Jihočeská univerzita v Českých Budějovicích
Přírodovědecká fakulta

Habitatové preference ptáků na mokřadech SV Čech a optimalizace managementu v připravované přírodní památce Sedmihorské slatiny

Diplomová práce

Bc. Vojtěch Šťastný

Vedoucí práce: Mgr. Jan Riegert, Ph.D.

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Šťastný, V., 2018: Habitatové preference ptáků na mokřadech SV Čech a optimalizace managementu v připravované přírodní památce Sedmihorské slatiny. Master thesis in Czech with English manuscript: The effect of water regime, vegetation structure and other characteristics on wetland bird communities in northeastern Bohemia – 44 p., Faculty of Science, University of South Bohemia, České Budějovice, Czech Republic.

Anotace:

Diplomová práce se zabývá vlivem stanovených environmentálních faktorů na složení ptačích společenstev a početnost jednotlivých druhů ptáků na vybraných mokřadech severovýchodních Čech. Dále studuje vliv těchto faktorů na diverzitu ptáků a procentuální zastoupení zvláště chráněných druhů dle zákona č. 114/1992 Sb. Nakonec poukazuje na využití těchto výsledků v praktické ochraně přírody. V úvodním komentáři práce je popsán charakter studované oblasti a následně rámcově možnosti implementace výsledků studie do ochrany studovaných lokalit vedoucí ke zvýšení kvality habitatů pro mokřadní společenstva ptáků. Podrobněji je zde navržena optimalizace stavu habitatů na území Sedmihorských slatin připravovaného k vyhlášení za přírodní památku.

Annotation:

The diploma thesis deals with the influence of the stated environmental factors on the composition of bird communities and density of particular bird species in selected wetlands of northeastern Bohemia. Then it studies influence of these factors on birds' diversity and proportion of specially protected species according to the Czech law (the Act No. 114/1992 Coll.). Lastly, it points out the use of these results in practical nature conservation. In the introductory comment of the thesis there is described the character of the study area and subsequently opportunities for implementation of the study results in conservation of study localities that will lead to increase of habitats quality for wetland bird communities. Detailed optimization of habitat conditions is suggested for the locality Sedmihorské slatiny that's establishment as a natural monument is prepared.

Prohlašuji, že svoji diplomovou práci jsem vypracoval samostatně pouze s použitím pramenů a literatury uvedených v seznamu citované literatury.

Prohlašuji, že v souladu s § 47b zákona č. 111/1998 Sb. v platném znění souhlasím se zveřejněním své diplomové práce, a to v nezkrácené podobě elektronickou cestou ve veřejně přístupné části databáze STAG provozované Jihočeskou univerzitou v Českých Budějovicích na jejích internetových stránkách, a to se zachováním mého autorského práva k odevzdanému textu této kvalifikační práce. Souhlasím dále s tím, aby toutéž elektronickou cestou byly v souladu s uvedeným ustanovením zákona č. 111/1998 Sb. zveřejněny posudky školitele a oponentů práce i záznam o průběhu a výsledku obhajoby kvalifikační práce. Rovněž souhlasím s porovnáním textu mé kvalifikační práce s databází kvalifikačních prací Theses.cz provozovanou Národním registrem vysokoškolských kvalifikačních prací a systémem na odhalování plagiátů.

V Českých Budějovicích, dne 17. dubna 2018

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Bc. Vojtěch Šťastný

Vyjádření o autorském podílu

VŠ collected data, VŠ and JR performed statistical analyses, VŠ (80 %) and JR (20 %) wrote manuscript. The manuscript will be sent to the journal ‘Wetlands Ecology and Management‘ (ISSN: 0923-4861 (Print) / 1572-9834 (Online), Impact Factor 1.508).

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Obsah

„No water, no life. No blue, no green.“

Sylvia Earle

1. Úvodní komentář

1.1. Úvod

Poznatky získané na základě studií habitatových preferencí různých skupin či konkrétních druhů živočichů jsou pro nás důležité ze dvou hlavních důvodů. Jednak zjišťujeme jejich nároky na prostředí a dozvídáme se tak důležitou informaci o jejich ekologii, dále nám umožňují využít je při praktické ochraně, zejména k tvorbě plánů péče o maloplošná chráněná území (MCHÚ) či dalších managementových opatření (Lõhmus 2003). Ptáci jsou jednou z nejvhodnějších skupin pro hodnocení kvality prostředí (habitatů), a proto studium jejich habitatových preferencí přináší zároveň informaci o stavu habitatů v rámci studovaných ekosystémů (BirdLife International / European Bird Census Council 2000). Vodní a mokřadní druhy patří mezi nejohroženější skupiny ptáků (Čížková et. al. 2017), stejně tak jako mokřady představují jedny ze světově nejohroženějších ekosystémů (Karakaş 2017, Nergis and Durmuş 2017). Detailní posouzení kvality ekosystémů – na základě výskytu a početnosti jednotlivých druhů ptáků, tak může významně přispět ke zvýšení efektivity jejich ochrany.

Studijní území pro tuto práci tvořila CHKO Český ráj a její okolí a několik lokalit bylo umístěno též v ptačí oblasti Rožďalovické rybníky, která je součástí soustavy chráněných území Natura 2000. Cílem práce bylo kromě stanovení vlivu vybraných faktorů na početnost ptáků, také poukázat na možnosti využití získaných výsledků v ochraně studovaných lokalit, zvláště pak na lokalitě Sedmihorské slatiny, kde je připravováno vyhlášení území za přírodní památku (PP).

1.2. Charakter studované oblasti

Ačkoliv v CHKO Český ráj dominují více lesní ekosystémy a fenomén pískovcových skalních měst, mokřady pokrývají významnou část rozlohy území a jsou její důležitou součástí.[1] I toto území však bylo v minulém století významně ovlivněno intenzivním odvodňováním. Oblast leží v povodí Labe, převažujícími dílčími povodími je řeka Jizera, která zde tvoří hlavní říční tepnu, a částečně též řeka Cidlina. Z dalších vodních systémů se zde nachází dva významné toky ústící do řeky Jizery – říčka Libuňka a Žehrovka. Na území

[1] http://webgis.nature.cz/mapomat

CHKO se nachází několik desítek rybníků – v povodí Libuňky jsou to Hrudka, Rokytnický (Rokytňák), Bažantník, Pilský a Smíchousův, v povodí Žehrovky potom Pařez, Dolský, Nebákov, Podsemínský, Vidlák, Krčák, Věžický (Věžák), soustava rybníků u Žehrova (Zezulák, Lápek, Dolní a Horní rybník), Oběšenec a Žabakor. Ze zbývajících jsou na základě rozlohy významné Jinolické rybníky (Oborský, Němeček a Vražda) a Komárovský rybník, mimo CHKO v rámci studované oblasti pak Červenský rybník u Dolního Bousova a Ostruženské rybníky u Jičína. Kromě rybníků se v oblasti nacházejí různé typy mokřadů situovaných často v zemědělské krajině, kde tvoří víceméně zbytky původně rozsáhlejších podmáčených území většinou v podobě terestrických rákosin (dvě rozlehlejší slatiniště – Libunecké rašeliniště a Sedmihorské slatiny (Obr. 1) a různé drobné mokřady v polích, situované zejména v nivě Libuňky a Žehrovky) či zarostlých odvodňovacích příkopů (tzv. liniové mokřady), ale setkáme se zde také se slatiništi v lesních údolích (např. u rybníka Krčák). Za důležité považuji zmínit prameny, které jsou významným zdrojem vody pro některé studované mokřady (např. Sedmihorské slatiny). V oblasti se nachází také lužní lesy, ty však nebyly předmětem této studie.[2] Řada zmíněných lokalit je součástí MCHÚ a mokřady jsou zde i předmětem ochrany – v rámci CHKO například PR Podtrosecká údolí, PR Žabakor nebo PP Libunecké rašeliniště, mimo CHKO se jedná o PP Ostruženské rybníky.[3]

V ptačí oblasti Rožďalovické rybníky jsou mokřady, zejména pak rybníky, stěžejními ekosystémy spolu s lesy pokrývajícími převážnou část území. V minulosti se v regionu nacházelo rybníků více. Dnes jich v rozsahu ptačí oblasti nalezneme zhruba tři desítky (např. Pilský, Hasina, Bučický, Zrcadlo, Kojetín, Nečaský, Komárovský, Vražda, Pustý, Jakubský).[4] Některé rybníky jsou rovněž chráněné jako MCHÚ – PP Dymokursko a PP Rybník Kojetín.[3] Jediným významnějším tokem v oblasti je řeka Mrlina.

Pro tuto studii bylo vybráno celkem 34 mokřadů různé rozlohy a typu (rybníky, polní mokřady (s nádrží), slatiniště a liniové mokřady) (Tab. I a Obr. 2-6, Přílohy + ESM1 a ESM3, viz. přiložený manuskript).

[2] http://ceskyraj.ochranaprirody.cz/charakteristika-oblasti/vodopis

[3] http://webgis.nature.cz/mapomat

[4] http://www.rozdalovickerybniky.eu

1.3. Vztah práce k území Sedmihorských slatin

Tato magisterská práce vznikla v návaznosti na přechozí bakalářský projekt na téma „Revitalizace mokřadu u Sedmihorek v CHKO Český ráj“ (v práci nyní užívaný název Sedmihorské slatiny). Zpracování projektu revitalizace a samotná realizace by měly proběhnout během několika následujících let, následně je v plánu Agentury ochrany přírody a krajiny (AOPK) ČR lokalitu vyhlásit za MCHÚ jako přírodní památku.

Lokalita je jednoznačně významná z hlediska zoologického, zvláště bohatá je zde avifauna (Šťastný 2015). V této práci bych rád na základě studie zaměřené na habitatové preference ptáků na mokřadech v regionu (včetně lokality Sedmihorských slatin), navrhl konkrétní managementová opatření vedoucí k dosažení optimálních podmínek pro hnízdění ptáků v celé její rozloze. Práce tak představuje jeden z klíčových podkladových dokumentů jak pro připravovaný projekt revitalizace, tak následný Návrh na vyhlášení a plán péče o PP Sedmihorské slatiny.

1.4. Využití výsledků v ochraně přírody studované oblasti

Studované mokřady v řadě případů nevykazují dle výsledků naší studie optimální prostředí pro mokřadní společenstva ptáků (viz. přiložený manuskript). Jedná se jak o chráněné, tak nechráněné lokality, a nabízí se proto různé způsoby péče o tyto lokality, případně i jejich rozsáhlejší revitalizace. Možnosti zvýšení atraktivity konkrétních lokalit pro mokřadní společenstva ptáků jsou rámcově uvedeny v Tab. I níže. Návrhy byly provedeny na základě znalosti jednotlivých lokalit z terénu a výsledků naší studie (viz. přiložený manuskript). **Nicméně, jakýmkoliv navrhovaným úpravám prostředí musí vždy předcházet komplexní průzkum lokality, aby nedošlo k neočekávanému negativnímu vlivu na ostatní skupiny živočichů či přítomnou floru.**

Tab. I. Charakteristika studovaných mokřadů a návrhy zlepšení jejich stavu s ohledem na společenstva mokřadních druhů ptáků. pm (n) – polní mokřad (s nádrží), r – rybník, lm – liniový mokřad, s – slatiniště; CHKO – chráněná krajinná oblast, PR – přírodní rezervace, PP – přírodní památka, PO – ptačí oblast; ○ / ◯ - velikost mokřadu < / > 10 ha, 💧 - trvalá otevřená vodní plocha, ≈ - podmáčená mokřadní vegetace.

Název mokřadu	Typ mokřadu	Ochrana	Současný stav prostředí	Návrh na zlepšení prostředí	Specifikace návrhu			
					zvýšení územní ochrany	úpravy managementu (v MCHÚ)	rozšíření mokřadu	revitalizace
Doubravice	pm	CHKO	○ ≈	A			+	+
Rybník Hrudka	r	CHKO, PR	○ 💧 ≈	A		+		
Pod Rokytňákem	pm	CHKO	○	N				
Rokytnice	pm	CHKO	○	A				+
Valdštejnsko	lm	CHKO	○	N				
Za Rokytňákem	pm	CHKO	○	A				+
Javornice	lm	CHKO	○	A				+
Rybník Křižák	r		○ 💧 ≈	N				
Libunecké rašeliniště	s	CHKO, PP	○ 💧	N				
Liščí Kotce	pm		○	A				+
Štěpánovice	pm		○ ≈	A				+
Sedmihorské slatiny	**s**	**CHKO**	**◯ ≈**	**A**	**+**			**+**
Sekerkovy Loučky	pm		○ ≈	A				+
Malý Porák	lm		○	N				
Ostruženský rybník	r	PP	◯ 💧 ≈	A		+		
Rybník Turecká	r	PP	◯ 💧 ≈	N				
Rybník Brodek	r		○ 💧 ≈	A	+			
Nový rybník	r		◯ 💧 ≈	A	+			
Nad Novým rybníkem	pm		○ ≈	A	+			+
Komárovský rybník	r	CHKO	◯ 💧 ≈	A	+			
Vesec u Sobotky	r	CHKO	○ 💧	N				
Veselá	pm		○ ≈	A				+
Přestavlky	r		○ 💧 ≈	A	+			

Název mokřadu	Typ mokřadu	Ochrana	Současný stav prostředí	Návrh na zlepšení prostředí	Specifikace návrhu			
					zvýšení územní ochrany	úpravy managementu (v MCHÚ)	rozšíření mokřadu	revitalizace
Rybník Žabakor	r	CHKO, PR	◯ ♦ ≈	A		+		
Všeň	pmn		○ ♦ ≈	N				
Červenský rybník	r		◯ ♦	A	+			
Zámostí, Vydalov-dům	pm		○	N				
Zámostí, Vydalov-pole	pm		○ ≈	A			+	+
Zámostí, Blata	pm	CHKO	○ ≈	A			+	+
Krčák	s	CHKO, PR	○ ≈	N				
Bezedná	s	CHKO	○	N				
Rybník Kojetín	r	PO, PP	○ ♦ ≈	N				
Rybník Zrcadlo	r	PO	◯ ♦ ≈	A	+			
Lohovský rybník	lm	PO	◯ ♦ ≈	N				

Zvýšení územní ochrany je až na jeden případ (Komárovský rybník – rozšíření 1. zóny CHKO) navrženo vyhlášením MCHÚ. Důvodem je zjištěná vysoká kvalita těchto lokalit během studie. Úpravy managementu spočívají zejména v zamezení nežádoucího nadměrného šíření dřevin do porostu rákosin a tím snižujících jejich rozlohu. Rozšíření je navrženo u těch mokřadů, které nedosahují zjištěné optimální minimální rozlohy 10 ha a dovolují to okolní podmínky. Revitalizace by pak z velké části znamenala kompenzaci v současné době více či méně degradovaných mokřadů vlivem meliorací (tvorba tůní), případně provedení zásahů vedoucích ke zvýšení hladiny podpovrchové vody, a tím zamokření mokřadní vegetace.

Obecně u velké části studovaných mokřadů chybí jejich propojení s okolní krajinou, respektive podobnými habitaty (56 %). V naprosté většině je však tato situace těžko řešitelná kvůli velké vzdálenosti mezi těmito habitaty a silné fragmentaci dopravou. Typickým příkladem je lokalita Rybník Kojetín představující kompletně izolovanou plošku (biocentrum) v intenzivní zemědělské krajině, která je zároveň přírodní památkou, a nevyhovuje tak principům vhodného designu rezervací, které by měly být propojeny (Primack 2012). V souvislosti s uvedenými problémy, nízkému počtu mokřadů v krajině a velkými vzdálenostmi mezi nimi, by v rámci studované oblasti měly být podporovány projekty zaměřené také na vytváření nových mokřadů.

1.4.1. Optimalizace managementu v připravované PP Sedmihorské slatiny

Ačkoliv lokalita byla v některých ohledech vyhodnocena jako jedna z nejkvalitnějších (nejvyšší počet druhů na mokřad, druhý nejvyšší Shannonův index diverzity), zdaleka ne všechny přítomné habitaty představují dle naší studie optimální prostředí pro typicky mokřadní druhy – dle analýz pouze jeden z celkových devíti sčítacích bodů – bod č. 20, Fig. 4, viz. přiložený manuskript (Obr. 7 a, b, Přílohy). Tento bod hostil rovněž nejvyšší počet zvláště chráněných druhů (n=6) a nejvyšší počet typicky mokřadních druhů (n=8, ostatní – rozsah 0-3). To, že se jedná o nejhodnotnější část lokality, dokazuje i pravidelný výskyt páru kriticky ohroženého jeřába popelavého (*Grus grus*) v hnízdním období již po dobu několika let. Prostředí zmíněného bodu lze charakterizovat následovně – jediný bod v rámci lokality s otevřenou vodní plochou (pokrývající však pouze 1 % z rozlohy sčítacího bodu) a zároveň jediný s nejvyšším indexem podmáčení mokřadní vegetace (tj. rozsáhlá podmáčená plocha) a 5 % zápojem keřů.

Na základě výše uvedených výsledků ornitologického monitoringu považuji prostředí zmíněného bodu v rámci lokality Sedmihorských slatin za vzorové a spolu s celkovými výsledky studie (viz. přiložený manuskript) jako dobrý základ pro stanovení budoucího managementu na této lokalitě. **Opět je však nutné provést nejdříve komplexní průzkum lokality** (AOPK ČR v současné době monitoringy ostatních skupin živočichů provádí a je v plánu i botanický průzkum – Čejka *in verb.*).

Obr. 1. Lokalita Sedmihorské slatiny z ptačí perspektivy. Foto: V. Šťastný.

V následujících bodech shrnuji konkrétní návrhy na zlepšení prostředí lokality Sedmihorské slatiny pro společenstva mokřadních druhů ptáků:

- **Provedení revitalizace v západní části území** jednak přehrazením odvodňovacích kanálů a zajištěním nefunkčnosti drenážního systému (zvýšení hladiny podpovrchové vody), jednak vytvořením soustavy tůní o různé velikosti a hloubce, s minimálně jednou tůní větší rozlohy vhodné pro hnízdění vodních druhů ptáků (např. kachen). Více viz konkrétní návrh revitalizace – Šťastný 2015 (s několika zásadními úpravami – a) ve fázi revitalizačních opatření provést pouze stržení svrchní drnové vrstvy se zachováním půdního profilu a tomu následně přizpůsobit i hloubku budovaných tůní s dosažením stejných parametrů jako v předchozím návrhu, b) největší tůň nemusí být tak rozsáhlá a může být nahrazena i dvěma menšími, důležité je však zajištění alespoň jedné či dvou trvalých tůní v rámci území s vodou po celý rok).

  Díky revitalizaci by mělo dojít k rozšíření území s viditelným podmáčením mokřadní vegetace a ke zvýšení celkové rozlohy otevřené vodní plochy na mokřadu, což by dle výsledků naší studie mělo vést ke zvýšení počtu teritorií mokřadních (i typicky vodních) druhů ptáků. Podle Nadeau and Conway (2015) je hydrologický režim mokřadu pro tyto druhy klíčový.
- **Zvýšení územní ochrany mokřadu jeho vyhlášením za přírodní památku v celém jeho rozsahu a stanovení vhodného managementu v plánu péče**. Management by spočíval v pravidelném průřezu okrajů přítomných drobných lesíků a skupin stromů, aby se zabránilo jejich nežádoucímu nadměrnému šíření do porostu rákosin. Zmlazení v těchto porostech je rovněž přínosné pro některé hnízdící mokřadní ptáky, např. slavíka modráčka (*Luscinia svecica*) (Chutný *in verb.*). Nicméně, ponechávání solitérních jedinců dřevin v rákosině, stejně tak jako udržování lesíků ve stávající rozloze, přispěje ke zvýšení druhové diverzity ptáků. Vzhledem k přítomnosti frekventované silnice a železniční trati v bezprostřední blízkosti mokřadu je vhodné udržovat v prostoru pod tratí v současnosti již přítomný pás náletových dřevin tvořící přírodní protihlukovou bariéru a alespoň částečně tak zmírňující negativní vliv hluku z dopravy (Fahrig and Rytwinski 2009). Prameniště a okolní podmáčené rákosiny s otevřenou vodní plochou (oblast zmiňovaná jako vzorová pro management lokality) by měly být nadále ponechány přirozené renaturaci a nově vzniklé vodní plochy v rámci revitalizace dle potřeby udržovány tak, aby byla v rámci území stále zajištěna určitá plocha s otevřenou vodní hladinou.

1.5. Seznam použité literatury v úvodním komentáři

BirdLife International/European Bird Census Council (2000) European bird populations: estimates and trends. BirdLife International, Cambridge

Čížková H, Vlasáková L, Květ J (ed.) (2017) Mokřady: ekologie, ochrana a udržitelné využívání. Episteme, České Budějovice

Fahrig L, Rytwinski T (2009) Effects of roads on animal abundance: an empirical review and synthesis. Ecology and Society 14:21

Karakaş R (2017) Ornithological importance of artificial ponds: a case study at Kabaklı Pond, south-eastern Anatolia, Turkey. Paddy and Water Environment 15:919-930

Lõhmus A (2003) Are certain habitats better every year? A review and a case study on birds of prey. Ecography 26:545-552

Nadeau C P, Conway C J (2015) Optimizing water depth for wetland-dependent wildlife could increase wetland restoration success, water efficiency, and water security. Restoration Ecology 23:292-300

Nergis H, Durmuş A (2017) Effects of habitat change on breeding waterbirds in Arin (Sodali) Lake, Turkey. Applied Ecology and Environmental Research 15:1111-1118

Primack R B (2012) A Primer of Conservation Biology. Sinauer Associates Inc.,U.S., Sunderland

Šťastný V (2015) Revitalizace mokřadu u Sedmihorek v CHKO Český ráj. Bc. Thesis, Faculty of Science, University of South Bohemia, České Budějovice, Czech Republic

Přílohy

Obr. 2. Lokalita Vesec u Sobotky – rybník. Foto: V. Šťastný.

Obr. 3. Lokalita Zámostí, Blata – polní mokřad. Foto: V. Šťastný.

Obr. 4. Lokalita Všeň – polní mokřad s nádrží. Foto: V. Šťastný.

Obr. 5. Lokalita Krčák – slatiniště. Foto: V. Šťastný.

Obr. 6. Lokalita Malý Porák – liniový mokřad. Foto: V. Šťastný.

Obr. 7. Lokalita Sedmihorské slatiny – sčítací bod reprezentující mokřadní habitat vysoké kvality v centrální části lokality (a) a bod reprezentující mokřadní habitat nízké kvality v západní části lokality (oblast s navrhovanou revitalizací) (b). Foto: V. Šťastný.

2. Manuskript

The effect of water regime, vegetation structure and other characteristics on wetland bird communities in northeastern Bohemia

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Abstract

Comprehensive studies on habitat preferences of wetland bird communities focussing on European reed-bed avifauna have been relatively scarce. We collected data on avian communities from 79 observational points distributed within 34 wetlands in north of the Czech Republic ranging in size from 0.76 to 70.42 ha, and relevant set of environmental factors (general, protection, size and distance characteristics, landscape characteristics, water regime and vegetation structure). We compared habitat use among wetland bird species in relation to these factors and tested their effect on species diversity and proportion of specially protected species. We found a significant effect of proportion of open water surface and bush cover, distance to open water surface and vegetation wetness index on the structure of avian communities. Shannon diversity index positively correlated with increasing proportion of bush cover, presence of neighbouring open water surface and with increasing area of wetland vegetation. The proportion of specially protected species increased with 1) decreased proportion of tree cover and number of timber species, 2) increased distance to road and 3) vegetation wetness index, 4) absence of neighbouring forest habitat or woodland landscape, 5) presence of open water surface and 6) absence of connection with other wetlands, 7) absence of the protected landscape area by the law and 8) increasing area of wetland. Results suggest that wetland quality is largely determined by water regime, vegetation structure as well as location and size of wetland. We suggest use of the results in regional practical nature conservation and recommend use in wider context.

Keywords: bird community, diversity, habitat use, management, protected species, wetland

Introduction

Wetlands represent an important ecosystem providing many functions or ecosystem services, e.g. supporting the balanced hydrological regime within landscape (Campbell and Ogden 1999). Around 20% of the world's bird species depend on wetlands as habitats for feeding, breeding, resting or overwintering (Rannestad et al. 2015). Wetlands are also most often considered as areas of conservation interest mainly due to high conservation value of their bird communities (Jenkins and Ormerod 2002). According to Tucker and Evans (1997) the inland wetlands host high numbers of bird species with conservation priority.

However, more than 90% of wetlands in Europe has been already lost (Mitsch and Gosselink 2000). They have disappeared even faster than most other landscape types (Rannestad et al. 2015) and they are one of the most endangered ecosystems around the world (Karakaş 2017, Nergis and Durmuş 2017). Inland wetlands are potentially threatened mostly by drainage and land-claim, inappropriate vegetation management and introducing of non-native species (Tucker and Evans 1997). Fragmentation of natural habitats caused that wetlands are often like islands surrounded by croplands or urbanized areas (Celada and Bogliani 1993). These remaining patches may be too isolated, too small, and too influenced by edge effects to provide environment for viable populations of breeding birds (Johnson 2001). Drainage also very often led to disappearance of many temporary wetlands within agricultural landscapes in the past (Tews et al. 2004). They can also easily disappear due to droughts as a response to climate change (Piarce-Higgins and Grant 2006).

Increasing intensity of human utilization of the environment (e.g. wetland destruction) and losses of wetlands have caused declines of particular bird species (BirdLife International/European Bird Census Council 2000, Cooper and Moore 2003, Nergis and Durmuş 2017). It has negatively affected also waterbirds depending on wetland habitats (Ma et al. 2010). Temporary wetlands within agricultural landscapes were, however, recognised as example of keystone structure and their conservation would help to maintain a high level of biodiversity (Tews et al. 2004). According to this study they are useful during integration of biodiversity conservation of conventional land use.

Birds are good indicators of the environmental stress (Buckton and Ormerod 1997, Tucker and Evans 1997, Fuller et al. 2005) and due to their widespread distribution, they can be used as indicators of change in the wider environment (BirdLife International/European Bird Census Council 2000). A key for understanding the presence of breeding birds in particular habitat is the knowledge of relative importance of different factors, such as variables at habitat and landscape scale (Báldi 2006) as well as the relationships of birds to vegetation cover (Pearce-Higgins and Grant 2006).

Comprehensive studies on habitat preferences (for definition see Morrison et al. 2006) of wetland bird communities and researches focused specifically on European reed-bed (*Fragmites* sp.) avifauna are still scarce. Tews et al. (2004) reviewed studies based on the relationship between habitat heterogeneity and animal species diversity and although he found high proportion of papers about avian fauna, in the proportion of ecosystems, the papers about wetlands were also scarce. Studies have been focused on habitat preferences on the landscape level studying the preferences among different habitats (e.g. Fuller et al. 2005), on the habitat level there have been published studies related to wetlands, however, many of them dealt with the influence of fragmentation on birds (e.g. Celada and Bogliani 1993, Johnson 2001) or for instance were focused on waterbird populations as a specific species group of wetland birds (e.g. Bolduc and Afton 2008) or other type of wetlands (e.g. Buckton and Ormerod 1997 - upland rivers, Pearce-Higgins and Grant 2006 – moorlands). Some studies have dealt with reed-nesting passerine birds, but in focus on influence of reed-bed edges (Báldi and Kisbenedek 1999) or reed archipelago (Báldi 2006).

Studies on habitat preferences are essential for establishing proper management for animal populations (Lõhmus 2003). According to this study, effective management should also consider in habitat studies often overlooked aspects of spatial and temporal patterns of habitat relationships and use the ecosystem-based approach. Complex habitat quality of wetland can be enhanced only when assessing particular priorities and trade-offs among different species and groups of conservation concern. Due to differences among regions, previous research is needed to create a specific guidance (Ma et al. 2010). Overall, biodiversity conservation is one of the main aims of wetlands management (Bobbink et al. 2006).

The aims of our study were: (1) to assess species diversity and bird community structure of wetland bird communities of different size, type, quality and in specific locations within landscape of northeastern Bohemia, (2) to compare habitat use among wetland bird species in relation to set of environmental factors (general, nature conservation, size and distance characteristics and landscape, landscape water and vegetation factors), (3) to test the effect of environmental factors on species diversity and proportion of specially protected species on wetlands and (4) based on our results to point out their usability in nature conservation, both in studied region and also in wider context.

Materials and methods

Study area

The research was performed in 34 wetlands of the northeast Bohemia in the Czech Republic (Fig. 1). The study area reached approximately 378.1 km^2. However, the studied wetlands represented only 4.2 km^2 (1.1%) of the whole surface and the area of all observational points covered 56.75 ha (13.6%) from these wetlands.

Wetlands were mostly situated in the Bohemian Paradise, Protected Landscape Area (PLA) and within its surrounding. Three wetlands were situated approximately 15 km apart from the others in the Rožďalovice Ponds, Special Protection Area - Important Bird and Biodiversity Area (IBA) that is part of the NATURA 2000 network. Basically, the Bohemian Paradise PLA is formed by harmonically created cultural hilly landscape with typical sandstone rock towns and significant representation of forests. In comparison, the Rožďalovice Ponds IBA is situated within a flat landscape with very low human population density that is essentially formed by complex of forests and ponds. The area of wetlands within the study area is nowadays smaller than in the past mainly due to the influence of amelioration in 20th century as well as in other parts of Czech Republic and Europe or in the world (Dugan 1993, Mitsch and Gosselink 2000, Millennium ecosystem assessment 2005). Therefore, the wetlands within the study area represent leftovers within fragmented the woodland–agricultural landscape.

Wetland localities included in the research were chosen based on aerial map and knowledge of the area. Wetlands of different types and sizes were selected. The proportion in types of wetlands was: fish-ponds (n=13) or others containing a reservoir (n=1), wetlands formed by isolated reed-beds situated along watercourse, within forest or as residues within the agricultural landscape (n=16) and peatlands (n=4) (ESM3). The wetland vegetation consisted predominantly of terrestrial reed (*Phragmites* sp.) - reed cover within observational point reached median 70% (range 0–100). Areas of the chosen wetlands differed greatly from 0.76 ha to 70.42 ha (median: 3.88 ha; 25 wetlands had lower size than 10 ha).

Altitude of the study area ranged between 210 to 341 meters above the sea level. The study area falls into the zone with total year amount of precipitation between 600–1000 mm and the mean year temperature 7–9 °C (743 mm and 7.7 °C in Turnov town).

Field work

In each wetland we put observational points (radius 50 meters, area 7854 m^2) with buffer the same size 50 meters. Around each wetland we placed also buffer 500 meters (Fig. 2). The shortest distance between the edges of two observational points was also 50 meters to eliminate the possibility of pseudo-replications, because most passerines nesting in wetlands have a relatively small territory (Báldi and Kisbenedek 1999). In total we collected data from 79 observational points. Number of points per a wetland depended on its size (median: 2, range 1–5 and once 9). In general, each hectare of wetland vegetation in particular wetland comprised one observational point, but in case of larger wetlands only several representative points were placed (n=6). The concrete location of points was selected with respect to capture the most representative parts of the wetlands.

The data of avian communities were collected during the two years 2016 (n=40 observational points) and 2017 (n=39 observational points). Each point was visited only in the first or second year and three times per breeding season (between 20th and 30th April, 10th and 20th May and 1st and 10th June). Birds were observed from the centre of each observational point. Every individual, which had been listened or watched within observational point during the 15 minutes observational period, was immediately written down to a printed aerial shot of the observational point with its approximate position. Bird observations were performed between dawn and 10:30 a.m. The sequence of visits the certain wetlands and also observational points within particular wetland was changed during three observations to intercept activity of different bird species and count the wetland community as widely as possible.

On every species at each observational point we collected two values - presence of species (0/1) and number of territories, which was stated based on activity of individuals of particular species (showed up interest for the area - e.g. sing, presence of pair or was observed with behaviour demonstrably showing the nesting - e.g. individual with food carrying to the nest).

During each observation the data on maximal cloudiness (0-3), precipitation (0/1), mean temperature (°C) and maximal wind (0-4) were collected. Maximal cloudiness greatly varied (median: 2, range 0-3), observations were mostly without precipitations (86.1%), mean temperature differed within the observation periods (medians and ranges: April: 2°C, 0-5°C; May: 12°C, 5-14°C; June: 13°C, 11-17°C) and maximal wind reached mostly level 0 (none) or level 1 (breeze) (in total 69.2%).

Assessment of environmental factors

In total 50 factors were collected or measured - factors related to the area of whole wetland and to observational point, some factors were also related to the wetland buffer (500 meters) or to the observational point buffer (50 meters). For simplification two superior groups of the environmental factors were defined - wetland dataset (w) and observational point dataset (op). Except for the group of general information as date, time and weather there were six different groups of environmental factors being processed. Some of them were expressed as binomial values (0/1) or as categorical levels (e.g. 0-2).

The complete list of the environmental factors consisted of:
(1) general: (w) name of wetland, x-coordinate and y-coordinate (S-JTSK Krovak) of wetland, number of observational points, (op) name of observational point, x-coordinate and y-coordinate (S-JTSK Krovak) and elevation of observational point; (2) protection: (w) protection as PLA / IBA / small-scale PLA (0/1) as three separated factors and the protection generally (presence of minimally one of these), (op) management (0-2); (3) size and distance characteristics: (w) area of whole wetland (ha), area of open water surface (% and ha), area of wetland vegetation (% and ha), distance to the nearest wetland (m), (op) distance to open water surface / watercourse / road / railway / buildings (m); (4) landscape characteristics: (w) woodland / agricultural landscape (0/1), hilliness (0-2), connection with other wetlands (0/1), human population density (1-7), the largest settlement within the wetland buffer (0-3), (op) number of natural fragments within observational point and its buffer, number of neighbouring habitats within the observational point buffer (1-7), neighbouring forest habitat (arable land / meadow / pasture) within the observational point buffer (0/1); (5) water regime: (op) vegetation wetness (0/1) and vegetation wetness index (1-3), presence of watercourse /

channel, open water surface (0/1 and %), neighbouring wetland / watercourse / open water surface within the observational point buffer (0/1); (6) vegetation structure: (op) tree / bush / herb cover (%), timber distribution (0-3), reed cover (m^2), wetland vegetation cover (%), number of timber species and non-wetland area (%).

Data for most of the environmental factors were gathered using a geographic information system (software ArcGIS), rest of them were assessed in the field. Values for most of factors were gathered once. Two factors (presence and level of the vegetation wetness) were changing during breeding season and their values were gathered during each particular visit of observational point. In general, each observational point as well as each wetland were formed by two main parts - wetland vegetation cover and open water surface, giving together 100% of the observational point area or the wetland area, respectively. Eventually some parts of observational point were classified as non-wetland area, especially in the cases of narrow or small wetlands when observational point had larger radius than the width or size of wetland. Then all the other factors related to an observational point were calculated only to wetland part of the observational point (e.g. if non-wetland area covered 20% of an observational point and half of the rest area of the observational point was covered by open water surface or tree cover, it was calculated as 50% of area). In case of wetlands, there was just one exception when wetland contained in addition also area with no vegetation neither water surface - the locality Rybník Turecká - a fishpond with very low level of water surface. The distance factors related to observational point were measured from the centre of observational point to the nearest point (edge) of relevant object, distance to the nearest wetland was measured from the centroid of particular studied wetland to the edge of the nearest wetland in landscape.

By mean, the ratio among the area of open water surface and the area of wetland vegetation (w) in wetland was 1:4. The surrounding landscape of a wetland was mostly slightly hilliness (n=15) or flat (n=12). 91% of the wetlands were situated only in agricultural landscape and 38% in woodland landscape, 29% of these wetlands were situated in mixed landscapes. Distance to nearest wetland in landscape was by mean (± s.d.) 580 ± 464 m (range 120–1948 m). Only 44% of studied wetlands were directly connected with surrounding landscape. Most of the wetlands were situated in countryside with low population density, no civilization in the 500 meters buffer was present only in 6 cases. 59% of the wetlands were preserved as PLA, small-scale PLA or IBA.

Medians for tree / bush / herb covers (op) reached 5, 5, and 95% respectively. Representation of timber species greatly varied – timbers as solitaires (1) were present at 30 points, timbers in small groups (2) were present at 26 points, one group of timbers (3) was present at 14 points (9 observational points were without timbers). Three the most dominant timber species were willow (*Salix* sp.) (n=59), alder (*Alnus* sp.) (n=40) and ash (*Fraxinus* sp.) (n=19). Median of wetland vegetation cover within an observational point reached 92% (range 35-100%), open water surface was present within an observational point in 43% and watercourse or channel in 58% of cases. No management was applied in 72% of cases. Number of natural fragments within observational point and its buffer had median 5 (range 2-16) and the mean number of neighbouring habitats was 4 from total 7 habitats (forest was present in 47%, wetland in 99%, watercourse in 59%, arable land in 51%, meadow in 63%, pasture in 13% and open water surface in 43% of cases). The vegetation wetness was present in 63% (water only in depressions: 23% - level 2, large waterlogged area: 41% - level 3), the soil of the rest of observational points was dry or only wet (level 1).

Data analyses

Firstly, the original birds' dataset based on three visits of the observational points (n=237 rows) was transformed into the observational point dataset (n=79 rows) that consisted of data merged from three observations to get maximal number of territories per observational point. Then we created the wetland dataset (n=34 rows) that consisted of data merged from the previous dataset by pooling data from all points within one particular wetland by similar manner as described above.

Subsequently, for both the datasets, we calculated three additional variables - number of bird species, proportion of specially protected species according to the Czech law (the Act No. 114/1992 Coll.) and Shannon diversity index after (Shannon 1948). In addition, we calculated one more variable for wetland dataset – number of typical wetland species. Lastly, we excluded from both these datasets (wetland dataset and observational point dataset) species that had no territory (n=38) and rare species with only one territory (n=9) in whole dataset (for typical wetland species, e.g. Eurasian Penduline Tit *Remiz pendulinus*, Gadwall *Anas strepera*, Black-headed Gull *Chroicocephalus ridibundus* and Garganey *Anas querquedula* with no territories and Common Snipe *Gallinago gallinago* and Bearded

Reedling *Panurus biarmicus* with a single territory). Then we performed regression between number of bird species and also only typical wetland species and area of whole wetland.

Multivariate data on the effect of environmental factors on composition of bird community at observational points were calculated using variance partitioning by principal coordinate analysis of neighbour matrices (PCNM) in Canoco 5 software (ter Braak and Šmilauer 2012), the method recently recommended by Marrot et al. (2015). This multivariate analysis enabled us to separate the effect of space predictors (i.e., geographical position of nest box) from the effect of primary predictors, further so-called environmental factors (Legendre and Legendre 2012). The analysis included nine steps: 1) primary predictor test (i.e., preliminary test of the overall effect of primary predictors on the dataset), 2) primary predictor selection by partial redundancy analysis (RDA) using forward selection based on partial Monte-Carlo permutation tests, 3) principal coordinate analysis (PCoA) based on Euclidean distances (i.e., finding the main space predictors based on coordinates), 4) PCNM for all predictors (i.e., preliminary test of the overall effect of space predictors on the dataset), 5) PCNM selection (i.e., the choice of space predictors based on coordinates using forward selection and partial Monte-Carlo permutation tests), 6) spatial effects analysis (i.e., assessing the amount of variability explained by space predictors), 7) primary predictor effects analysis (i.e., assessing the amount of variability explained by primary predictors), 8) joint effects analysis (i.e., assessing the amount of variability explained by both predictor types) and 9) removal of spatial effects (Šmilauer and Lepš 2014). The data unit was represented by each observational point. Response variables were represented as numbers of territories of each bird species within observational point (ESM2). As a covariate we used area of whole wetland and percentage of non-wetland area at particular observational point. The x- and y-coordinates (S-JTSK Krovak) of centres of observational points were used as the variables representing spatial coordinates. The following factors were used as explanatory variables: elevation, management, distance to open water surface, distance to watercourse, distance to road, distance to railway, distance to buildings, number of natural fragments, number of neighbouring habitats, neighbouring forest habitat, neighbouring arable land, neighbouring meadow, neighbouring pasture, vegetation wetness, vegetation wetness index, presence of watercourse / channel, presence and percentage of open water surface, neighbouring wetland, neighbouring watercourse, neighbouring open water surface, tree cover, bush cover, herb cover, timber distribution, reed cover, wetland vegetation cover, number of timber species and number of bird species. Statistical significance was obtained by Monte-Carlo permutation tests under 499 permutations.

The effect of factors on Shannon diversity index and proportion of specially protected species (dependent variables) was analysed for both datasets (observational point and wetland dataset) using generalized linear mixed models (GLMM) in R 2.14 software (R Core Team 2013) using lmer function in package LME4. Because distribution of Shannon diversity indices did not significantly differ from Gaussian distribution (Kolmogorov-Smirnov test, maximal P=0.356), we used identity link function in these analyses. Distribution of proportions of specially protected species differed in both cases from Gaussian distribution (Kolmogorov-Smirnov test, P at least 0.002) and thus we used quasi models. In graphs we used means ± s.d. in cases, when the dependent variable did not differ from Gaussian distribution. In other cases, we used medians and related parameters (25-75% of data, non-outlier range). In the analyses with dataset from observational points, we used random factor name of wetland and covariate percentage of non-wetland area within observational point. We used following independent variables: area of whole wetland, presence of watercourse / channel, distance to open water surface, distance to watercourse, distance to road, distance to railway, distance to buildings, number of timber species, tree cover, bush cover, herb cover, reed cover, wetland vegetation cover, presence and percentage of open water surface, number of natural fragments, number of neighbouring habitats, neighbouring forest habitat, neighbouring wetland, neighbouring watercourse, neighbouring arable land, neighbouring meadow, neighbouring pasture, neighbouring open water surface, vegetation wetness index, management and timber distribution.

In the analyses with dataset from wetlands, we used number of observational points as a covariate. We used following independent variables: area of wetland, area of open water surface, area of wetland vegetation, protection as small-scale PLA, protection as IBA, protection as PLA, protection generally, presence of woodland landscape, presence of agricultural landscape, distance to the nearest wetland, connection with other wetlands, hilliness, the largest settlement within the wetland buffer and human population density.

In both analyses, we used forward selection of factors based on AIC values, starting with creating a null model only with random factors / covariates.

Results

In total 2 153 adult individuals of 94 bird species were observed (56 species with minimum one territory), including 30 species that were specially protected (4 critically endangered, 11 endangered and 15 vulnerable) according to the Czech law and 33 were species typical for wetlands. In total 791 territories of birds were counted within all wetlands of which 14.7% were territories of the specially protected species (median 6.3%, range 0.0-33.3). Number of typical wetland bird species within wetlands reached median 5 (range 0-20). Within observational points, we recorded median 14 bird species (range 6-23). Three the most frequent species within observational point were Common Reed Bunting *Emberiza schoeniclus* (n=66), Common Starling *Sturnus vulgaris* (n=55) and Reed Warbler *Acrocephalus scirpaceus* (n=50) and within whole wetland they were represented by Common Starling (n=30), Common Reed Bunting (n=29) and Eurasian Blue Tit *Cyanistes cearuleus* (n=27). The first three species with highest density of territories within observational point were Reed Warbler, Sedge Warbler *Acrocephalus schoenobaenus* and Common Reed Bunting (ESM2).

Number of bird species (R^2=0,45, $F_{(1,32)}$=26,6, P < 0,001) as well as number of typical wetland species (R^2=0,58, $F_{(1,32)}$=44,2, P < 0,001) were positively correlated with area of whole wetland (Fig. 3).

Variance partitioning showed that environmental factors explained 10.2% of variability, two spatial predictors (PCO 1 and 15) explained 3.2% of variability and shared fraction was 0.3% of variability. From environmental factors, significant effect was found for open water surface (pseudo-F=4.2, P=0.002), distance to open water surface (pseudo-F=1.7, P=0.008), vegetation wetness index (pseudo-F=3.2, P=0.002) and bush cover (pseudo-F=3.3, P=0.002). Open water surface was positively correlated (correlation coefficient 0.65) and distance to open water surface was correlated negatively (-0.41) with the scores on the first ordination axis. With increasing score on the first ordination axis, we also found increasing vegetation wetness index at the observational point (Fig. 4a). Bush cover was significantly positively correlated with the scores on the second ordination axis (0.68). Bird species were clearly arranged along the first and second ordination axis. In general, typical wetland species (e.g. Water Rail *Rallus aquaticus*, Great Reed Warbler *Acrocephalus arundinaceus*, Reed Warbler, Savi’s Warbler *Locustella luscinioides*) were often recorded at observational points with highest value of vegetation wetness index and increased proportion of open water surface. Typical waterbird species (e.g. Mute Swan *Cygnus olor*, Mallard *Anas platyrhynchos*) were found at observational points with highest proportion of open water surface. Abundance of common species increased at observational points with increased bush cover (e.g. Eurasian Jay *Garrulus glandarius*, Great Spotted Woodpeck *Dendrocopos major*). Some other species (e.g. Marsh Warbler *Acrocephalus palustris*, Common Grasshopper W. *Locustella naevia*, Yellowhammer *Emberiza citrinella*) were found mainly at observational points with low proportion of bush cover and with the minimal and intermediate vegetation wetness index (Fig. 4a). When we looked at distribution of observational points of one particular wetland in the graph, we found that in most cases the observational points had different avifauna community composition (e.g. Sedmihorské slatiny [19-27], Červenský rybník [57-61], but see Rybník Zrcadlo [72-76], Fig. 4b, ESM3). On species score graphs, based on dataset used for PCNM analysis, showing three couples of species the same species family (Acrocephalidae, Emberizidae and Locustellidae) (Fig. 5), we can see that number of territories of Reed Warbler, Common Reed Bunting and Savi's Warbler increased with higher vegetation wetness index in comparison to Marsh Warbler, Yellowhammer and Common Grasshopper Warbler, of which number of territories was higher in observational points with low vegetation wetness index.

Using GLMM analyses we tested both two datasets – observational point dataset and wetland dataset. In the analysis using the observational point dataset and Shannon diversity index as dependent variable two independent variables had significant effect – bush cover and presence of neighbouring open water surface (Table 1). Bush cover was positively correlated with Shannon diversity index (Fig. 6a) and presence of neighbouring open water surface also led to increased Shannon diversity index (Fig. 6b). The second analysis based on the observational point dataset and proportion of specially protected species as dependent variable showed that six independent variables had significant effect – tree cover, distance to road, presence of neighbouring forest, presence of open water surface, number of timber species and vegetation wetness index (Table 1). Tree cover was negatively correlated with proportion of specially protected species (Fig. 6c) and distance to road was correlated positively (Fig. 6d). Presence of neighbouring forest caused lower (Fig. 6e) and presence of open water surface within an observational point higher (Fig. 6f) proportion of specially protected species than in case of absence. Number of timber species was negatively correlated with proportion of specially protected species (Fig. 6g), however, positively correlated with tree cover (r_s=0.48, P=0.009). Lastly, proportion of specially protected species was increased with higher vegetation wetness index (Fig. 6h). In the analysis using the wetland dataset and Shannon diversity index as dependent variable only area of wetland vegetation had significant effect (Table 1). Area of wetland vegetation was positively correlated with Shannon diversity index (Fig. 7a). The second analysis based on the wetland dataset and proportion of specially protected species as dependent variable showed that four independent variables had significant effect – presence of connection with other wetlands, area of whole wetland, presence of protected landscape area and presence of woodland landscape (Table 1). Presence of connection with other wetlands led to decrease of proportion of specially protected species (Fig. 7b) and area of whole wetland was positively correlated with proportion of specially protected species (Fig. 7c). Lastly, presence of protected landscape area as well as presence of woodland landscape caused decreased proportion of specially protected species (Fig. 7d and 7e). Nonetheless, the percentage of explained variability in these analyses with both, the observational point dataset and the wetland dataset, was always significantly higher with Shannon diversity index as dependent variable (Table 1).

Discussion

High total number of bird species as well as number of specially protected species recorded within the study wetlands is in agreement with previous findings (e.g. Tucker and Evans 1997, Tews et al. 2004). Presence of many rare species in wetlands relates to a scarcity of these habitats (Fuller et al. 2005). Low proportion of typical wetland species was probably caused often by small size of wetlands surrounded by landscape with non-wetland habitats and in degraded wetlands by low habitat quality (ESM1). Great variability in number of bird species among observational points reflected habitat quality of studied wetlands. The species with negligible number of territories (0 or 1 territory) equalled 50% of total number of species and contained also typical wetland species with decreasing population trend in the Czech Republic (e.g. Common Snipe). In contrast, within the first twelve species with the highest density of territories within observational points, three of them were specially protected species – Water Rail, Savi’s Warbler and Bluethroat *Luscinia svecica* that also reflect their increasing population trend in the Czech Republic. The most typical species (with the highest densities or frequencies of occurrence at observational points / wetlands) were Common Reed Bunting, Reed Warbler and Sedge Warbler, the species with increasing population trends in the Czech Republic (Šťastný et al. 2006).

Positive correlation between area of whole wetland and number of bird species (typical wetland species) is in accordance with previous results (e.g. Celada and Bogliani 1993). However, according to Johnson (2001), knowledge of area sensitivity of birds in wetlands is still weak. His finding that habitat patches required by some species are many times larger than the size of their territories could also pose a problem in case of small wetlands as remaining patches within landscape, which can hardly offer optimal conditions for breeding bird communities. We found stabilizing trend in number of bird species (typical wetland species) in wetlands that's area reached size approximately 10 ha.

In general, distribution of passerines across the reedbeds varies greatly among species due to their different ecomorphology or habitat preferences (Báldi and Kisbenedek 1999). Our results suggest that proportion of open water surface, bush cover and vegetation wetness index figured as crucial factors influencing the whole wetland bird community. Typical wetland species were abundant mostly in habitats with low proportion of bush cover, high proportion of open water surface and with high vegetation wetness index. Therefore, avian communities of observational points of one particular wetland often greatly differed among each other, as a result of variability of habitat quality among observational points. For example, the locality Sedmihorské slatiny that contained nine observational points, included only one point that's avian community was comparable with others high-quality observational points of other wetlands. Based on this finding we suggest that proportion of suitable micro-habitats within wetland may have substantial impact on shaping avian community of wetlands. This is especially the case of water conditions that clearly showed (represented as scores from multivariate analysis) its importance for chosen typical wetland species as Reed Warbler, Common Reed Bunting and Savi's Warbler.

At the observational point level, we found a positive effect of proportion of bush cover and presence of neighbouring open water surface on Shannon diversity index. We suggest that increased diversity was a result of increased habitat heterogeneity. However, in the case of bush cover, we do not suppose further increase of diversity above particular bush cover due to increasing habitat homogeneity (Tews et al. 2004). In accordance with Nadeau and Conway (2015) who considered water regime as a critical factor of wetlands for many bird species, we found a positive effect of open water surface presence and increasing vegetation wetness index on the proportion of specially protected species. In contrast, decreasing proportion was recorded within observational points with higher proportion of tree cover. Because wetland habitats, and especially reeds, host high number of bird species with high conservation priority (Tucker and Evans 1997), increased proportion of trees probably caused decreased proportion of reed vegetation and other typical wetland habitats and led to lower proportion of specially protected species. Presence of forest on a larger scale (neighbouring forest and presence of woodland landscape) caused decrease of the proportion of these species as well. We suggest that woodlands probably cause the isolation of wetlands and thus decrease value of wetland for typical wetland species, especially due to habitat closure. We expect this effect may play a key role especially in very small wetlands, where are these negative conditions accumulated. Positive correlation between proportion of specially protected species and distance to the nearest road is in accordance with most previous studies considering roads as element with negative or no effects on birds, affected mainly through traffic disturbance (Fahrig and Rytwinski 2009).

At the whole wetland level, we found that increased area of wetland vegetation increased Shannon diversity index that agree with results of other studies (e.g. Celada and Bogliani 1993). Similar relationship was found between area of wetland and proportion of specially protected species. Negative influence of presence of connection between wetlands and presence of PLA on the proportion of specially protected species were against general awareness and it was possible that these results partly reflect distribution of wetlands within landscape or their selection in the beginning of the study. However, potentially these results bring a big problem from view of the landscape-ecology due to negative aspects resulting from the isolation of patches with the high proportion of endangered species caused by agricultural intensification and landscape fragmentation (e.g. Bastian et al. 2002, Primack 2012). The second problem may be that even high-quality wetlands are still not protected (or just not as PLA).

Studies on habitat preferences in fact indirectly show wetland habitats optima for particular breeding bird species and therefore pose an important background for nature conservation. Specifically, these findings should be implemented into management plans for particular wetland localities as well as use within wetlands restoration or creation projects. Management plans that may improve habitat quality should, however, use holistic (whole ecosystem-based) approach assessing particular priorities and trade-offs among different species and groups of conservation concern due to different requirements on the environment. Restored wetlands benefit by diverse waterbird community and artificial wetlands can provide alternative or complementary habitats for these species (Ma et al. 2010, Karakaş 2017).

Practical use of our study for nature conservation in the northeastern Bohemia was also one of the main purpose of our research. Based on the results we suggest several key steps for studied wetlands: 1) restoration of some wetlands (e.g. localities Sedmihorské slatiny or Za Rokytňákem), 2) higher protection (as small-scale PLA) of some wetlands as their quality is comparable with other high-quality wetlands (e.g. localities Červenský rybník or Rybník Zrcadlo), 3) applying timber cross-section in some wetlands currently protected as small-scale PLA (e.g. localities Rybník Hrudka or Rybník Žabakor), 4) extension of some very small wetlands (e.g. localities Doubravice or Zámostí, Blata) and 5) improvement the connectivity of some wetlands with surrounding landscape via bio-corridors (e.g. localities Rybník Kojetín or Všeň) or new wetlands creation.

To conclude, avian community structure can be a reliable indicator of the wetland quality. Wetlands that contain micro-habitats of good quality with functioning natural water regime pose a key landscape structures for preserving high biodiversity within the landscape. Although achievement of such conditions in particular wetlands requires high ambitions and support in laws, it should be essentially the main purpose of studies related to habitat preferences.

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VŠ collected data, VŠ and JR performed statistical analyses, VŠ and JR wrote manuscript.

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References

Báldi A (2006) Factors influencing occurrence of passerines in the reed archipelago of Lake Velence (Hungary). Acta Ornithologica 41:1-6

Báldi A, Kisbenedek T (1999) Species-specific distribution of reed-nesting passerine birds across redd-bed edges: Effects of spatial scale and edge type. Acta Zoologica Academiae Scientiarum Hungaricae 45:97-114

Bastian O et al (2002) Landscape structures and processes. In: Bastian O, Steinhardt U Development and Perspectives of Landscape Ecology, Springer Science & Business Media, Netherlands, pp 49-112

BirdLife International/European Bird Census Council (2000) European bird populations: estimates and trends. BirdLife International, Cambridge

Bobbink R, Whigham D F, Beltman B, Verhoeven J T A (2006) Wetland Functioning in Relation to Biodiversity Conservation and Restoration. In: Bobbink R et al Wetlands: Functioning, Biodiversity Conservation, and Restoration, Springer, Verlag, Berlin, Heidelberg, pp 1-12

Bolduc F, Afton A D (2008) Monitoring waterbird abundance in wetlands: The importance of controlling results for variation in water depth. Ecological modelling 216:402-408

Buckton S T, Ormerod S J (1997) Use of a new standardized habitat survey for assessing the habitat preferences and distribution of upland river birds. Bird Study 44:327-337

Campbell C S, Ogden M H (1999) Constructed Wetlands in the Sustainable Landscape. John Wiley & Sons, New York

Celada C, Bogliani G (1993) Breeding bird communities in fragmented wetlands. Bolletino di zoologia 60:73-80.

Cooper C M, Moore M T (2003) Wetlands and Agriculture. In: Holland M M, Blood E R, Shaffer L R Achieving Sustainable Freshwater Systems: A Web of Connections, Island Press, Washington D.C., pp 221-235

Dugan P (1993) Wetlands in Danger. Michael Beasley, Reed International Books, London

Fahrig L, Rytwinski T (2009) Effects of roads on animal abundance: an empirical review and synthesis. Ecology and Society 14:21

Fuller R M et al (2005) Indices of bird-habitat preference from field surveys of birds and remote sensing of land cover: a study of south-eastern England with wider implications for conservation and biodiversity assessment. Global Ecology and Biogeography 14:223-239

Jenkins R K B, Ormerod S J (2002) Habitat preferences of breeding Water Rail *Rallus aquaticus*. Bird Study 49:2-10

Johnson D H (2001) Habitat fragmentation effects on birds in grasslands and wetlands: A critique of our knowledge. Great Plains Research 11:211-231

Karakaş R (2017) Ornithological importance of artificial ponds: a case study at Kabaklı Pond, south-eastern Anatolia, Turkey. Paddy and Water Environment 15:919-930

Legendre P, Legendre L (2012) Numerical Ecology. Elsevier, Amsterdam

Lõhmus A (2003) Are certain habitats better every year? A review and a case study on birds of prey. Ecography 26:545-552

Ma Z, Cai Y, Li B, Chen J (2010) Managing Wetland Habitats for Waterbirds: An International Perspective. Wetlands 30:15-27

Marrot P, Garant D, Charmantier A (2015) Spatial autocorrelation in fitness affects the estimation of natural selection in the wild. Methods in Ecology and Evolution 6:1474-1483

Millennium Ecosystem Assessment (2005) Ecosystems and Human Well-being: Wetlands and Water Synthesis. World Resources Institute, Washington D.C.

Mitsch W J, Gosselink J G (2000) Wetlands. Wiley, New York

Morrison M L, Marcot B G, Mannan R W (2006) Wildlife-Habitat Relationships, Concepts and Applications. Island Press, Washington D.C.

Nadeau C P, Conway C J (2015) Optimizing water depth for wetland-dependent wildlife could increase wetland restoration success, water efficiency, and water security. Restoration Ecology 23:292-300

Nergis H, Durmuş A (2017) Effects of habitat change on breeding waterbirds in Arin (Sodali) Lake, Turkey. Applied Ecology and Environmental Research 15:1111-1118

Pearce-Higgins J W, Grant M C (2006) Relationships between bird abundance and the composition and structure of moorland vegetation. Bird Study 53:112-125

Primack R B (2012) A Primer of Conservation Biology. Sinauer Associates Inc.,U.S., Sunderland

R Core Team (2013) R: A language and environment for statistical computing. R Foundation for Statistical Computing, Vienna

Rannestad O T, Tsegaye D, Munishi P K T, Moe S R (2015) Bird Abundance, Diversity and Habitat Preferences in the Riparian Zone of a Disturbed Wetland Ecosystem – the Kilombero Valley, Tanzania. Wetlands 35:521-532

Shannon C E (1948) A mathematical theory of communication. The Bell System Technical Journal 27:379-423,623-656

Šmilauer P, Lepš J (2014) Multivariate analysis of ecological data using Canoco 5. Cambridge University Press, Cambridge

Šťastný K, Bejček V, Hudec K (2006) Atlas hnízdního rozšíření ptáků v České republice. Aventinum, Prague

ter Braak C J F, Šmilauer P (2012) Canoco reference manual and user's guide: software for ordination, version 5.0. Microcomputer Power, Ithaca

Tews J et al (2004) Animal species diversity driven by habitat heterogeneity/diversity: the importance of keystone structures. Journal of Biogeography 31:79-92

Tucker G M, Evans M I (1997) Habitats for birds in Europe: a conservation strategy for the wider environment. BirdLife International, Cambridge

Table 1. The effect of factors to diversity and proportion of specially protected species based on data from observational points and whole wetland datasets (GLMM analyses, Shannon diversity index - Gaussian models, % of specially protected species - quasi models). PLA - protected landscape area.

Dependent variable	**N**	**Independent variable**	**df**	**Chi**	**beta**	**% of explained variability**	**P**
Shannon diversity index	79	Bush cover (%)	45	12.9	0.64	20.7	<0.001
		Neighbouring open water surface (0/1)	44	10.9		17.5	<0.001
% of specially protected species	79	Tree cover (%)	45	25.6	-0.54	4.2	<0.001
		Distance to road (m)	44	14.4	0.82	2.4	0.002
		Neighbouring forest habitat (0/1)	43	10.0		1.6	0.002
		Open water surface (0/1)	42	9.6		1.6	0.002
		Number of timber species (n)	41	12.8	-0.38	2.1	<0.001
		Vegetation wetness index (1-3)	39	5.2		0.8	0.073
Shannon diversity index	34	Area of wetland vegetation (ha)	32	6.0	0.71	16.4	0.014
% of specially protected species	34	Connection with other wetlands (0/1)	31	8.1		3.1	0.005
		Area of whole wetland (ha)	30	4.0	0.19	1.6	0.046
		PLA (0/1)	29	4.3		1.7	0.038
		Woodland landscape (0/1)	28	4.0		1.6	0.045

Figure 1. Map of study area.

Figure 2. Methodology of gathering areas and distances for environmental factors used in analyses.

Figure 3: Relationship between number of bird species (all species - full dots / typical wetland species - empty dots) and area of whole wetland (ha).

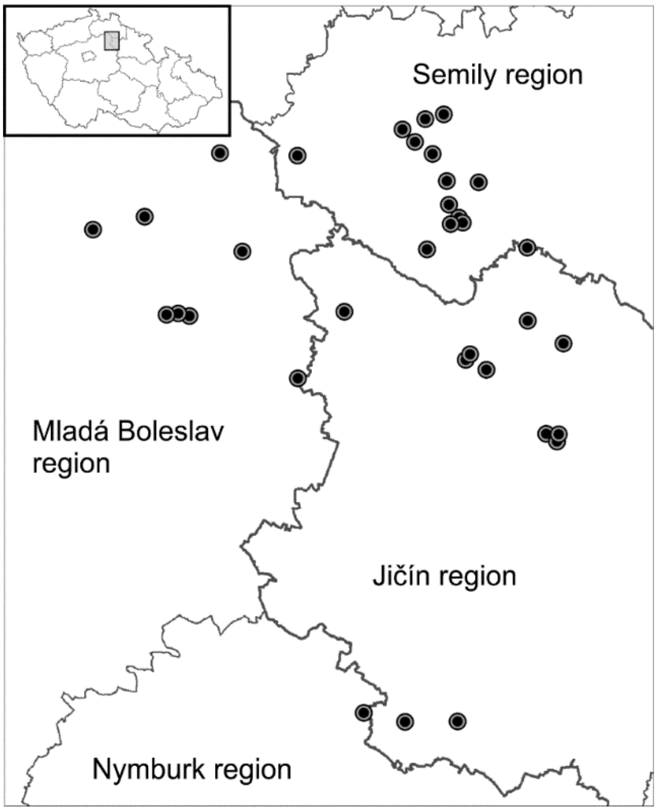
Figure 4. Projection scores for bird species number of territories (a) and wetland localities (b) in relation to environmental factors based on observational point dataset (n=79 points). Species that are typical for wetlands are in bold, other common species are not highlighted. Observational points of the wetland Sedmihorské slatiny are in italic. PCNM analysis (I and II canonical axes explain 16.7% of variability). For localities numbers see ESM1.

Figure 5. The effect of wetness vegetation index on breeding densities for three bird species pairs'. (a) Reed Warbler (empty boxes) and Marsh Warbler (full boxes), (b) Common Reed Bunting (empty boxes) and Yellowhammer (full boxes) and (c) Savi's Warbler (empty boxes) and Common Grasshopper Warbler (full boxes).

Figure 6. The effect of bush cover (a) and presence of neighbouring open water surface (b) on Shannon diversity index of avian wetland community. The effect of tree cover (c), distance to nearest road (d), presence of neighbouring forest habitat (e), presence of open water surface (f), number of timber species (g) and vegetation wetness index (h) to proportion of specially protected species. GLMM analyses based on observational point dataset (n=79 points).

Figure 7. The effect of area of wetland vegetation (a) to Shannon diversity index of avian community. The effect of connection with other wetlands (b), area of whole wetland (c), presence of protected landscape area (PLA) (d) and woodland landscape (e) to proportion of specially protected species. GLMM analyses based on wetland dataset (n=34 wetlands).

Figure 1.



Semily region
Mladá Boleslav
region
Jičín region
Nymburk region

Figure 2.

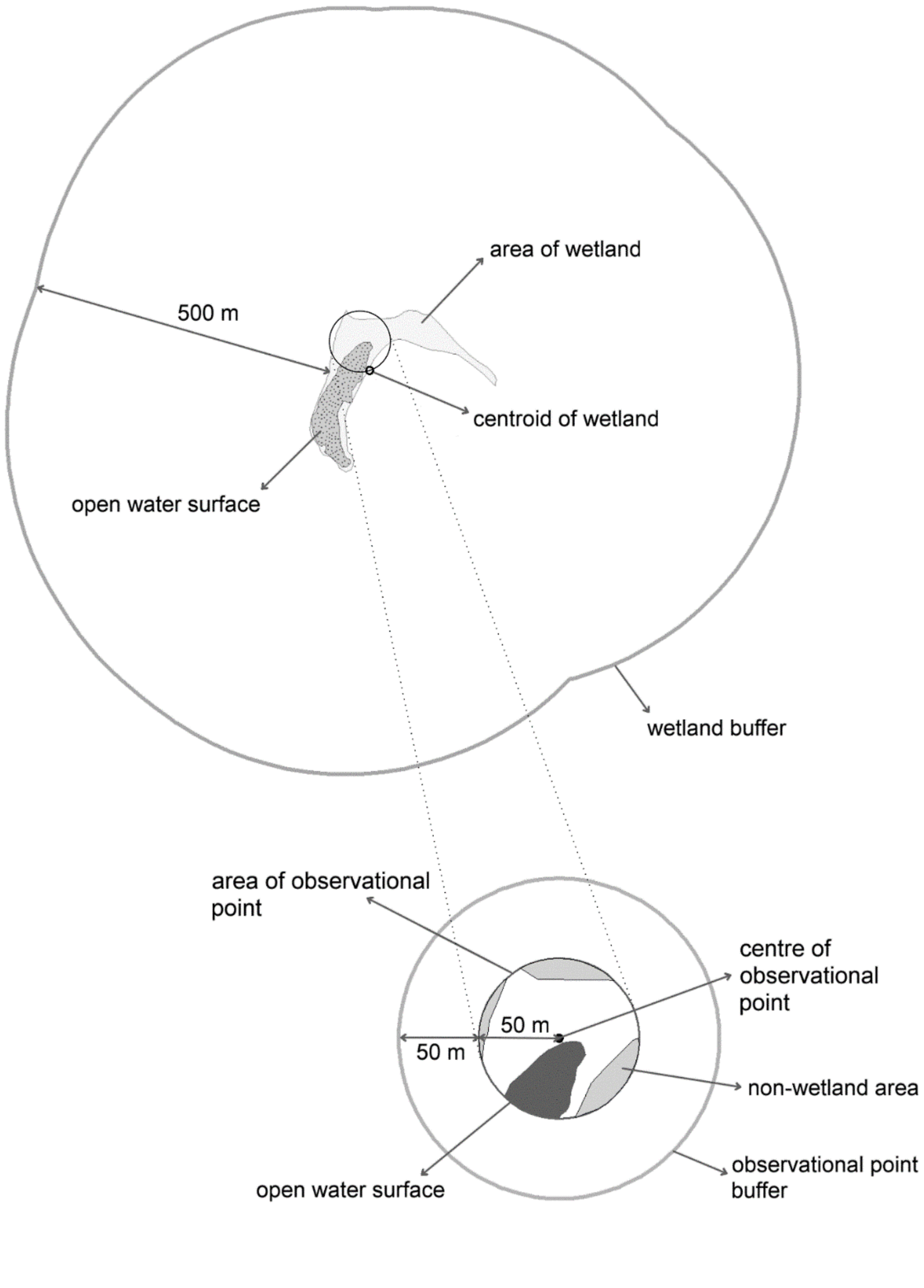
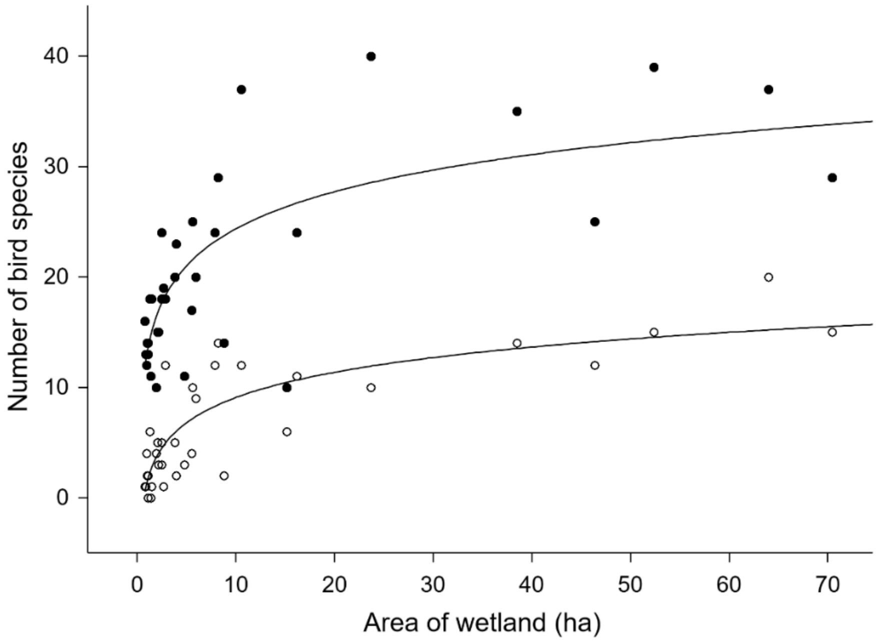
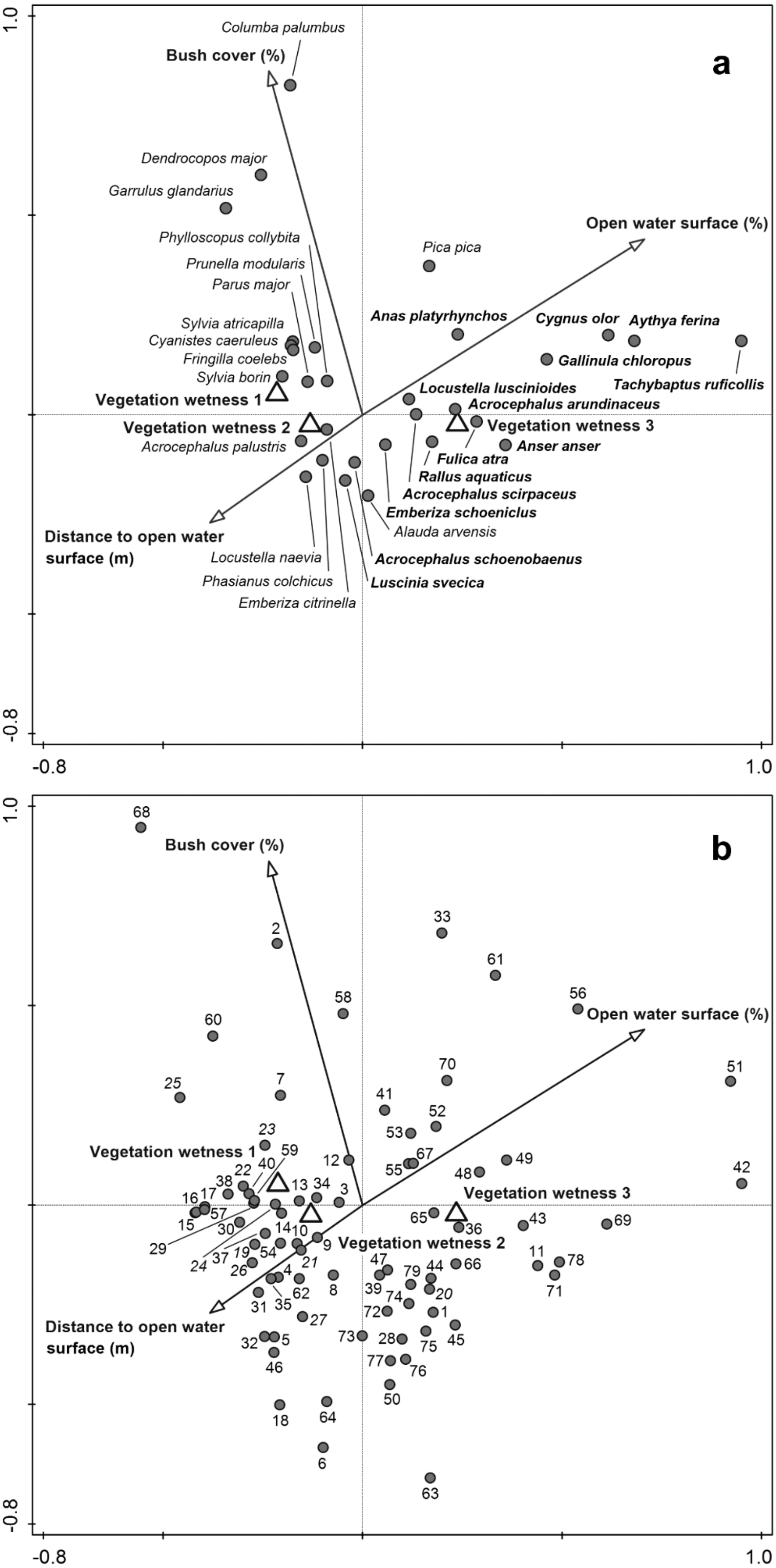

area of wetland
500 m
centroid of wetland
open water surface
wetland buffer
area of observational point
centre of observational point
50 m
50 m
non-wetland area
open water surface
observational point buffer

Figure 3.



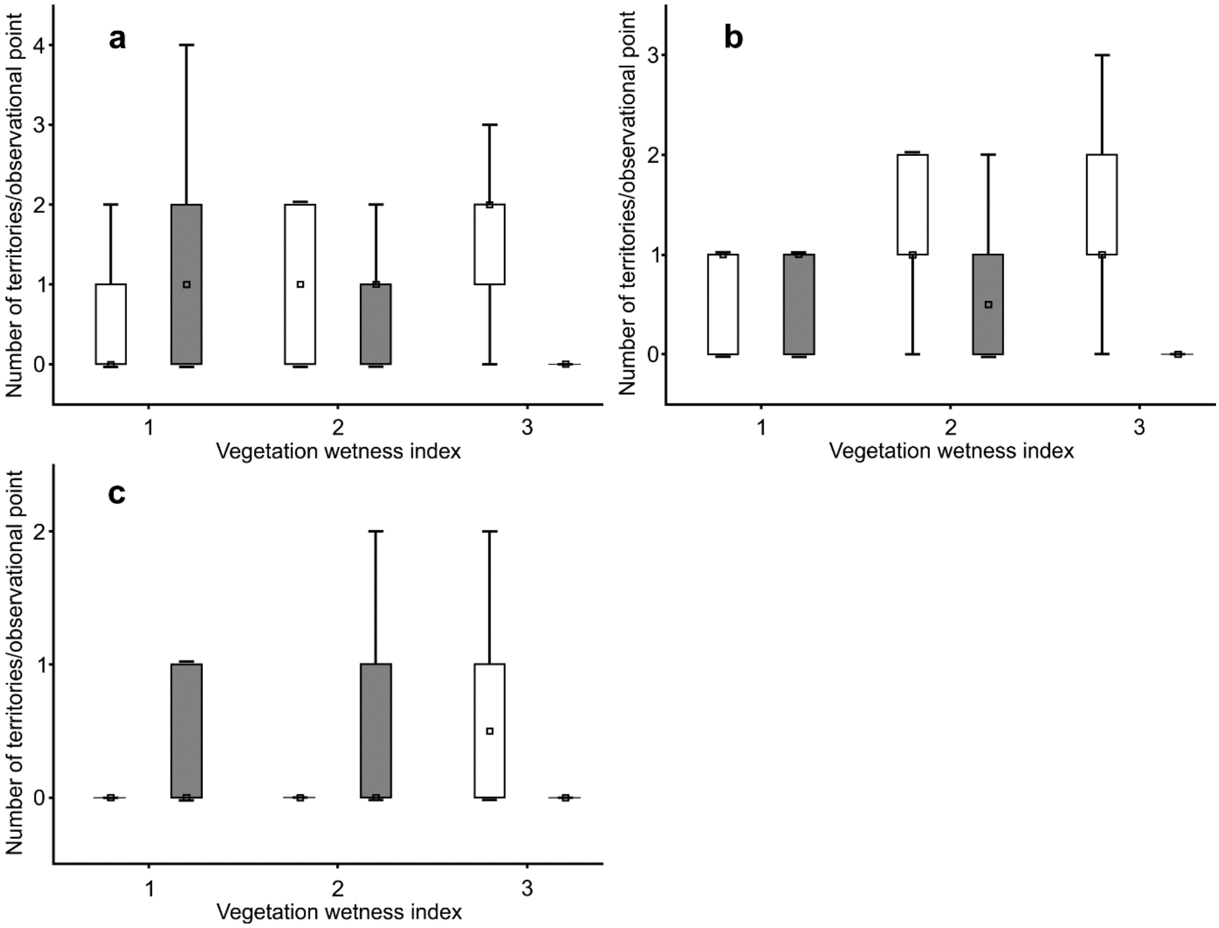
Number of bird species
40
30
20
10
0
0
10
20
30
40
50
60
70
Area of wetland (ha)

Figure 4.



a
1.0
-0.8
-0.8
1.0
Bush cover (%)
Open water surface (%)
Distance to open water surface (m)
Vegetation wetness 1
Vegetation wetness 2
Vegetation wetness 3
Columba palumbus
Dendrocopos major
Garrulus glandarius
Phylloscopus collybita
Prunella modularis
Parus major
Sylvia atricapilla
Cyanistes caeruleus
Fringilla coelebs
Sylvia borin
Acrocephalus palustris
Pica pica
Anas platyrhynchos
Cygnus olor
Aythya ferina
Gallinula chloropus
Tachybaptus ruficollis
Locustella luscinioides
Acrocephalus arundinaceus
Anser anser
Fulica atra
Rallus aquaticus
Acrocephalus scirpaceus
Emberiza schoeniclus
Alauda arvensis
Acrocephalus schoenobaenus
Luscinia svecica
Locustella naevia
Phasianus colchicus
Emberiza citrinella
b
1.0
-0.8
-0.8
1.0
Bush cover (%)
Open water surface (%)
Distance to open water surface (m)
Vegetation wetness 1
Vegetation wetness 2
Vegetation wetness 3

Figure 5.



a
b
c
Number of territories/observational point
Vegetation wetness index
0
1
2
3
4

Figure 6.

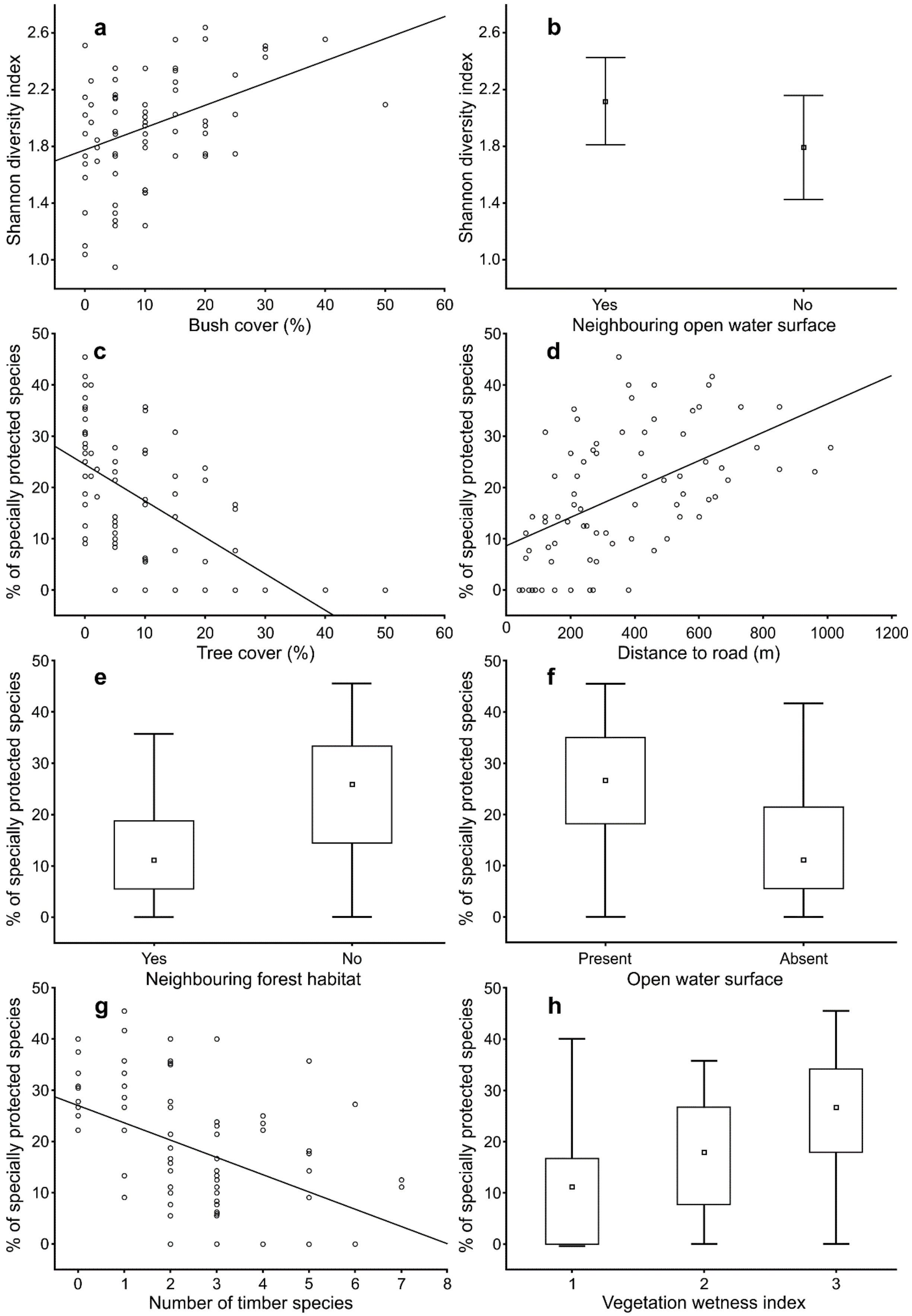
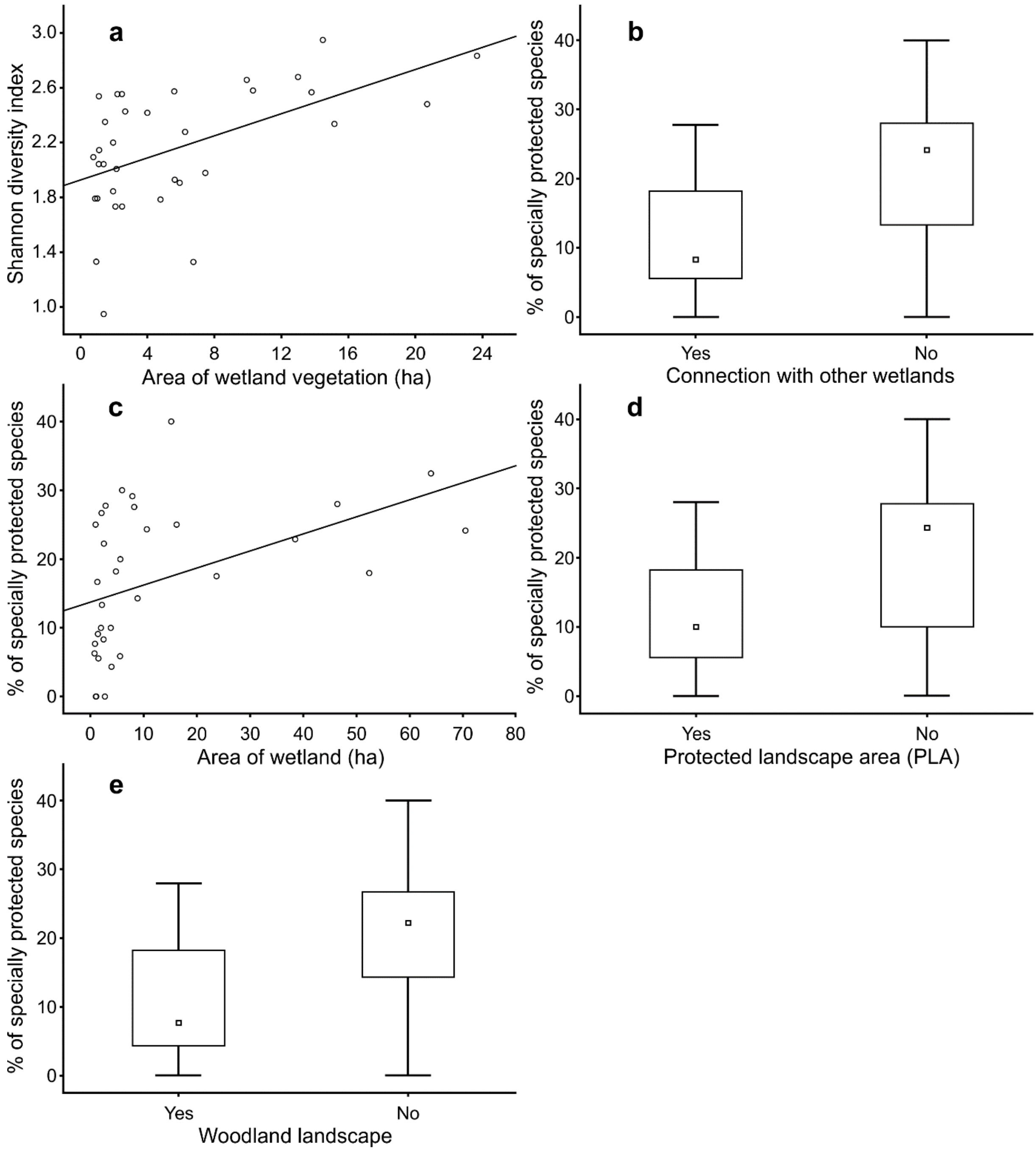

a
Shannon diversity index
Bush cover (%)
b
Shannon diversity index
Yes
No
Neighbouring open water surface
c
% of specially protected species
Tree cover (%)
d
% of specially protected species
Distance to road (m)
e
% of specially protected species
Yes
No
Neighbouring forest habitat
f
% of specially protected species
Present
Absent
Open water surface
g
% of specially protected species
Number of timber species
h
% of specially protected species
Vegetation wetness index

Figure 7.



a
Shannon diversity index
3.0
2.6
2.2
1.8
1.4
1.0
0
4
8
12
16
20
24
Area of wetland vegetation (ha)
b
% of specially protected species
40
30
20
10
0
Yes
No
Connection with other wetlands
c
% of specially protected species
40
30
20
10
0
0
10
20
30
40
50
60
70
80
Area of wetland (ha)
d
% of specially protected species
40
30
20
10
0
Yes
No
Protected landscape area (PLA)
e
% of specially protected species
40
30
20
10
0
Yes
No
Woodland landscape

ESM1. List of studied wetlands and their coordinates and characteristics. OP – observational points; FW – field wetland, FP – fishpond, LW – line wetland, PL – peatland, FWR – field wetland with reservoir; PLA – protected landscape area, NR/NM – Nature reserve/Nature monument (small-scale PLAs), IBA - Important Bird and Biodiversity Area.

Name of wetland (name of OP)	X-coordinate (S-JTSK Krovak)	Y-coordinate (S-JTSK Krovak)	Type of wetland	Area of whole wetland (ha)	Area of wetland counted by OP (%)	Area of open water surface (%)	Area of wetland vegetation (%)	Protection	Bird species (n) / Typical wetland species (n)
Doubravice (1)	-680109	-999609	FW	1,46	53	0	100	PLA	18/1
Rybník Hrudka (2)	-679926	-1001737	FP	5,53	14	60	40	PLA, NR	17/4
Pod Rokytňákem (3)	-679513	-1001416	FW	1,09	51	0	100	PLA	14/2
Rokytnice (4)	-679994	-1000791	FW	1,1	61	0	100	PLA	13/0
Valdštejnsko (5-6)	-682294	-997077	LW	2,48	35	0	100	PLA	18/3
Za Rokytňákem (7-8)	-679337	-1001676	FW	2,47	54	0	100	PLA	24/5
Javornice (9-10)	-674369	-1007610	LW	2,67	50	0	100	PLA	19/1
Rybník Křižák (11-12)	-681166	-996570	FP	3,79	27	49	51		20/5
Libunecké rašeliniště (13-14)	-676124	-1006487	PL	8,81	18	16	84	PLA, NM	14/2
Liščí Kotce (15-17)	-676157	-1002896	FW	3,97	59	0	100		23/2
Štěpánovice (18)	-678549	-999679	FW	1,38	57	0	100		11/0
Sedmihorké slatiny (19-27)	-681676	-997688	PL	23,67	29	0	100	PLA	40/10
Sekerkovy Loučky (28)	-680256	-996327	FW	0,85	69	0	100		13/1
Malý Porák (29-32)	-674688	-1012444	LW	5,61	47	0	100		25/10
Ostruženský rybník (33-36)	-675223	-1012054	FP	38,47	8	66	34	NM	35/14
Rybník Turecká (37-40)	-674604	-1012086	FP	10,55	29	3	94	NM	37/12
Rybník Brodek (41-42)	-692761	-1006255	FP	8,18	17	32	68		29/14
Nový rybník (43)	-693893	-1006210	FP	15,14	5	56	44		10/6
Nad Novým rybníkem (44-45)	-693309	-1006136	FW	5,94	26	1	99		20/9
Komárovský rybník (46-48)	-690158	-1003081	FP	46,37	5	78	22	PLA	25/12
Vesec u Sobotky (49)	-685149	-1006041	FP	2,14	30	36	64	PLA	15/3
Veselá (50)	-697519	-1002007	FW	2,07	38	0	100		15/5
Přestavlky (51)	-694963	-1001366	FP	2,86	27	25	75		18/12
Rybník Žabakor (52-54)	-691263	-998249	FP	70,42	3	71	29	PLA, NR	29/15
Všeň (55-56)	-687461	-998362	FWR	1,3	58	16	84		18/6
Červenský rybník (57-61)	-687428	-1009334	FP	52,35	7	72	28		39/15
Zámostí, Vydalov - dům (62)	-678966	-1008155	FW	0,99	71	0	100		14/2
Zámostí, Vydalov - pole (63)	-679174	-1008413	FW	0,93	46	0	100		12/4
Zámostí, Blata (64)	-678172	-1008912	FW	1,94	40	0	100	PLA	10/4
Krčák (65-67)	-681074	-1002975	PL	4,77	49	0	100	PLA, NR	11/3
Bezedná (68)	-680818	-998285	PL	0,76	73	0	100	PLA	16/1
Rybník Kojetín (69-71)	-679572	-1026218	FP	7,86	30	21	79	IBA, NM	24/12
Rybník Zrcadlo (72-76)	-682165	-1026249	FP	63,97	6	78	22	IBA	37/20
Lohovský rybník (77-79)	-684187	-1025794	LW	16,19	15	6	94	IBA	24/11

ESM2. List of typical wetland bird species recorded during our research and main characteristics of their frequency.

Species name in Latin	**Number of territories / OP (mean ± SD)**	**Number of territories / OP (range)**	**Frequency of species in wetlands**	**Category of conservation according to the Czech law**
Acrocephalus arundinaceus	0.2 ± 0.4	0 - 1	6	endangered
Acrocephalus schoenobaenus	1.1 ± 1.2	0 - 4	17	
Acrocephalus scirpaceus	1.1 ± 1.0	0 - 4	20	
Anas crecca	0.0 ± 0.2	0 - 2	1	vulnerable
Anas platyrhynchos	0.1 ± 0.5	0 - 3	16	
Anas querquedula	0.0 ± 0.0		1	endangered
Anas strepera	0.0 ± 0.0		3	vulnerable
Anser anser	0.1 ± 0.2	0 - 1	2	
Ardea cinerea	0.0 ± 0.0		7	
Aythya ferina	0.1 ± 0.5	0 - 4	6	
Charadrius dubius	0.0 ± 0.0		1	
Chroicocephalus ridibundus	0.0 ± 0.0		2	
Circus aeruginosus	0.0 ± 0.2	0 - 1	13	vulnerable
Cygnus olor	0.0 ± 0.2	0 - 1	11	
Emberiza schoeniclus	1.0 ± 0.7	0 - 3	29	
Fulica atra	0.2 ± 0.4	0 - 1	9	
Gallinago gallinago	0.0 ± 0.1	0 - 1	3	endangered
Gallinula chloropus	0.1 ± 0.3	0 - 1	6	
Grus grus	0.0 ± 0.2	0 - 1	5	critically endangered
Locustella fluviatilis	0.1 ± 0.3	0 - 1	6	
Locustella luscinioides	0.4 ± 0.6	0 - 2	9	vulnerable
Luscinia svecica	0.2 ± 0.4	0 - 1	12	endangered
Lymnocryptes minimus	0.0 ± 0.0		1	
Motacilla alba	0.0 ± 0.0		14	
Motacilla cinerea	0.0 ± 0.0		1	
Pandion haliaetus	0.0 ± 0.0		1	critically endangered
Panurus biarmicus	0.0 ± 0.1	0 - 1	1	endangered
Rallus aquaticus	0.4 ± 0.7	0 - 3	12	endangered
Remiz pendulinus	0.0 ± 0.0		3	vulnerable
Riparia riparia	0.0 ± 0.0		1	vulnerable
Tachybaptus ruficollis	0.0 ± 0.2	0 - 1	2	vulnerable
Tringa nebularia	0.0 ± 0.0		1	
Vanellus vanellus	0.0 ± 0.2	0 - 1	4	

ESM3. (a) Small fishpond (wetland locality Vesec u Sobotky, 2.14 ha) in contrast to (b) large fishpond (wetland locality Červenský rybník, 52.35 ha) illustrating wetlands containing reservoir with open water surface and (c) small field wetland (wetland locality Zámostí, Vydalov - pole, 0.93 ha) in contrast to (d) large peatlands (wetland locality Sedmihorské slatiny, 23.67 ha) illustrating wetlands as remaining patches within landscape. Photo: Vojtěch Šťastný.