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Original Articles

Are birds reliable indicators of most valuable natural areas? Evaluation of special protection areas in the context of habitat protection

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ABSTRACT

Territorial protection of nature in any country is limited by various factors and therefore it is necessary to carefully select protected areas. Currently, they are often selected according to particular indicator taxa because of the simplicity and applicability of this approach. For example, Natura 2000 Special Protection Areas (SPAs) in EU are established to protect selected species of birds. We asked how well do SPAs cover valuable natural habitats, i.e., whether the areas selected for the protection of birds are also important for the conservation of natural habitats. We focused on the Czech Republic because detailed data on habitat composition are available for the whole country. Although SPAs covered only 9% of the whole country they contained disproportionately high part of the whole area of preserved natural habitats (36%). This was because 64% of SPAs area was covered by natural habitats compared to only 11% in the rest of the country. However, the importance of SPAs for different habitats and their formation groups varied significantly. Further, we found a positive relationship between habitat rareness and the proportion of rare habitats within SPAs. Despite their relatively small overall area SPAs host disproportionally large areas of natural habitats in the Czech Republic. This pattern suggests that birds are reliable indicators for territorial protection. SPAs thus show large importance for habitat conservation.

1. Introduction

One of the most effective means of nature conservation is territorial protection realized through protected areas. This entails excluding or limiting human activities in particular areas to benefit particular focal species or habitats (Caughley and Gunn, 1996; Leverington et al., 2010; Secretariat of the Convention on Biological Diversity, 2014; Opršal et al., 2018). However, because of conflicts with other human interests, this type of protection cannot be applied to too large proportions of the national territory; thus, particular areas designed for conservation need to be meticulously selected within each country. Selection criteria rely on different factors: areas whose protection is a manageable option; areas under imminent threat; areas inhabited by the rarest species; areas with highest species richness; areas with endemic species; areas inhabited by indicator species, i.e., taxa specific to particular habitats of interest (Evans, 2002; Primack 2014). Because of its impartiality and simplicity the most often currently used approach is the last one (i.e., indicator species: Noss, 1990; Parker et al., 1996; McGeoch, 1998; Vellend et al., 2008).

This principle has been applied in the network of protected areas Natura 2000. Specifically, within the framework of Natura 2000 Special Protection Areas (hereafter: SPAs) were established to protect particular species of birds covered in Birds Directive (2009/147/EC), namely species occurring only or mainly in the European Union (EU), species considered threatened in EU, range-restricted species, species sensitive to habitat changes and endemics. However, if biodiversity is to be protected comprehensively, the areas selected for protection via Birds Directive should protect not only the focal species but also other species and threatened habitats. Thus, criterion species should include not only rare taxa (deserving special protection *per se*) but also umbrella species (Murphy and Wilcox, 1986; Ryti, 1992; Franklin, 1994; Lambeck, 1997, Roberge and Angelstam, 2004).

In the Czech Republic, SPAs were established based on principles of Important Bird Areas (Donald et al., 2019), i.e. only on bird distribution data. This is logistically understandable: birds are among the best researched animal groups (del Hoyo et al., 2020). The knowledge of

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their biology, ecology and distribution enable to precisely determine which species are threatened and which taxa are specific to particular habitats (Gardner et al., 2007; Kushlan, 1993; Morelli et al., 2014; Padoa-Schioppa et al., 2006; Parker et al., 1996; Reynaud and Thioulouse, 2000). However, do SPAs protect only focal bird species as designated, or do they, as an added benefit, protect also endangered habitats and, consequently, all groups of organisms? Although this phenomenon is theoretically expected (e.g., in the Birds Directive), there is little concrete evidence from larger areas. Therefore, we capitalized on a unique opportunity to investigate it using data on the occurrence of habitats in the whole territory of one country.

We tested how well do SPAs cover well-developed "natural habitats" (including their other, i.e., non-avian inhabitants), i.e. habitat types not strongly affected by human activities (sensu Chytrý et al. 2010; for details see Materials and Methods). We used data from all 41 SPAs designated to protect 47 focal bird species (Fig. 1, Appendix A) in a Central European country, the Czech Republic. This country has one of the most detailed data on natural habitats in the world (Guth and Kučera, 2005; Pechanec et al., 2018). This is because of the country-wide mapping of all habitat types on a very detailed scale (Guth and Kučera, 2005). Based on indicator species concept (Noss, 1990; Carignan and Villard, 2002; Heink and Kowarik, 2010; Hoare et al., 2010) we predicted that SPAs would contain disproportionately large proportions of natural habitats compared to areas not protected as SPAs.

2. Materials and methods

2.1. Area of investigation

We retrieved the data on the distribution of well-developed "natural habitat" (in the sense of Chytrý et al. 2010) in both all SPAs and the whole area of the Czech Republic from results of habitat mapping projects realized by the Nature Conservation Agency of the Czech Republic (2014).

Specifically, in the period of 2000–2004, a nationwide mapping of habitats was carried out as part of the preparation of the Natura 2000 system. The mapping was carried out according to the consistent national methodology (Guth and Kučera, 2005). On the basis of this mapping, natural and non-natural habitats were defined throughout the territory of the Czech Republic. Classification and overview of habitats is published in the work of Chytrý et al. (2010). The categorisation of individual areas into the relevant habitat units was based on the presence of diagnostic and dominant species (see Guth and Kučera 2005, Chytrý et al. 2010). The classification of naturalness was based on several indicators, among which the representativeness and conservation (or degradation) of habitat were separate levels. Each indicator had clearly defined criteria for each of the four defined levels (see Chytrý et al., 2010).

The mapping covered the complete area of the country with the only exception of areas covered solely by unnatural habitats, namely intensively managed fields and densely built-up urban areas. In the framework of the mapping, Chytrý et al. (2010) recognized 173 habitat units and subunits. In the present work, we employed 127 these basic units of natural habitats (without subunits). For some analyses we pooled theese basic units into eight formation groups (following Chytrý et al. 2010; Appendix B, see below).

2.2. Statistical analyses

In the analyses we used mapping data updated to January 1, 2014. We used ArcGIS (ver. 10.5) to analyse data on presence and quality of natural habitats in (1) all mapped segments of the Czech Republic and (2) SPAs. The quality of natural habitats was categorised on the basis of representativeness of habitat composition and preservation of the habitat (see Guth and Kučera 2005). In separate analyses, we focused on the most valuable parts of natural habitats (hereafter: "habitat group 1″), specifically those showing highest quality, i.e., classified in the best category of the four differentiated categories of preservation and in one of the first three of the four differentiated categories of representativeness (following Lustyk and Oušková, 2011).To compare the proportion of natural habitats in SPAs with that available in the whole Czech Republic (i.e., null expectation) we used paired comparisons of parameters of particular habitats within each formation group: (1) Proportional area of a particular habitat within the whole (pooled) area of all SPAs in the Czech Republic (hereafter: index_SPA); (2) Proportional area of a particular habitat within the Czech Republic (index_CZ). In contrast to typical ecological studies based on sampling we had a complete data for the study area (i.e., not a sample). Thus, any potentially found differences would reflect differences existing in reality. However, to check whether the differences were statistically significant we used two-tailed

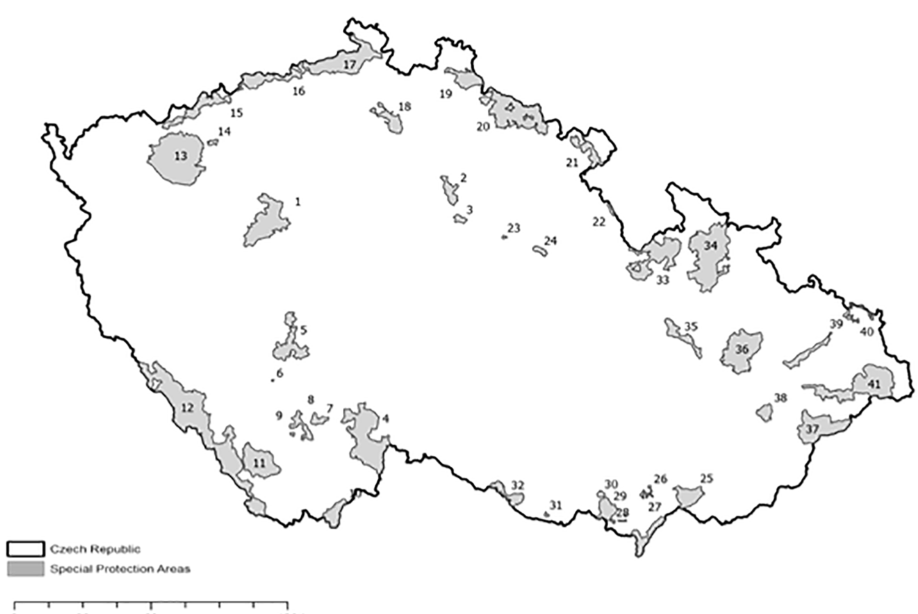

Fig. 1. Distribution of Special Protection Areas (shaded) in the Czech Republic. The numbers refer to the individual SPAs as listed and characterised in Appendix A.

Wilcoxon matched-pairs signed-rank tests.

Further, we analysed another descriptive variable which quantified a proportion of a particular habitat that occurred within SPAs out of the whole area of that habitat (hereafter: prophab_SPA). We used Spearman correlation coefficients (r_s) to test for associations between prophab_SPA and (1) habitat area (index_CZ, see above) and (2) habitat threat. The latter variable was quantified on an ordinal scale following The Red List of Habitats of the Czech Republic (Chytrý et al., 2019). We excluded category "Collapsed" because such habitats cannot harbour any wild living bird species. Thus, we employed the following five categories: 1 = LC (Least Concern), 2 = NT (Nearly Threatened), 3 = VU (Vulnerable), 4 = EN (Endangered), 5 = CR (Critically Endangered). In cases where a particular habitat showed several subunits we used average values (weighed by areas of subunits).

We repeated the same analyses as defined above for natural habitats group 1. All analyses were performed in Stata 15 (StataCorp, 2017). All parameter estimates are given as mean ± SE.

3. Results

3.1. Natural habitats coverage in the Czech Republic and SPAs

In 2014 natural habitats covered 12 445.29 km^2 (15.78%) of the whole country. Out of this total area 4 491.31 km^2 (36.09 %) of natural habitats occurred in Special Protection Areas (SPAs).

SPAs had a total area of 7 034.00 km^2 (8.92% of the whole country area). Natural habitats covered 63.85% of SPAs total area. In contrast, natural habitats covered only 15.78% of the whole country area.

Natural habitats group 1 (i.e., habitats of the highest quality, see Materials and Methods) occupied 2 932.34 km^2 (3.72%) of the whole country. Out of this total area 608.53 km^2 of natural habitats group 1 occurred in SPAs which represented 8.65% of SPAs total area and 0.77% of the whole country area. In contrast, natural habitats group 1 covered only 3.24% of areas outside the boundaries of SPAs (Fig. 2).

3.2. Habitat composition in the Czech Republic and its SPAs

Overall, the area of the Czech Republic was dominated by unnatural habitats, i.e., those strongly modified by humans (Fig. 3). In turn, natural habitats were dominated by "Forests" and "Secondary grasslands and heathlands"; however, their contribution to the whole area of the Czech Republic was relatively small. Contribution of the remaining formation groups was negligible (in total<2% of the total area of the Czech Republic: Fig. 3).

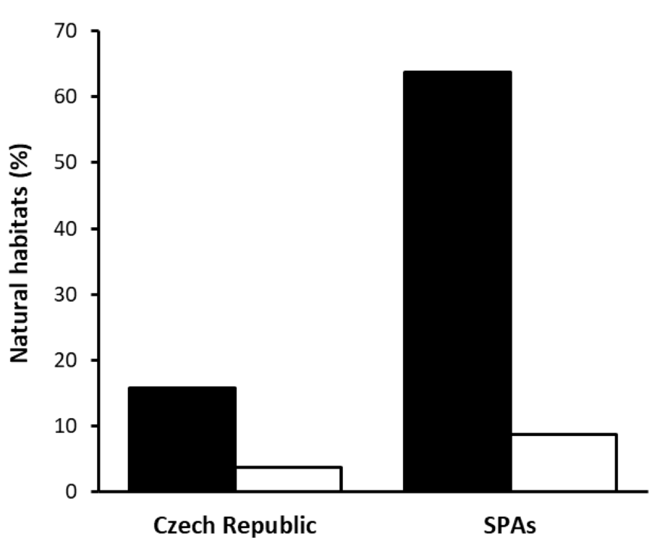

Fig. 2. Percentage of natural habitats (filled bars) and natural habitats group 1 (open bars) in the whole Czech Republic and SPAs.

In contrast, SPAs were dominated by natural habitats from the formation group of "Forests", followed by habitats strongly modified or created by humans and natural habitats from the formation group of "Secondary grasslands and heathlands" (Fig. 3). Contribution of the remaining formation groups was small (in total ca. 6% of the total area of SPAs: Fig. 3).

The average proportion of area of particular natural habitats within SPAs (index_SPA = 0.0050 ± 0.001) was much higher than the average proportion of area of particular natural habitats within the whole country (index_CZ: 0.0012 ± 0.0003; Wilcoxon matched-pairs signed-rank test: $z = 9.68$, $n = 127$, $p < 0.001$).

An analysis of natural habitats within particular formation groups showed similar results: in all formation groups index_SPA was higher than index_CZ and in all cases the differences were statistically significant (Table 1).

An average proportion of area of particular habitats group 1 within SPAs (index_SPA: 0.00068 ± 0.0002) was higher than an average proportion of area of particular habitats within the whole country (index_CZ_1: 0.00029 ± 0.00007; Wilcoxon matched-pairs signed-rank test: $z = 7.92$, $n = 127$, $p < 0.001$). Further, an analysis of natural habitats group 1 for particular formation groups showed similar results: in all formation groups index_SPA_1 was higher than index_CZ_1 and in all cases the differences were statistically significant at least at the $\alpha = 0.10$ (Table 2).

3.3. Coverage of formation groups by SPAs

"Alpine treeless habitats" and "Springs and mires" were best covered by SPAs, i.e., the largest proportions of these formation groups were found inside SPAs (97% and 72%). Other formation groups were covered by SPAs in the range of 42–52% (Fig. 4).

Similarly, for habitats group 1 "Alpine treeless habitats" were best covered by SPAs. However, the remaining formation groups had much lower proportions of their areas covered by SPAs (Fig. 4).

3.4. Habitat rarity and threat and SPAs habitat coverage

A proportion of a particular habitat that occurred within SPAs out of the whole area of that habitat (prophab_SPA) correlated negatively with a proportional area of a particular habitat within the Czech Republic (index_CZ; $r_s = -0.45$, $n = 127$, $p < 0.001$). Thus, habitat coverage by SPAs increased with habitat rareness. Further, prophab_SPA covaried positively with habitat threat and the correlation was statistically significant ($r_s = 0.18$, $n = 127$, $p = 0.048$).

The results of correlational analyses within particular formation groups were mostly statistically non-significant. The exceptions for which we found significant correlations between prophab_SPA and index_CZ were "Forests" ($r_s = -0.48$, $n = 33$, $p = 0.005$), "Wetlands and riverine vegetation" ($r_s = -0.75$, $n = 19$, $p < 0.001$) and "Secondary grasslands and heathlands" ($r_s = -0.36$, $n = 31$, $p = 0.045$). We also found a significant positive correlation between prophab_SPA and threat for "Wetlands and riverine vegetation" ($r_s = 0.66$, $n = 19$, $p = 0.002$).

Similarly to all habitats, also a proportion of a particular habitat group 1 that occurred within SPAs out of the whole area of that habitat (prophab_SPA_1) correlated negatively with a proportional area of a particular habitat group 1 within the Czech Republic but the relationship was statistically non-significant ($r_s = -0.11$, $n = 127$, $p = 0.242$). Interestingly, the coverage of habitats group 1 covaried with habitat threat negatively but the relationship was marginally non-significant at the 5% level ($r_s = -0.16$, $n = 126$, $p = 0.068$).

Also for habitat group 1, the results of correlational analyses within particular formation groups were mostly statistically non-significant with the following exceptions for which we found significant correlations between prophab_SPA_1 and index_CZ_1: "Wetlands and riverine vegetation" ($r_s = 0.56$, $n = 19$, $p = 0.012$), "Secondary grasslands and

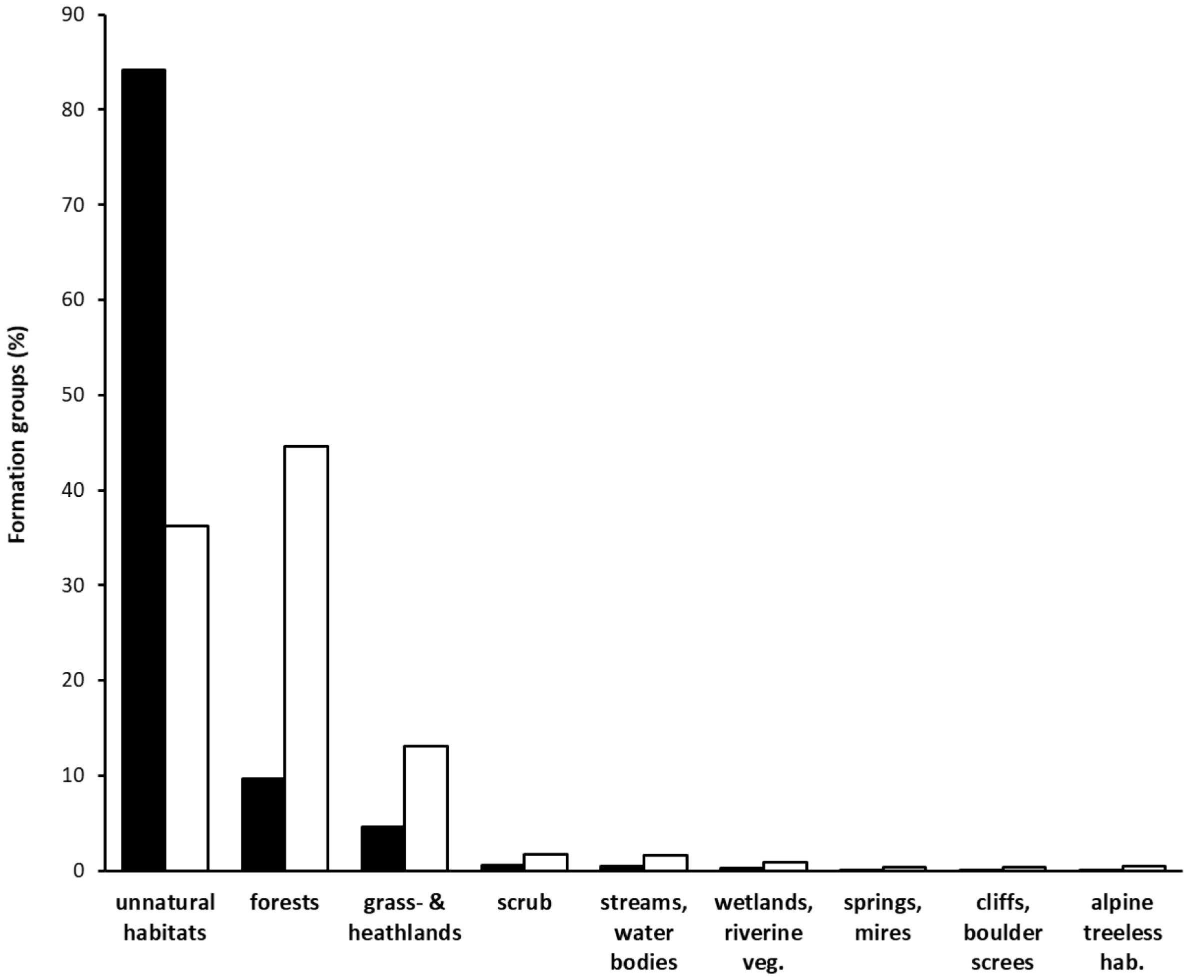

Fig. 3. Habitat composition of the whole area of the Czech Republic (filled bars) and the SPAs (open bars) according to formation groups.

Table 1
A comparison of proportions of natural habitats between SPAs (index_SPA) and the whole Czech Republic (index_CR) across various formation groups. Results of two-tailed Wilcoxon matched-pairs signed-rank tests are shown.

Formation group	n	index_SPA (mean ± SE)	index_CR (mean ± SE)	Wilcoxon test (z)	P
Alpine treeless habitats	13	0.00042 ± 0.00015	0.00003 ± 0.00001	3.18	0.002
Scrub	5	0.00344 ± 0.0025	0.00114 ± 0.0008	2.02	0.043
Forests	33	0.01353 ± 0.0043	0.00292 ± 0.0008	4.96	<0.001
Wetlands and river vegetation	19	0.00047 ± 0.00024	0.00015 ± 0.00008	3.82	<0.001
Springs and mires	13	0.00074 ± 0.00028	0.00009 ± 0.00003	3.18	0.002
Cliffs and boulder screes	7	0.00052 ± 0.00047	0.00011 ± 0.0001	2.37	0.018
Secondary grass- & heathlands	31	0.00423 ± 0.0019	0.00148 ± 0.0008	4.86	<0.001
Streams and water bodies	6	0.00270 ± 0.0017	0.00080 ± 0.0006	2.20	0.028

heathlands” ($r_s = -0.49$, n = 31, p = 0.006). We also found a significant positive correlation between prophab_SPA_1 and threat for “Wetlands and riverine vegetation” ($r_s = 0.88$, n = 6, p = 0.021).

Table 2
A comparison of proportions of natural habitats of group 1 between SPAs (index_SPA) and the whole Czech Republic (index_CR) across various formation groups. Results of two-tailed Wilcoxon matched-pairs signed-rank tests are shown.

Formation group	n	index_SPA_1 (mean ± SE)	index_CR_1 (mean ± SE)	Wilcoxon test (z)	P
Alpine treeless habitats	13	0.00033 ± 0.00012	0.00003 ± 0.00001	3.18	0.002
Scrub	5	0.00095 ± 0.0008	0.00028 ± 0.00022	1.75	0.080
Forests	33	0.00179 ± 0.0006	0.00079 ± 0.00023	3.37	0.001
Wetlands and river. vegetation	19	0.00009 ± 0.00006	0.00004 ± 0.00002	2.05	0.040
Springs and mires	13	0.00024 ± 0.0001	0.00004 ± 0.00001	2.90	0.004
Cliffs and boulder screes	7	0.00019 ± 0.00017	0.00004 ± 0.00003	1.69	0.091
Secondary grass- & heathlands	31	0.00038 ± 0.0002	0.00023 ± 0.00012	4.64	<0.001
Streams and water bodies	6	0.00017 ± 0.0001	0.00012 ± 0.00008	2.20	0.028

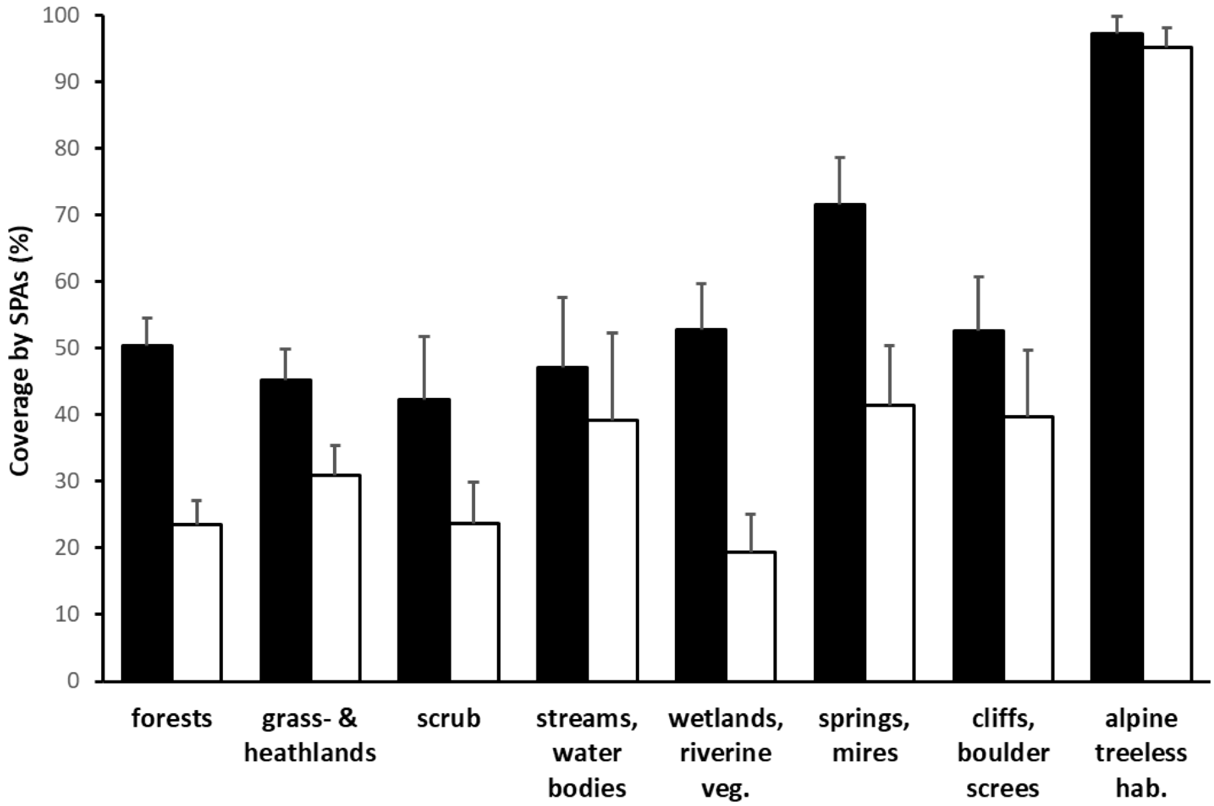

Fig. 4. Percentage of natural habitats (filled bars) and natural habitats group 1 (open bars) across various formation groups covered by the SPAs. Shown are means ± SE.

4. Discussion

Special Protection Areas (SPAs) in the focal country, the Czech Republic, were established to protect selected species of birds. We report that, additionally to this aimed benefit, SPAs have an added advantage: SPAs cover disproportionately high proportions of high quality natural habitats. Thus, the occurrence of criterion bird species may, via concept of SPAs, serve as an indicator of areas with non-randomly high proportions of well preserved natural environment. This finding confirms theoretical predictions (Padoa-Schioppa et al., 2006).

Previous empirical studies were done on very limited spatial scales, specifically a single city (Reynaud and Thioulouse, 2000) or a small part of a country (Morelli et al., 2014). Further, they did not focus on protected areas, instead studying locations heavily affected by human activities, i.e. urban and farmland, respectively. In contrast, our study explicitly focused on areas of conservation concern and comprised an unprecedented spatial scale of the whole country.

An average proportion of area of particular habitats group 1 within SPAs was also higher than an average proportion of area of particular habitats within the whole country. However, the difference was not as pronounced as that based on natural habitats of all levels of preservation (i.e., not only group 1). This pattern could be explained by relatively low habitat preferences in our sample of bird taxa: habitat specificity of criterion species may not be constrained to best preserved parts of natural habitats (i.e., habitats group 1); instead criterion species may show only general preferences for areas with relatively higher proportions of particular natural habitats or habitat formations. This may reflect the fact that our study area was located in the temperate zone: habitat preferences of temperate birds are wider than those of tropical taxa (MacArthur et al., 1966; Karr and Roth, 1971; Salisbury et al., 2012; LaManna and Martin, 2017).

An alternative or additional explanation stems from small area and/or wide scatter of the most preserved habitats in the Czech Republic relatively to large areas of SPAs. Under this scenario, the relatively low number of SPAs cannot spatially strongly correlate with the relatively large number of widely spatially separated locations of the most preserved habitats.

The variation we found in the coverage of different formation habitat groups by SPAs suggests that SPAs show different importance for the protection of different habitats and formation groups. The largest proportions of SPAs were covered by forest and meadow habitats which were the most common habitats across the whole area of the Czech Republic anyway; however, rare formation groups like treeless alpine habitats and moors were mostly confined to SPAs (Fig. 4). An overall analysis of all habitats (i.e., with no respect to which formation group they belonged to) confirmed that habitats of the Czech Republic of increasing rareness and threat are increasingly well covered by SPAs. Thus, criterion species of birds were more commonly found in areas with higher concentration of rare habitats. This pattern could be explained via higher habitat diversity in areas where rare habitats are present (leading to higher species richness: Thiollay, 1990; Veech and Crist, 2007; Maskell et al., 2019) and because rare species of birds prefer rare habitats (Debinski and Brussard, 1994; Lloyd, 2008; Seymour et al., 2015). This has important implications for nature conservancy: some criterion species may serve as useful indicators of rare habitats and SPAs may be crucial for protection of such rare habitats.

On the other hand, we caution against over-generalising these conclusions and applying them to large geographical areas with different ecological and climatic conditions (e.g., large part of continents). At such scales indication value of different bird species may vary across different locations (e.g., Alexandrino et al., 2016 vs. Parker et al., 1996). However, because of the scale of our study (whole area of the country) we can confidently state that at least in the Czech Republic SPAs are considerably richer in natural habitats compared to non-SPAs areas and that their importance increases with increasing rareness of particular habitats. These patterns suggest large indicatory potential of birds for selection of the most valuable areas for territorial conservation.

To realize this potential, a complex protection of particular areas is required. Specifically, not only particular individuals of criterion species and their breeding grounds need protection – also the whole complex of environments they use needs protection. This should translate into protection of other non-criterion species of birds other taxa. Although this sounds trivial, there is a discrepancy between conservation practice and theoretical and legislative recommendations (Fernandez and Gurrutxaga, 2010; Guixe and Arroyo, 2011; Sandor and Domsa, 2012). However, in the Czech Republic SPAs partly overlay other types protected areas – national parks, protected landscape areas, nature reserves and natural monuments (Pechanec et al., 2018). Therefore, already at present it is feasible to provide relatively effective habitat protection measures through bird species protection. Nevertheless, we suggest that nature conservancy in the Czech Republic might benefit from declaring additional SPAs.

Our results suggest that a suitable selection of so far not protected areas for SPAs designation would benefit not only focal criterion bird species but also increase protective coverage of particular habitat formations. This is in line with a recent finding from a study of wintering birds in the Czech Republic: Musilová et al. (2018) documented insufficient Natura 2000 coverage of water bodies used by waterfowl. It is an open question to what proportion of the country SPAs could be extended; however, any extension would benefit not only focal birds but also other organisms and habitats. In addition, although birds seem to be a very suitable indicator group, it is certainly advisable to expand the group of indicators for the selection of protected areas as much as possible to include other types of organisms and to define the most valuable areas for them as well. In this sense, the concept of Key Biodiversity Areas (Donald et al. 2019) seems to be particularly useful. This builds on the IBAs project in its concept and criteria, but broadens its scope to include threatened species within all groups of organisms.

CRediT authorship contribution statement

Petr Kovařík: Conceptualization, Methodology, Resources, Writing – original draft, Writing – review & editing. **Vilém Pechanec:** Conceptualization, Methodology, Software, Formal analysis, Visualization, Writing – original draft, Writing – review & editing. **Ivo Machar:** Conceptualization, Methodology, Resources, Writing – original draft, Writing – review & editing, Supervision, Project administration. **Jaromír Harmáček:** Formal analysis, Writing – original draft. **Tomáš Grim:** Validation, Writing – review & editing.

Declaration of Competing Interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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Appendix A: Special Protection Areas of the Czech Republic. Reference number = number of the area in the map (Fig. 1).

Reference number	SPA	Area (km sq.)	Subject of protection
1	CZ0211001 - Křivoklátsko	319.60	Dendrocopos medius Picus canus Pernis apivorus Glaucidium passerinum Alcedo atthis Bubo bubo Ficedula parva Ficedula albicollis
2	CZ0211010 - Rožďalovické rybníky	66.13	Grus grus Circus aeruginosus
3	CZ0211011 - Žehuňský rybník - Obora Kněžičky	19.64	Porzana porzana Ixobrychus minutus
4	CZ0311033 - Třeboňsko	473.60	Glaucidium passerinum Dryocopus martius Anas clypeata Sterna hirundo Egretta alba Anas strepera Dendrocopos medius Haliaeetus albicilla Luscinia svecica Nycticorax nycticorax Caprimulgus europaeus Lullula arborea Alcedo atthis Picus canus Ciconia nigra Pernis apivorus Circus aeruginosus Aegolius funereus Anser anser
5	CZ0311034 - Údolí Otavy a Vltavy	183.38	Glaucidium passerinum Bubo bubo
6	CZ0311035 - Řežabinec	1.11	Anser anser
7	CZ0311036 - Hlubocké obory	33.22	Dendrocopos medius

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Reference number	SPA	Area (km sq.)	Subject of protection
			Ficedula albicollis
8	CZ0311037 - Českobudějovické rybníky	63.62	Anas strepera
			Luscinia svecica
			Sterna hirundo
			Nycticorax nycticorax
			Anser anser
9	CZ0311038 - Dehtář	3.52	Sterna hirundo
			Anser anser
10	CZ0311039 - Novohradské hory	90.53	Bonasa bonasia
			Picoides tridactylus
11	CZ0311040 - Boletice	235.65	Crex crex
			Glaucidium passerinum
			Picoides tridactylus
			Lullula arborea
			Bonasa bonasia
12	CZ0311041 - Šumava	974.93	Crex crex
			Tetrao tetrix tetrix
			Tetrao urogallus
			Aegolius funereus
			Bonasa bonasia
			Dryocopus martius
			Glaucidium passerinum
			Ciconia nigra
			Picoides tridactylus
13	CZ0411002 - Doupovské hory	631.17	Ficedula parva
			Sylvia nisoria
			Dryocopus martius
			Crex crex
			Pernis apivorus
			Picus canus
			Ciconia nigra
			Lanius collurio
			Bubo bubo
			Circus aeruginosus
			Caprimulgus europaeus
14	CZ0421003 - Nádrž vodního díla Nechranice	11.91	Anser fabalis
15	CZ0421004 - Novodomské rašeliniště - Kovářská	159.63	Tetrao tetrix tetrix
			Picus canus
16	CZ0421005 - Východní Krušné hory	163.68	Tetrao tetrix tetrix
17	CZ0421006 - Labské pískovce	354.87	Crex crex
			Dryocopus martius
			Bubo bubo
			Falco peregrinus
18	CZ0511007 - Českolipsko - Dokeské pískovce a mokřady	94.09	Luscinia svecica
			Lullula arborea
			Grus grus
			Circus aeruginosus
			Caprimulgus europaeus
19	CZ0511008 - Jizerské hory	116.72	Tetrao tetrix tetrix
			Aegolius funereus
20	CZ0521009 - Krkonoše	409.39	Dryocopus martius
			Crex crex
			Aegolius funereus
			Luscinia svecica
			Tetrao tetrix tetrix
			Ficedula parva
			Ciconia nigra
21	CZ0521014 - Broumovsko	91.22	Bubo bubo
			Falco peregrinus
22	CZ0521015 - Orlické Záhoří	9.04	Crex crex
23	CZ0531012 - Bohdanečský rybník	3.07	Porzana porzana
24	CZ0531013 - Komárov	20.31	Circus cyaneus
			Asio flammeus
25	CZ0621025 - Bzenecká Doubrava - Strážnické Pomoraví	117.25	Dendrocopos syriacus
			Circus aeruginosus
			Lullula arborea
			Dendrocopos medius
			Ciconia ciconia
			Caprimulgus europaeus
26	CZ0621026 - Hovoransko - Čejkovicko	14.12	Sylvia nisoria
			Emberiza hortulana
			Dendrocopos syriacus
27	CZ0621027 - Soutok-Tvrdonicko	95.76	Dendrocopos medius
			Picus canus
			Pernis apivorus
			Alcedo atthis

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Reference number	SPA	Area (km sq.)	Subject of protection
			Milvus milvus
			Falco cherrug
			Milvus migrans
			Ciconia ciconia
			Ficedula albicollis
28	CZ0621028 - Lednické rybníky	6.85	Anas clypeata
			Netta rufina
			Anser anser
			Nycticorax nycticorax
29	CZ0621029 - Pálava	85.39	Sylvia nisoria
			Dendrocopos syriacus
			Lanius collurio
			Haliaeetus albicilla
			Dendrocopos medius
			Ciconia ciconia
			Pernis apivorus
			Ficedula albicollis
30	CZ0621030 - Střední nádrž vodního díla Nové Mlýny	10.47	Anser fabalis
			Haliaeetus albicilla
			Sterna hirundo
			Anser albifrons
			Anser anser
31	CZ0621031 - Jaroslavické rybníky	3.57	Nycticorax nycticorax
32	CZ0621032 - Podyjí	76.66	Sylvia nisoria
			Dendrocopos syriacus
33	CZ0711016 - Králický Sněžník	301.92	Crex crex
34	CZ0711017 - Jeseníky	521.65	Bonasa bonasia
			Crex crex
35	CZ0711018 - Litovelské Pomoraví	93.19	Alcedo atthis
			Dendrocopos medius
			Ficedula albicollis
36	CZ0711019 - Libavá	327.24	Crex crex
37	CZ0721023 - Horní Vsacko	269.78	Ciconia nigra
			Dendrocopos leucotos
			Crex crex
			Bonasa bonasia
			Lanius collurio
			Ficedula parva
			Picoides tridactylus
38	CZ0721024 - Hostýnské vrchy	51.77	Ficedula parva
			Dendrocopos leucotos
39	CZ0811020 - Poodří	80.43	Anas strepera
			Alcedo atthis
			Circus aeruginosus
			Botaurus stellaris
40	CZ0811021 - Heřmanský stav - Odra - Poolší	31.01	Alcedo atthis
			Luscinia svecica
			Ixobrychus minutus
41	CZ0811022 - Beskydy	417.02	Ficedula parva
			Tetrao urogallus
			Picoides tridactylus
			Dryocopus martius
			Dendrocopos leucotos
			Glaucidium passerinum
			Strix uralensis
			Ciconia nigra
			Picus canus
			Bonasa bonasia

Appendix B: Used categorization of habitats (Chytrý et al. 2010) and their Red List category (Chytrý et al., 2019).

Groups of habitats and included habitats	Red List category
1. "Natural" Habitats Units	
V - Streams and water bodies	
V1 - Macrophyte vegetation of naturally eutrophic and mesotrophic still waters	VU
V2 - Macrophyte vegetation of shallow still waters	NT
V3 - Macrophyte vegetation of oligotrophic lakes and pools	EN
V4 - Makrophyte vegetation of water streams	NT
V5 - Charophycae vegetation	VU
V6 - Vegetation with *Isoëtes* sp.	EN
M - Wetlands and riverine vegetation	
M1.1 - Reed beds of eutrophic still waters	VU

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Groups of habitats and included habitats	Red List category
M1.2 - Halophilous reed and sedge beds	EN
M1.3 - Eutrophic vegetation of muddy substrata	VU
M1.4 - Riverine reed vegetation	VU
M1.5 - Reed vegetation of brooks	EN
M1.6 - Mesotrophic vegetation of muddy substrata	EN
M1.7 - Tall-sedge beds	VU
M1.8 - Calcareous fens with *Cladium mariscus*	EN
M2.1 - Vegetation of exposed fishpond bottoms	VU
M2.2 - Annual vegetation on wet sand	EN
M2.3 - Vegetation of exposed bottoms in warm areas	EN
M2.4 - Vegetation of annual halophilous grasses	EN
M3 - Vegetation of perennial amphibious herbs	VU
M4.1 - Unvegetated river gravel banks	
M4.2 - River gravel banks with *Myricaria germanica*	EN
M4.3 - River gravel banks with *Calamagrostis pseudophragmites*	EN
M5 - *Petasites* fringes of montane brooks	VU
M6 - Muddy river banks	NT
M7 - Herbaceous fringes of lowland rivers	VU
R - Springs and mires	
R1.1 - Meadow springs with tufa formation	EN
R1.2 - Meadow springs without tufa formation	EN
R1.3 - Forests springs with tufa formation	VU
R1.4 - Forests springs without tufa formation	VU
R1.5 - Subalpine springs	VU
R2.1 - Calcareous fens	EN
R2.2 - Acidic moss-rich fens	EN
R2.3 - Transitional mires	EN
R2.4 - Peat soils with *Rhynchospora alba*	EN
R3.1 - Open raised bogs	EN
R3.2 - Raised bogs with *Pinus mugo*	EN
R3.3 - Bog hollows	VU
R3.4 - Degraded raised bogs	
S - Cliffs and boulder screes	
S1.1 - Chasmophytic vegetation of calcareous cliffs and boulder screes	VU
S1.2 - Chasmophytic vegetation of siliceous cliffs and boulder screes	VU
S1.3 - Tall grasslands on rock ledges	VU
S1.4 - Tall-forb of fine-soil-rich boulder screes	
S1.5 - *Ribes alpinum* scrub on cliffs and boulder screes	VU
S2 - Mobile screes	VU
S3 - Caves	
A - Alpine treeless habitats	
A1.1 - Wind-swept alpine grasslands	VU
A1.2 - Closed alpine grasslands	VU
A2.1 - Alpine heathlands	VU
A2.2 - Subalpine *Vaccinium* vegetation	VU
A3 - Snow beds	VU
A4.1 - Subalpine tall grasslands	NT
A4.2 - Subalpine tall-forb vegetation	VU
A4.3 - Subalpine tall-fern vegetation	NT
A5 - Cliff vegetation in the Sudeten cirques	VU
A6 - Acidophilous vegetation of alpine cliffs and boulder screes	NT
A7 - *Pinus mugo* scrub	VU
A8.1 - *Salix lapponum* subalpine scrub	NT
A8.2 - Subalpine deciduous tall scrub	VU
T - Secondary grasslands and heathlands	
T1.1 - Mesic *Arrhenanterum* meadows	VU
T1.2 - Montane *Trisetum* meadows	VU
T1.3 - *Cynosurus* pastures	NT
T1.4 - Alluvial *Alopecurus* meadows	VU
T1.5 - Wet *Cirsium* meadows	VU
T1.6 - Wet *FIlipendula* grasslands	EN
T1.7 - Continental inundated meadows	CR
T1.8 - Continental tall-forb vegetation	CR
T1.9 - Intermittently wet *Molinia* meadows	VU
T1.10 - Vegetation of wet disturbed soils	VU
T2.1 - Subalpine *Nardus* grasslands	EN
T2.2 - Montane *Nardus* grasslands with alpine species	VU
T2.3 - Submontane and montane *Nardus* grasslands	VU
T3.1 - Rock-outcrop vegetation with *Festuca pallens*	VU
T3.2 - Sesleria grasslands	EN
T3.3 - Narrow-leaved dry grasslands	VU
T3.4 - Broad-leaved dry grasslands	EN
T3.5 - Acidophilous dry grasslands	VU
T4.1 - Dry herbaceous fringes	VU
T4.2 - Mesic herbaceous fringes	VU
T5.1 - Annual vegetation of sand dunes	EN

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(*continued*)

Groups of habitats and included habitats	Red List category
T5.2 - Open sand grasslands with *Corynephorus canescens*	EN
T5.3 - *Festuca* sand grasslands	VU
T5.4 - Pannonian sand steppe grasslands	VU
T5.5 - Acidophilous grasslands on shallow soils	VU
T6.1 - Acidophilous vegetation of spring therophytes and succulets	VU
T6.2 - Basiphilous vegetation of spring therophytes and succulets	VU
T7 - Inland salt marshes	EN
T8.1 - Dry lowland and colline heaths	VU
T8.2 - Secondary submontane and montane heaths	VU
T8.3 - *Vaccinium* vegetation of cliffs and boulder screes	VU
K - Scrub	
K1 - Willow carrs	VU
K2.1 - Willow scrub of loamy and sandy river banks	VU
K2.2 - Willow scrub of river gravel banks	VU
K3 - Tall mesic and xeric scrub	VU
K4 - Low xeric scrub	VU
L - Forests	
L1 - Alder carrs	VU
L2.1 - Montane grey alder galleries	VU
L2.2 - Ash-alder alluvial forests	VU
L2.3 - Hardwood forests of lowland rivers	VU
L2.4 - Willow-poplar forests of lowland rivers	VU
L3.1 - Hercynian oak-hornbeam forests	VU
L3.2 - Polonian oak-hornbeam forests	VU
L3.3 - Carpathian oak-hornbeam forests	VU
L3.4 - Pannonian oak-hornbeam forests	VU
L4 - Ravine forests	VU
L5.1 - Herb-rich beech forests	VU
L5.2 - Montane sycamore-beech forests	VU
L5.3 - Limestone beech forests	VU
L5.4 - Acidophilous beech forests	VU
L6.1 - Peri-Alpidic basiphilous thermophilous oak forests	VU
L6.2 - Pannonian thermophilous oak forests on loess	NT
L6.3 - Pannonian thermophilous oak forests on sand	VU
L6.4 - Central European basiphilous thermophilous oak forests	VU
L6.5 - Acidophilous thermophilous oak forests	VU
L7.1 - Dry acidophilous oak forests	VU
L7.2 - Wet acidophilous oak forests	VU
L7.3 - Subcontinental pine- oak forests	EN
L7.4 - Acidophilous oak forest on sand	NT
L8.1 - Boreo-continental pine forests	VU
L8.2 - Forest-steppe pine forests	VU
L8.3 - Peri-Alpidic serpentine pine forests	VU
L9.1 - Montane *Calamagrostis* spruce forests	VU
L9.2 - Bog spruce forests	EN
L9.3 - Montane *Athyrium* spruce forests	EN
L10.1 - Birch mire forests	VU
L10.2 - Pine mire forests with *Vaccinium*	VU
L10.3 - Pine forests of continental mires with *Eriophorum*	EN
L10.4 - *Pinus rotundata* bog forests	EN
2. "Unnatural" Habitats Units *– habitats strongly influenced or created by man*	
X1 - Urbanized areas	
X2 - Intensively managed fields	
X3 - Extensively managed fields	
X4 - Permanent agricultural crops	
X5 - Intensively managed meadows	
X6 - Anthropogenic areas with sporadic vegetation outside human settlements	
X7 - Herbaceous ruderal vegetation outside human settlements	
X8 - Scrub with ruderal or alien species	
X9 - Forest plantations of allochtonous trees	
X10 - Forest clearings	
X12 - Stands of early succesional woody species	
X13 - Woody vegetation outside forest and human settlements	
X14 - Streams and water-bodies without vegetation of conservational importance	

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