functional groups due to diverse larval ecology (Schweiger et al., 2007). In fact, hoverflies are one of the better studied groups of insects, especially in Europe where national faunas have been published for several countries (Bartsch et al., 2009a, 2009b; Haarto and Kerppola, 2007; Reemer et al., 2009; Stubbs and Falk, 2002; Torp, 1984), along with national and regional red lists (Cederberg et al., 2010; Doczkal et al., 1999; Farkač et al., 2005; Jentzsch, 1998; Ssymank and Doczkal, 1998; Ssymank et al., 2011; Stuke et al., 1998).

In Europe, hoverflies have been recognised as a threatened group (Biesmeijer et al., 2006; Speight, 2000, 1989; Speight et al., 2013) due to the pressing problem of pollinator decline. The European Union (EU) Project on Status and Trends of European Pollinators (STEP, http://www.step-project.net) (2010–2015) has initiated action for developing the European Red List of hoverfly species, which should be used in combination with data for butterflies and bees in developing a Red List of European pollinators (STEP, http://step-project.net). As a result of the 6th International Symposium on Syrphidae (2011) in Glasgow (UK), Martin Speight (2011, unpublished) prepared a list of 60 threatened European Syrphid hoverfly species from the 886 European hoverfly species in the Syrph the Net (StN) database (Speight, 2011) and suggested that they should be proposed for Annex II of the Habitats Directive (92/43/EEC), the EU directive aiming to ensure survival of Europe's most endangered and vulnerable species. Species listed in Annex II must have core areas of their habitat protected and managed in accordance with species ecological requirements (http://ec.europa.eu/environment/nature/conservation/species/habitats_dir_en.htm). There is, however, indirect protection of characteristic or typical species of Annex I habitats, which does cover some hoverflies. For Germany, these species are listed in the German Habitats Interpretation Manual (Ssymank et al., 1998), which is currently under revision for a new edition with extended information on characteristic species.

In Serbia, intensive and continuous studies of hoverfly fauna began in the 1950s (Glumac, 1955). Hoverflies have been a continual focus of Serbian research, which has improved our knowledge of their taxonomy, zoogeography, phylogeny and ecology, while also providing important insight into the complex history of the Serbian landscape. So far, more than 400 hoverfly species have been identified in Serbia (Glumac, 1972; Nedeljković, 2011; Radenković, 2008; Steenis et al., 2015; Vujić, 1997, 1999a; Vujić et al., 2013b; Vujić, unpublished), a large percentage of which are rare and endemic species (Claussen and Vujić, 1995, 1993; Nedeljković et al., 2013; Radenković et al., 2013; Smith and Vujić, 2007; Vujić, 1999a, 1999b, 1997, 1994a, 1994b, 1990; Vujić and Claussen, 2000, 1994a, 1994b; Vujić and Stuke, 1998; Vujić et al., 2013a, 2013b, 2008, 2004, 1999a, 1999b, 1995). This is in agreement with the complex geological history and diverse habitat present in the Balkan Peninsula, which creates favourable conditions for rich biodiversity.

Two important legal achievements have resulted from this extensive research and conservation efforts in Serbia:

1. Three areas were protected based on hoverfly fauna (Pil and Vujić, 2004); the first European example of site protection based solely on diversity and the importance of Diptera species.

2. 77 hoverfly species and their habitats were protected by a national legal act (33 protected and 44 strictly protected) (Code on declaration and protection of strictly protected and protected wild species of plants, animals and fungi ("Official Gazette of RS", no. 5/2010)).

Despite these major achievements, it has come into question whether the current protection scheme in Serbia is sufficient to meet conservation goals for hoverflies. This is of particular importance with respect to the new Global Strategic Plan for Biodiversity (2011–2020), which emphasises areas where species groups lacking information on important habitat areas may be have been previously ignored in conservation efforts.

To remedy this situation, an attempt was made via a national project (Conservation strategy for protected and strictly protected hoverflies (Insecta: Diptera: Syrphidae) in Serbia – Case study) to identify areas important for hoverfly conservation, called Prime Hoverfly Areas (PHA). The selection process was criteria-driven and relied on expert opinion. The success of implementing these results into practice will largely depend on the strength of expert arguments.

To supplement this PHA identification process, we took the complementary approach of systematic conservation planning, applying gap and irreplaceability analysis in order to evaluate the sufficiency of the current national protected area (NPA) network for hoverfly conservation, and the contribution of the expert-generated PHA to this aim.

As of 2012, only 6% of the territory of Serbia was under legal protection (Serbian Biodiversity Conservation Strategy 2011–2018, "Official Gazette of RS", 13/11). The plan for the future is to increase the coverage of protected areas to 10% by 2015, and to 12% by 2021 (Spatial Plan for the Republic of Serbia, "Official Gazette of RS", 88/10). Recently, additional protected areas were announced, increasing the total protected area to 7% (http://www.zzps.rs/novo/index.php?jezik=sr&strana=zastita_prirode_osnovni_podaci). Efforts were also made to define important areas for the protection for various species of birds, plants, and butterflies (IBA, IPA and PBA respectively). These areas, together with the NPA, represent a national ecological network, the cornerstone of the future Natura 2000 Network (the EU wide Network of nature protection areas) in Serbia.

Excluding the NPA, the national ecological network is not yet formally protected, and needs further revision and specification of borders. At present it only represents inventories of areas of special importance for certain groups of species and plant communities, but is not based on systematic conservation planning or evaluation of its contribution to species conservation. Thus, it would be futile to assess these areas before it is known whether they sufficiently cover important areas for the species groups in question.

In the present study, we evaluate the adequacy of the NPA for hoverfly conservation, an important pollinator group. In addition we propose an approach for systematic inclusion of important conservation areas. The present study is the first to apply systematic spatial conservation planning to hoverflies with the goal of testing the efficiency of expert-based selection and delineation of PHA areas in Serbia. Finally, we analysed the degree of overlap between the PHA and a similarly designed habitat network aimed to conserve butterflies, since this is of interest in planning conservation strategies for pollinators.

2. Materials and methods

2.1. Data on hoverfly species distribution

Hoverfly species distribution throughout Serbia has been regularly recorded for the last 35 years. Although systematic grid-based mapping of hoverfly distribution has never been conducted in Serbia, a large amount of accurately and precisely geo-referenced data on species presence has been collected throughout the country, covering all geographical regions, biogeographical zones and all habitat types. Areas with important habitats for hoverfly species of interest have been explored more intensively in faunistic and taxonomic studies. During sampling, adult specimens were collected during the peak flight period of the species expected for the area. All presence records were geo-referenced and compiled in an internal database at the Faculty of Sciences, University of Novi Sad. Currently, the database contains 21,606 species — locality pair data, but this number will likely increase to >30,000 pending verification of additional data. The total number of species — locality pair data on species analysed in the present study (selection process described below) was 2166 (GBIF: http://hoverf-biosense.rhcloud.com/resource?r=hfdata).

2.2. Identification of hoverfly species of conservation interest and designation of the PHA network

Based on long-term fieldwork data and supported by expert opinion, PHAs were identified as part of a national project designed to develop conservation strategies for hoverflies in Serbia. The process was criteria-driven, where:

1. Five criteria were defined to identify species of conservation interest (Table 1A). The criteria are similar to those used for identification of butterfly species of conservation importance (Jakšić, 2008). The focus is on species protected by national and European legislation, and on species that have very limited distribution (local or regional endemics), because endemic species are considered to be more vulnerable (Işik, 2011; Lamoreux et al., 2006; Primack, 2006) and are often used as indicators of biodiversity richness (Bonn et al., 2002; Myers et al., 2000; Xu et al. 2008).

2. Five criteria were defined to identify areas important for hoverfly conservation (PHA) (Table 1B). These were based on criteria used for PBA, IPA and IBA designation and considered a site's contribution to the preservation of a species of interest as well as their communities.

Boundaries of PHAs were established by experts, respecting the boundaries of natural and semi-natural habitats appropriate for the identified important hoverfly species. Areas delineated by this approach are basically polygons of continuous suitable landscape for important hoverfly species.

Table 1
Description of criteria for:

Criterion	Explanation	Comment
A) Identification of important hoverfly species		
Criterion 1.	Protected and strictly protected species by Serbian legal act (Code on declaration and protection of strictly protected and protected wild species of plants, animals and fungi ("Official Gazette of RS", no. 5/2010 from 5.2.2010)	Criterion 1 should be chosen according to appropriate act from national or EU legislative
Criterion 2.	Species distributed only in Europe, or species of European concern (based on Speight, 2013)	Based on criteria for Prime Butterfly Areas in Serbia (Jakšić, 2008)
Criterion 3.	Species restricted by range to the Balkan Peninsula (Balkan endemics)	Prime Butterfly Areas in Serbia (Jakšić, 2008)
Criterion 4	Species with restricted distribution on the Balkan Peninsula and very restricted distribution in Serbia (3–5 localities)	Prime Butterfly Areas in Serbia (Jakšić, 2008)
Criterion 5.	Species connected with specific habitat type listed in Annex I of the Habitats Directive (http://ec.europa.eu/environment/nature/natura2000/index_en.htm)	Based on expert knowledge about species appearance in Serbia combined with Speight and Castella (2008) information on species connection with macro-habitat type
B) Designation of PHA network		
Criterion 1.	Site contains threatened species at national level and species of European concern	
Criterion 2.	Site contains national endemic species with demonstrable threat	Based on Important Plant Areas criteria
Criterion 3.	Site contains near endemic/restricted-range species with demonstrable threat	Based on Important Plant Areas criteria
Criterion 4.	The site is known or thought to hold a significant component of the group of species whose distributions are largely or completely confined to one biogeographical regions in accordance with Habitats Directive	Based on Important Bird Areas criteria
Criterion 5.	The site supports species connected with particular habitat, refer to Annex I of the Habitats Directive (http://ec.europa.eu/environment/nature/natura2000/index_en.htm)	

Other guidelines for PHA network designation
1. If areas selected for two or more species overlap they should be combined to form a single area.
2. For widespread species without obvious core areas, separate PHAs should not be selected when it is possible to include the species in PHAs selected primarily for other species.

2.3. Evaluation of the NPA (NPA) and NPA expanded by PHA addition (NPA + PHA)

Two complementary analyses (gap and irreplaceability analysis) were performed in order to evaluate the NPA and expert-generated PHA (38 areas in total). We considered the 155 species identified as important (Table A.1). Data on species distributions was extracted from an internal database, where more than 2000 geo-referenced records were obtained. Species occurrence was represented in 1 × 1 km cells within the Universal Transverse Mercator grid. Data on the location of protected areas and their boundaries (covering 6210 km^2, approximately 7% of the Serbian territory) were obtained from the Institute for Nature Conservation of Serbia (Fig. 1, Fig. 5A).

Since the sampling effort was not evenly distributed throughout the entire territory, it was necessary to build a species distribution model (SDM), for which each species must have more than 6 records (Hernandez et al., 2006; Pearson et al., 2007; Rinnhofer et al., 2012; Shcheglovitova and Anderson, 2013). As not all species met this condition, they were classified in two groups: Non-SDM species, comprised of species with less than 6 records (mainly species meeting Criterion 3, 4 or 5), and SDM species, comprised of species with more than 6 records. In total, 72 SDM species and 83 non-SDM species were identified. Spatial filtering was then performed for SDM species.

For non-SDM species, a grid-based approach was applied; grid cells (1 km^2) in which species were registered were considered to be occupied. For the SDM species, habitat suitability maps were generated using the presence only modelling approach Maxent, a widely used machine learning tool based on a maximum entropy function for building distribution models closest to uniform (Philips and Dudik, 2008; Philips et al., 2006). For each species model, 7 bioclimatic variables and a combination of 3–5 land cover variables (depending on species habitat preferences) were used. The bioclimatic variables (annual mean temperature, maximum temperature of the warmest month, mean temperature of the wettest quarter, mean temperature of the driest quarter, annual precipitation, precipitation during the wettest quarter and precipitation during driest quarter) were derived from bioclim envelope (http://www.worldclim.org), while land cover variables - amount (total area) of artificial surfaces, broad-leafed forests, coniferous forests, mixed forests, grasslands (natural grasslands + pastures), heterogeneous agricultural areas, arable land, inland wetlands, inland waters, transitional woodland-shrubs and rocky habitats (bare rock + sparsely vegetated areas) were derived from the CORINE land cover map (http://www.eea.europa.eu/data-and-maps/data/corin-land-cover-2006-raster-2). Land cover variables were transformed into different land cover categories in every grid cell, and all variables were re-sampled to a resolution of 1 × 1 km grid cells.

In order to obtain the best model for a species-specific suitable area, model complexity and performance (Warren and Seifert, 2011) and small sample size (Shcheglovitova and Anderson, 2013) were considered. For each species, 48 replicate models were created, and based on AICc values the "best" model settings were selected (Burnham and

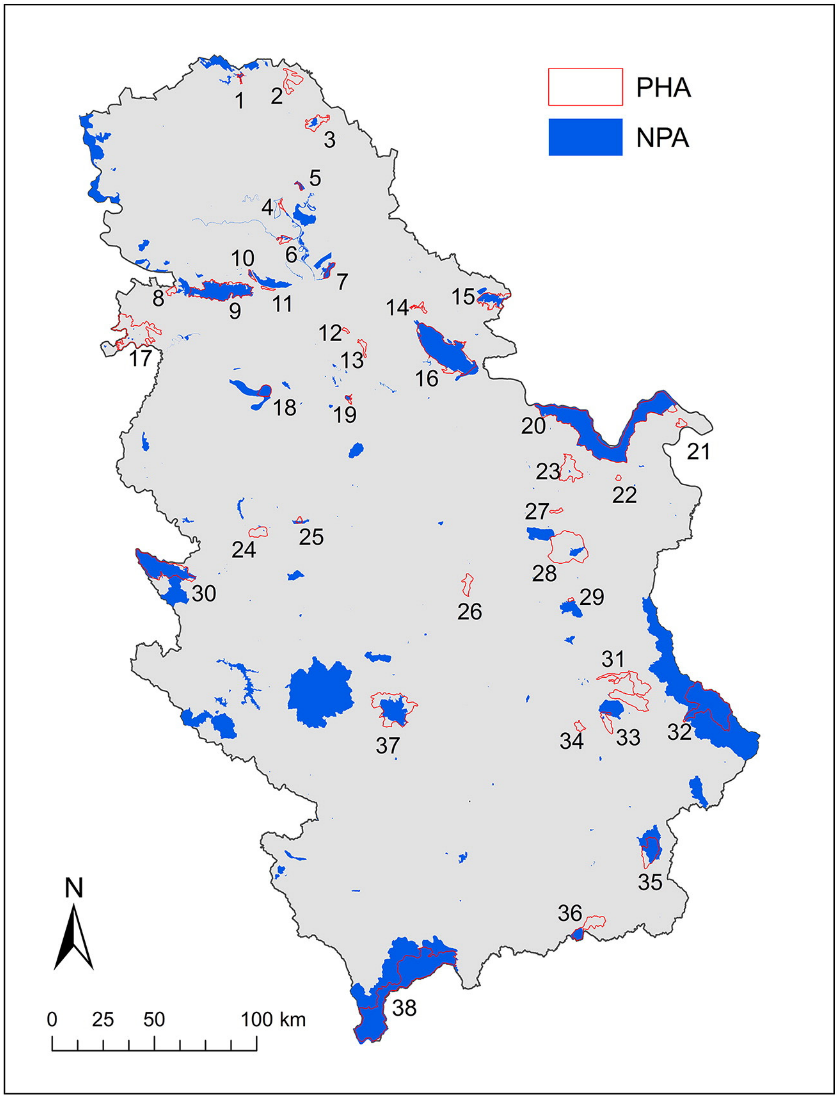

Fig. 1. Map of the national protected areas (NPA) and Prime Hoverfly Areas (PHA) in Serbia. PHAs: 1 — Ludoško jezero, 2 — Pašnjaci Filić-Siget, 3 — Mokrinski pašnjaci, 4 — Mrtva Tisa, 5 — Slano Kopovo, 6 — Jegrička, 7 — Carska bara, 8 — Fruška gora zapad, 9 — Fruška gora istok, 10 — Petrovaradinski rit, 11 — Čortanovački rit, 12 — Glogonjski rit, 13 — Jabučki rit, 14 — Alibunar, 15 — Vršačke planine, 16 — Deliblatska peščara, 17 — Bosutske šume, 18 — Obedska bara, 19 — Avala, 20 — Đerdap, 21 — Milutinovac, 22 — Klokočevac, 23 — Debeli lug, 24 — Divčibare, 25 — Rajac, 26 — Juhor, 27 — Žagubica, 28 — Malinik-Dubašnica, 29 — Rtanj, 30 — Tara, 31 — Svrljiške planine, 32 — Stara planina, 33 — Jelašnička klisura, 34 — Seličevica, 35 — Vlasina, 36 — Pčinja, 37 — Kopaonik, 38 — Šar planina.

Anderson, 2004; Muscarella et al., 2014; Warren and Seifert, 2011). Habitat suitability maps were created using a 10% training omission threshold rate, cells with an occurrence probability higher than the threshold were considered to be suitable.

2.4. Gap analysis

Gap analysis was employed to identify the degree to which important hoverfly areas are represented within the NPA, and how the PHA would improve the protection of focal species. The representation target was defined as: 1) the species-specific portion of the occupied grid cells (for non-SDM species), and 2) suitable area cells (for SDM species). The target amount of protection was determined for each species depending on the extent of its distribution (wide or narrow distribution), ranging from 10 to 100% of total species-specific occupied cells or suitable area cells (according to D'Amen et al., 2013).

The number of occupied/suitable area cells was then compared between the NPA and the NPA + PHA. The difference in mean percentage of suitable cells within the NPA and NPA + PHA for SDM species was tested using a dependent T-test for paired samples. To assess the extent to which the representation target was achieved in each case, the number of occupied/suitable area cells was compared with species-specific targets. If the number of occupied/suitable area cells was equal or larger than the target, the target was considered to be met (Target Met). Species for which only a portion of occupied/suitable area cells was found in the assessed area (NPA or NPA + PHA) were assigned to a Partial Gap group, while species for which all occupied/suitable area cells were outside the assessed area were assigned to a Total Gap group.

2.5. Irreplaceability analysis

Irreplaceability analysis serves to measure the relative conservation importance of different areas (Pressey et al., 1994). In this study, every 2×2 km cell was checked for its importance in meeting a previously set target. The analysis was run with C-Plan Systematic Conservation Planning System, Version 4 (Pressey et al., 2009).

The number of occupied/suitable 1×1 km cells within a 2×2 km grid cell was used as the “amount of feature”, while all 2×2 km grid cells were considered as “initially available” for conservation. A weighted sum irreplaceability index was counted, which represents the level of importance of a particular unit for all listed species, and indicates the conservation status of the unit that should be attained (D'Amen et al., 2013). All species were weighted for their vulnerability, depending on the level of protection ("Official Gazette of RS", no. 5/2010 from 5.2.2010). Strictly protected species were assigned a weight of 1, protected species 2, and non-protected species 3. Using this method, it was possible to define "hot spot" areas (areas that fit into 5% of cells with the largest value of irreplaceability index), and to compare their number between the NPA and NPA + PHA. Lastly, we checked whether cells with high irreplaceability value were better represented within the NPA and NPA + PHA than in randomly chosen grid cells, by comparing mean irreplaceability values of the NPA and NPA + PHA with the mean value of 5000 randomly chosen grid cells within the territory of Serbia.

2.6. Comparison of the two expert-generated networks

The PBA network in Serbia was designed at the end of 20th century. It contains 41 areas covering a surface area of 9347.2 km^2 (Jakšić, 2008). However, as previously explained, this network has not been evaluated for its sufficiency in conserving butterflies. Since the network was expert-generated, relying on similar criteria to those used for the PHA, it was interesting to check the degree to which these networks fit each other: this was performed by creating a simple overlap of the maps in QGis 1.8.

3. Results

3.1. The expert-generated network of Prime Hoverfly Areas (PHA)

Based on the five defined criteria for the identification of species in need of conservation, 155 hoverfly species (Table A.1) were identified, where: 76 species met criterion 1, 61 species met criterion 2, 1 species met criterion 3, 133 species met criterion 4, and 10 species met criterion 5 (Fig. 2A). None of the species fulfilled all five criteria. Most of them met two or three criteria, while 63 species were chosen according to only one of the selected criteria.

Based on the five defined criteria for the selection of areas important for conservation of hoverflies, 38 areas (Fig. 1) were selected. The total surface of the obtained PHA network is 3580 km^2 (approximately 4% of the total country surface). Almost all nominated areas (34) met criterion 3, while only 7 areas fulfilled criterion 4 (Fig. 2B). Criteria 1, 2 and 5 were met by 22, 13 and 12 PHAs, respectively. Only 1 PHA (Šar planina) fulfilled all five criteria, while 7 PHAs were chosen according to only one of the selected criteria.

The PHAs with the highest number of hoverfly species important for conservation (Table A.2) were mountains: Kopaonik (66), Malinik – Dubašnica (34), Fruška Gora istok (25) and Stara planina (21). 11 of the nominated areas had only 1 important species, while the rest of the PHAs had between 2 and 12 species.

3.2. Gap analysis

3.2.1. Evaluation of the NPA

3.2.1.1. SDM species. On average, 29% (SD ± 15.76) of the suitable habitats were recorded within the NPA. The contribution of suitable habitat area ranged from 10 to 20% of total suitable surface area in Serbia for 32% species (Fig. 3A). For individual species it ranged between 3% and 74%. For most of these species (81%), the coverage of suitable habitats did not meet defined representation targets (Table 2).

3.2.1.2. Non-SDM species. In 49% of cases, locations where non-SDM species were found were fully present within the NPA, therefore achieving the target (Table 2). However, 15 species (18%) were completely unrepresented in the NPA (Table 2, Fig. 3B).

3.2.2. Evaluation of the NPA + PHA

3.2.2.1. SDM species. Following addition of the PHA to the NPA, the average area of suitable habitats increased to 32%, which is statistically significant (dependent T-test: $t (71) = -9.57$, $P < 0.0001$). For 33% of these species, 20–30% habitats (Fig. 3A) were found within the NPA + PHA, while for each individual species this ranged from 4% to 76%. Although the number of species with achieved target increased significantly from 14 to 21 (10%) (Table 2), most of the species (71%) did not completely satisfy the target objective.

3.2.2.2. Non-SDM species. None of the areas where non-SDM species were recorded were found completely outside the NPA + PHA (Table 2). In addition, the number of species for which the target was fully met increased to 60, a 24% increase in comparison to the NPA alone.

For SDM species, the NPA and NPA + PHA achieve the conservation target mainly for species with wider distributions (representation target 10–20% of suitable habitats). Species with narrow and specific distribution were insufficiently represented in both cases. Four species had their representation target achieved only after addition of the PHA to the NPA (*Cheilosia cumanica*, *Cheilosia hypena*, *Eumerus clavatus*, *Xylota abiens*).

In the case of non-SDM species, 20 species achieved the target only after NPA + PHA treatment (*Epistrophella coronata*, *Eristalis megacephalus*, *Eristalis rupium*, *Eupeodes nielseni*, *Heringia vitripennis*, *Lejops vittata*, *Mallota cimbiciformis*, *Mallota fuciformis*, *Melangyna lucifera*, *Melangyna quadrimaculata*, *Merodon desturinus*, *Merodon natans*, *Orthonerva gemula*, *Paragus absidatus*, *Pelecocera tricincta*, *Platycheirus aurolateralis*, *Platycheirus complicatus*, *Psarus abdominalis*, *Trichosomyia lucida* and *Xylota tarda*). 10 of 13 areas for these species were fully outside the NPA.

The majority of species for which the NPA achieved the defined objective (Table 3) are those of lower protection importance in Serbia (i.e. not protected by national law). For species of higher protection

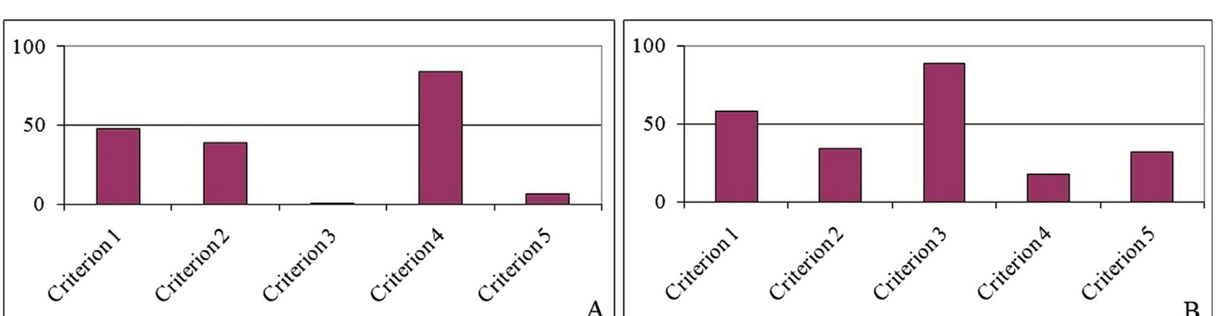

Fig. 2. Percent of species meeting each criterion: A — Criteria for species; B — Criteria for areas.

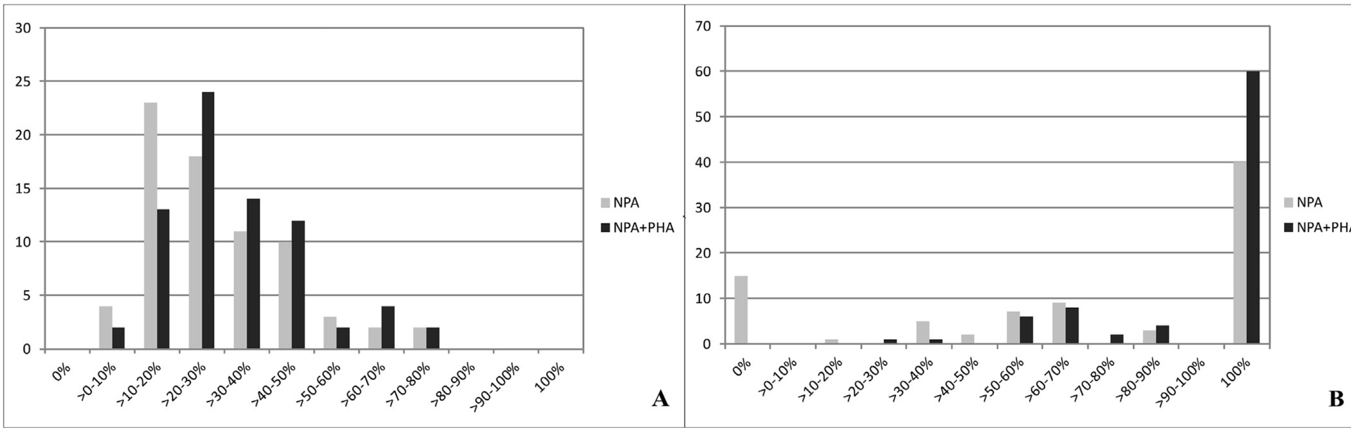

Fig. 3. Species frequency distribution — different ranges of protection (%) within the national protected area (NPA) network and the NPA + Prime Hoverfly Areas (PHA). A — The results for species distribution model (SDM) species; B — The results for non-SDM species.

importance, the number of met targets was lower. At the same time, a total gap in representation was found for a similar number of strictly protected, protected and non-protected species. Protection of the PHA removes the total gap and increases the target met: by nearly 2-fold for species of higher protection importance.

3.3. Irreplaceability analysis

A map of "hotspot" areas for hoverfly conservation was made based on the index of irreplaceability (Fig. 4). Cells with the highest irreplaceability are distributed across the country. Their highest concentration, however, is visible in mountainous areas of southwestern, eastern and southern Serbia, as well as in proximity to large rivers in Vojvodina (e.g. the Danube, Tisa, Sava, Tamiš). Cells with high irreplaceability are distinctly absent from a greater part of Vojvodina (the lowland region, where agricultural type land use is prevalent; see also Fig. 5A). Similarly, their absence is also visible in the lowland and hilly areas of central Serbia, while their highest concentration was found in high mountains.

30% of hot spot areas were found within the NPA. This value increased to 37% in the NPA + PHA treatment. The mean value of the weighted sum irreplaceability index for the NPA was 0.64 ($\pm$2.04), while for the NPA + PHA this value was 0.60 ($\pm$1.91). The mean value of 5000 randomly chosen grid cells was 0.09 ($\pm$0.60), significantly smaller than mean values obtained for cells both within the NPA and NPA + PHA (two-tailed T-test probability: $P < 0.01$ in both cases).

3.4. Comparison of the Prime Hoverfly Areas (PHA) with the Prime Butterfly Areas (PBA)

Superposition of the PHA map with the PBA map (Fig. 5B) revealed that only 52% of important hoverfly areas (1850.5 km^2) lie within the PBA network. Positing them on the CORINE land cover map showed that the highest overlap for the two networks is within forest land cover type and inland water (Table 4). They are to a large extent represented in forests, and less so in other land cover types. Differences between the PHA and PBA are visible for agricultural land cover type, where butterfly areas were more present than hoverfly areas.

4. Discussion

The diversity and ecology of hoverflies in Europe has been well-researched (e.g. Bartsch et al., 2009a, 2009b; Haarto and Kerppola, 2007; Reemer et al., 2009; Speight, 2013; Stubbs and Falk, 2002; Torp, 1984). However, few studies on their conservation status have been conducted. Moreover, those studies that do exist are mainly incorporated in National Red lists and within strategies for invertebrate conservation, focused mainly on saproxylic hoverflies, or are related to regional databases and reviews of national scarce and threatened species (e.g. Ball and Moris, 2014; Macadam and Rotheray, 2009; Rotheray et al., 2001; Speight and Castella, 2010). Generally, invertebrate conservation has been poorly assessed (Clausnitzer et al., 2009) and recent studies (D'Amen, 2013) suggest that their representation in conservation areas is inadequate. Gap and irreplaceability analyses are often used to evaluate ecological networks (e.g Araujo et al., 2007; Maiorano et al., 2007; de la Montaña et al., 2011); however studies employing these techniques to evaluate the status of hoverflies have not previously been performed. Our analyses provide evidence that hoverflies are insufficiently represented in the Serbian NPA network, and suggest strategies for improvement.

4.1. The evaluation of the NPA and the NPA + PHA

Historically, the establishment of protected areas in Serbia has been based on criteria not solely designed to conserve biodiversity. Designation of these areas was based on expert opinion rather than on systematic conservation planning (Oldfield et al., 2004; Pressey et al., 1993; Scott et al., 2001). Thus, it is not surprising that the NPA does not sufficiently include the habitats of important hoverfly species. The percent of SDM species that achieved their representation target is relatively low (19%); the number of non-SDM species for which there is a total representation gap is high (18%). This indicates that the NPA does not include

Table 2
The level of achieved representation target for species distribution model (SDM) and non-SDM species in the national protected area (NPA) and NPA + Prime Hoverfly Areas (PHA). Number of species and their percent is shown in each row.

	SDM species			Non-SDM species		
	Total gap	Partial gap	Target met	Total gap	Partial gap	Target met
NPA	0 (0%)	59 (81%)	14 (19%)	15 (18%)	27 (33%)	40 (49%)
NPA + PHA	0 (0%)	52 (71%)	21 (29%)	0 (0%)	22 (27%)	60 (73%)

Table 3
Number of strictly protected (SP), protected (P) and unprotected (NP) hoverfly species in relation to the achieved representation target. Percent from the total number of species from each protection category is shown in brackets.

	NPA			NPA + PHA		
	SP	P	NP	SP	P	NP
Total gap	5 (16%)	4 (10%)	6 (7%)	0 (0%)	0(0%)	0 (0%)
Partial gap	19 (61%)	28 (67%)	39 (48%)	18 (58%)	24 (57%)	32 (39%)
Target met	7 (23%)	10 (24%)	37 (45%)	13 (42%)	18 (43%)	50 (61%)

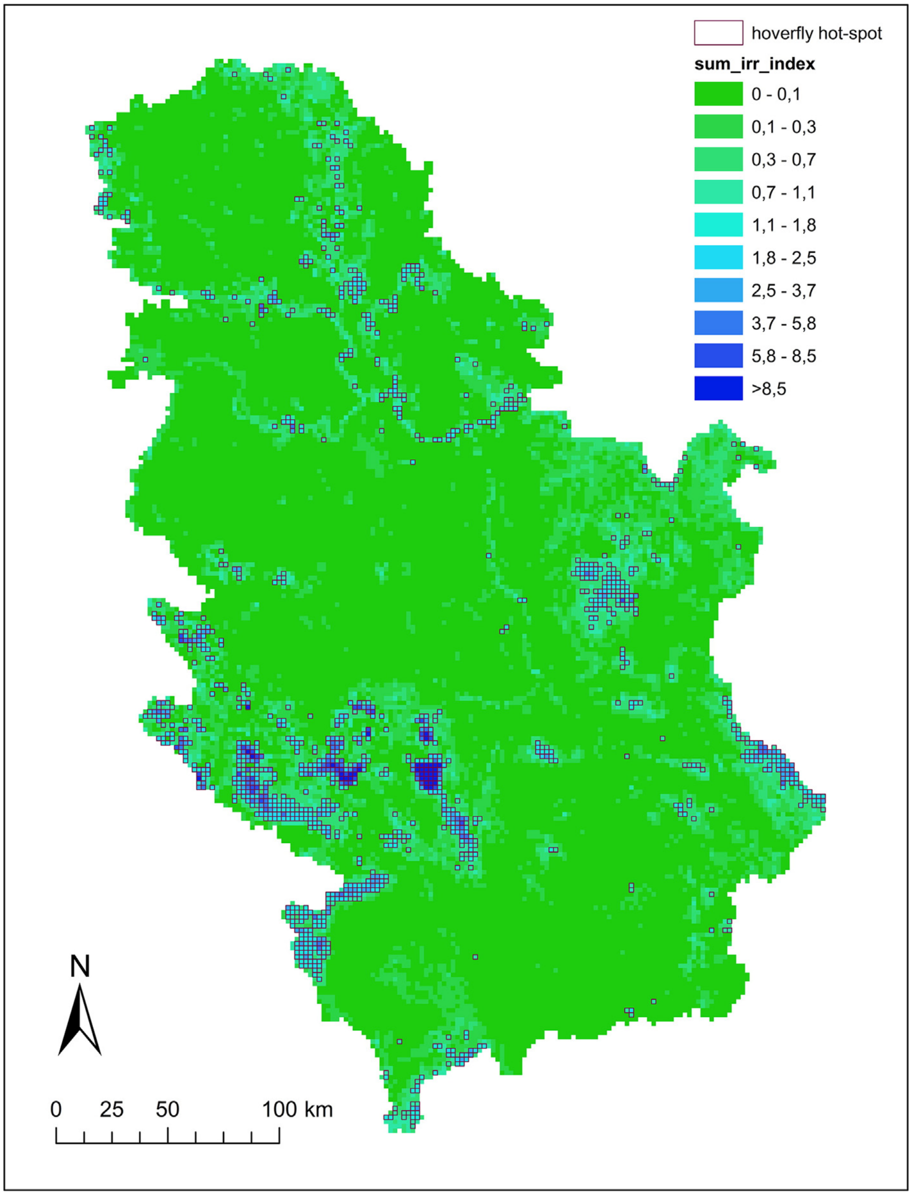

Fig. 4. Map of hoverflies "hot-spot" areas in Serbia based on the index of irreplaceability.

the most important and in some cases the only habitats of certain species. In fact, the habitats of 5 strictly protected species (*Cheilosia alba*, *Sphiximorpha subsessilis*, *Lejops vittata*, *Orthonerva gemmula* and *Psarus abdominalis*) are completely unrepresented in the NPA.

The conservation target has been achieved for a relatively high proportion of non-SDM species, in comparison to SDM species. This could be explained by the fact that a high number of non-SDM species are typical high mountain endemic and/or relict species with small ranges that are fully protected with the NPA. In Serbia, as in most European countries, protection zones encompass more mountainous areas than lowland areas, especially vs. lowland agricultural/farmland landscapes (Oldfield et al., 2004; Scott et al., 2001).

Some hoverfly species are extremely sensitive to changes in habitats, namely xylophagous species which depend on well-preserved forests with highly mature and senescent trees necessary for larval development, and phytophagous species that are closely associated with their host plants. Habitats that have not been influenced by anthropogenic activity are found only within protected areas, in small, strictly protected nature reserves. Many of the species associated with these specific habitats were found only inside the protected areas, as was the case for species associated with mountain conifer forests and mountain swamps. Thus, there may be sampling bias associated with the measurements (spatial filtering could not be performed for non-SDM species). The sites with these habitats are known as biodiversity centres of the Balkan Peninsula (Savić, 2008); accordingly hoverfly hotspots (areas with the highest percent of irreplaceability) were identified in these regions.

Due to the high overlap (2373 km^2) between the PHA and NPA (together covering 7417 km^2, or 7.49% of the total surface area of the country), the PHA network designation would lead to the enlargement of the total protected area by only 1207 km^2 (1.36% of the national territory). However, this land area increase would significantly contribute to the conservation aims for both SDM and non-SDM species. The greatest achievement would be removal of the total representation gap previously present for 15 species, including 5 strictly protected species. The hot spots for hoverfly conservation (Fig. 4) were found on mountains in south-west and south-east of Serbia (Kopaonik, Golija, Tara, Zlatar, Prokletije, Šar planina, Stara planina and Kučajske planine), as well as in the north, along the Danube, Sava and Tisa rivers. The mountain regions are home to rare and endemic species that occupy heterogeneous

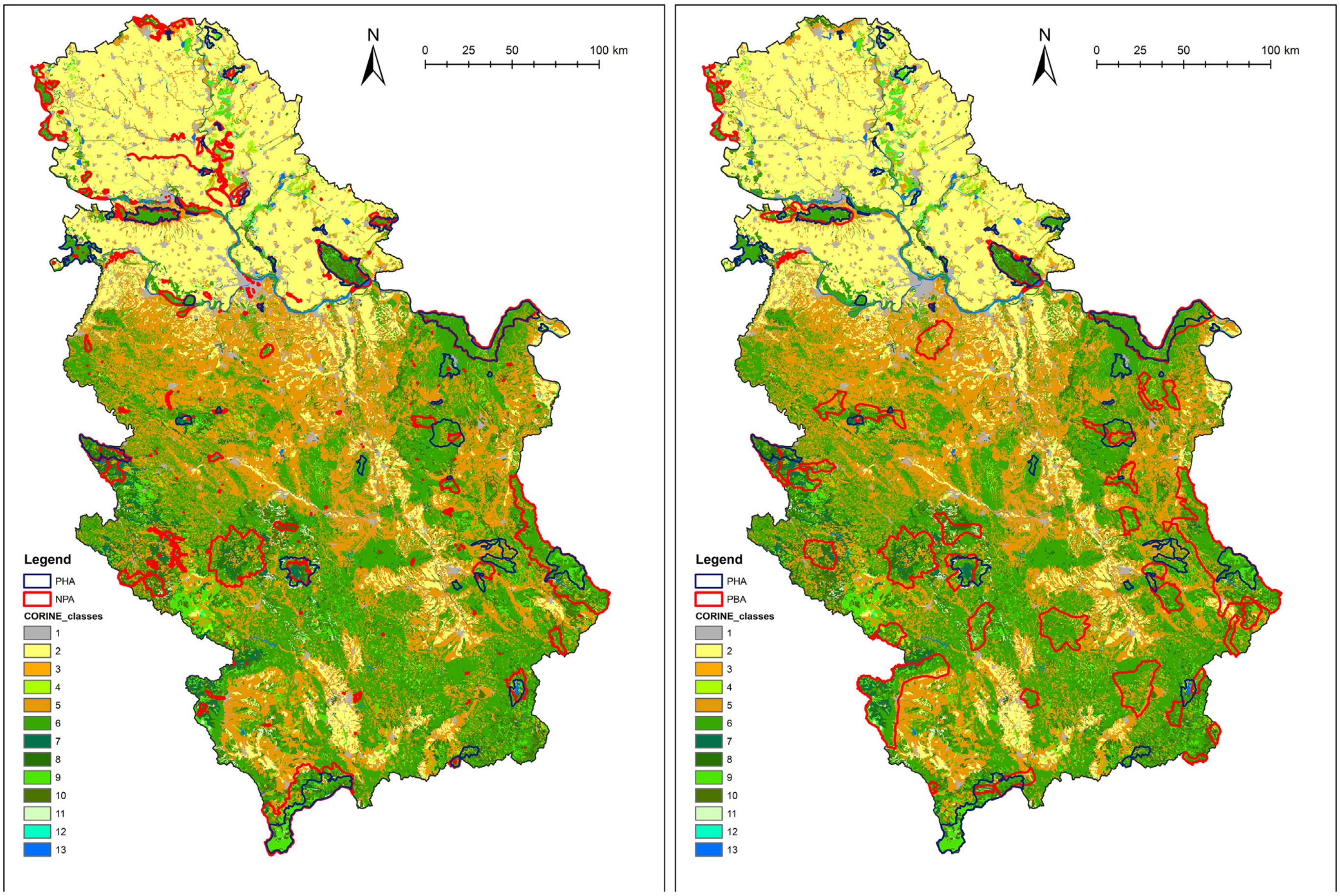

Fig. 5. A) Map showing the overlap between the NPA and PHA within different land cover types. Legend: 1 — artificial surfaces, 2 — arable land, 3 — permanent crops, 4 — pastures, 5 — heterogenous agricultural areas, 6 — broadleaved forest, 7 — coniferous forests, 8 — mixed forests, 9 — natural grasslands, 10 — transitional woodland-shrub, 11 — open spaces with little or no vegetation, 12 — inland wetlands, 13 — inland waters. B) Map showing the overlap between the PBA and PHA within different land cover types. Legend: 1 — artificial surfaces, 2 — arable land, 3 — permanent crops, 4 — pastures, 5 — heterogenous agricultural areas, 6 — broadleaved forest, 7 — coniferous forests, 8 — mixed forests, 9 — natural grasslands, 10 — transitional woodland-shrub, 11 — open spaces with little or no vegetation, 12 — inland wetlands, 13 — inland waters.

niches and are rich in glacial relicts. In riverine regions, aquatic saprophagous live in wetland habitats (Stevanović and Vasić, 1995). Taken together, this suggests that effective conservation of hoverflies can be achieved only by preservation of their scarce, near pristine habitats.

4.2. Expert-generate and systematic conservation approaches

Our results show that the proposed PHA is an important strategy for the future of hoverfly conservation. Additionally, this project displays the strength of the employed expert opinion-based approach, which is widely used (e.g. Macadam and Rotheray, 2009) but understudied in determining the conservation value of large land areas. However,

Table 4
Area percent of the Prime Hoverfly Areas (PHA), national protected area (NPA), Prime Butterfly Areas (PBA) within different CORINE ("coordination of information on the environment") land cover categories, and the percent of overlap between the PHA and PBA within each CORINE land cover category.

	Forest %	Herbaceous and shrubs %	Agricultural land %	Inland water %
Serbia	30.6	8.9	53.1	1.2
PHA	58.9	28.8	10.1	1.7
NPA	54.8	27.8	12.3	3.9
PBA	53.3	21.6	21.5	1.4
Overlap between the PHA and PBA	59.9	3.1	5.6	31.2

there were some shortcomings, as some species retained a partial gap in their conservation coverage. This is likely due to the fact that the PHA designation relied on field data concerning species distributions that did not cover all potentially important hoverfly areas. The distribution models have identified many suitable habitats for hoverflies, which were not thoroughly investigated during fieldwork. For example, hoverfly populations in mountain areas in south-western Serbia were not thoroughly researched, so the PHA does not include these areas, even though they contain high mountain conifer forests and grasslands (see Fig. 5A), and contain habitats similar to other mountain regions included in the PHA (e.g. Kopaonik). This suggests that the process of PHA definition should also include suitable habitats, a habitat-based approach, and localities where species were recorded, as well as the current site-based approach. Additionally, distribution models should be used in conservation planning, as they provide information on distribution of habitats with a high probability of species presence. This approach is widely used in conservation planning, including hot spot area mapping (Myers et al., 2000; Statterfield et al., 1998). Creating more reliable species distribution models or refining existing ones for implementation of habitat based approach would require systematic sampling of all habitats types in a sufficient number of sites.

Our model of species distribution has some shortcomings. We modelled species distribution on the landscape level using climatic parameters and variables based on CORINE land cover categories. It is well known that many hoverfly species inhabit microhabitats with specific vegetation or vegetation composition (Speight, 2013), but these are not defined within CORINE land cover classifications. Further, the size of microhabitats may be smaller from the resolution of data used as inputs in creation of ecological variables. For example, habitats as mountain streams are not represented in CORINE maps. This means that, in practice, there is a high chance that a particular species does not inhabit some of the areas suggested by the model as suitable, because specific habitat characteristics or components are absent. Additionally, complex geological history, speciation processes, stochastic evolution processes, local extinctions, dispersions, as well as biotic interactions, all influence species distribution together with the availability of suitable habitats in parts of the geographic area (Guisan and Thuiller, 2005; Guisan and Zimmerman, 2000). These processes create hoverfly distribution patterns that are more complex than suggested by distribution patterns of the PHA. Nevertheless, the application of hoverfly species distribution models is suggested for use during the preparatory phases, because these models can promptly produce precise species distributions. These distribution model data can also be used in subsequent field work for systematic ground verification of real distributions.

Many hoverfly species with inaccessible habitats are not easily observed during field data collection. Similarly, species with a short period of activity and small population sizes that oscillate annually are difficult to record. As a result, some hoverfly species in these habitat types may have been overlooked.

Taking these shortcomings into account, we suggest the following process for a comprehensive functional network design for hoverfly conservation: 1) inventory of data on species distribution; 2) development of species distribution models, accounting for potential sampling bias; 3) ground-truthing; 4) delineation of the network based on expert opinion; 5) evaluation of the network using gap and irreplaceability analyses.

This suggested approach would be feasible in most European countries, as high-quality faunistic data on hoverflies are available (especially in UK, Netherlands, Germany, Denmark, Finland, France, Greece and Spain).

4.3. Comparing expert-generated networks

Hoverflies and butterflies may be assumed to have similar ecological demands because they are both pollinators that strongly depend on plant composition and distribution. However, we found that a large area of the PHA was outside of the PBA (52% overlap). This may be due to the diverse larval development characteristics of hoverflies, allowing for occupation of a wide spectrum of ecological niches, in comparison to the less diverse trophic strategies of butterfly larvae (Altermatt and Pearse, 2011). Their presence and overlap was highest in forest ecosystems, where the more complex landscape provides a variety of habitat opportunities for different invertebrate groups. Lower overlap was found between the PHA and PBA in open type habitats (agricultural land, herbaceous and shrub habitats), as a result of their ecological differentiation. In open land, the differences in ecological requirements are more visible. Areas along inland water, where the presence of land areas identified as important areas was lowest, are azonal and more uniform. This analysis clearly shows that implementing conservation networks for pollinators that rely only on one pollinator group are insufficient in identifying critical habitat areas for all pollinators.

4.4. From an operational point of view

Spatial prioritisation for species conservation is only one step in achieving conservation goals. Systematic conservation planning is a stage-wise model, with the later stages dealing with implementation, maintenance, management and monitoring of conservation areas (Kukkala and Moilanen, 2013). It is also crucial to involve stakeholders early in the planning process. Inventories of the important sites play a key role in informing designation or expansion of protected areas in conjunction with public involvement in conservation issues. IBAs are the best example (e.g. Special Protected Areas in the European Union), as there is evidence of the positive impact of protected areas on species populations (Donald et al., 2007).

Evidence of the achievement of conservation goals in important taxon sites is scarce. This is largely due to their recent establishment, and is not surprising considering our lack of knowledge with respect to the effectiveness of protected areas (Cabeza, 2013). Still, Butchart et al. (2012) found that species extinction risk is higher for unprotected ecologically important habitat areas than for those under protection. This implies that contribution of important sites to biodiversity conservation will rely on formal protection and management (Leverington et al., 2010). In Serbia, current management practice may not be suitable for hoverfly conservation. Over the past 20 years the habitats of strictly protected hoverfly species have disappeared due to inadequate management practices (Vujić, in prep.). Many strict nature reserves are very small in size (less than 10 ha). In Kopaonik National Park, construction of new ski tracks has resulted in downgrading a strictly protected zone to a less restricted one, while at the same time destroying the habitat of two strictly protected hoverflies (*Orthonevra montana* and *Sphegina sublatifrons*). In the same park, prioritisation of timber harvesting has resulted in construction of several kilometres of new roads, within an area with the highest level of protection and one of the most important habitats for hoverflies in Serbia. In Fruška Gora National Park, one strictly protected area was destroyed by clear-cutting. Systematic conservation planning can help to inform management, but effective and enforced management practices are of equal importance in pollinator conservation.

4.5. Conclusion and future prospects

The results of the present study support the prevailing opinion that established protected areas are not equally representative of different taxa. Inclusion of habitat information on multiple species in protected area designation is a necessary step in designing comprehensive conservation networks, and will require systematic evaluation and revision of suggested protected areas. The approach we outline here combines expert opinion, models of species distribution and analytical tools for systematic conservation planning. This combined approach has been shown to be more effective for conservation planning than applying these individual steps separately. Ground truthing of the distribution of modelled species is an important final step in protected area designation.

It is essential to determine whether the criteria used for identification of a PBA are appropriate and useful in the identification of important habitat areas of other pollinator groups, such as hoverflies. Although this is beyond the scope of the present study, some insight has been gained with respect to the degree of overlap between expert-generated PBAs and expert-generated PHAs. Our results also suggest that prospects for hoverfly conservation are promising, especially considering that their important habitat areas are predominantly present in mountainous, forested areas, which are often already located in protected zones. Although most insect conservation areas are butterfly and beetle focused; conservation network design targeting pollinators may be improved by the inclusion of hoverflies. This is supported by the large amount of long-term monitoring data on their presence in Serbia. Because pollinators require preservation of rare microhabitats, it is especially important to consider the needs of multiple species in conservation network design. We have shown that a small increase in the area under protection would significantly improve the conservation of hoverflies, pollinators, and invertebrate biodiversity in Serbia.

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Map. KML file containing the Google map of the most important areas described in this article.

Appendix A. Supplementary data

Supplementary data associated with this article can be found in the online version at http://dx.doi.org/10.1016/j.biocon.2016.03.032. These data include the Google map of the most important areas described in this article.

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