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Summary of the Doctoral thesis

Impact of Climate Change on Czech Bird Populations

Vliv klimatické změny na ptačí populace v České Republice

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Abstract

Climate change is one of the most important drivers of biodiversity. If it proceeds at current pace, it will lead to homogenization and pose a serious threat to biodiversity. Birds, as one of the most researched taxonomic groups, are successfully used as indicators of biodiversity of the whole ecosystems, and thus offer an excellent opportunity to study the overall impact of climate change. We use data from repeated annual monitoring programmes in Czech Republic, Breeding Bird Monitoring Programe, based on point counts, and Constant Effort Sites mist-netting ringing programme, capture-mark-recapture schema. We found that:

1. Population growth of 6 out of 37 resident species responded negatively to seasons with lower winter temperatures. The response was stronger in species feeding on animals.
2. Long-distance (LD) migrants' breeding productivity responds negatively to higher spring temperatures and advanced spring as indicated by earlier leaf unfolding of three tree species. Residents and short-distance migrants responded positively. This distinct contrast brings clear support for the trophic mismatch hypothesis.
3. LD migrants' adult survival was positively affected by moisture (AET/PET) in the Sahelian part of their non-breeding ranges. The effect was not present in the southern part. We found no support for the carry-over effect.
4. Spring climate explained 62% variability of the breeding productivity of LD migrants, whereas AET/PET in Sahelian part of their region explained 20% of the variability of adult survival. Climate on the breeding grounds was thus more important for migrant species than the on the non-breeding grounds. Nevertheless, survival was more correlated with population growth than breeding productivity; which suggests an important missing piece of its variability was not explained by climate. This study is likely the first one to make such comparable measurement across wide spectre and long-term data of long-distance migrant species.
5. Montane species moved upwards; species breeding t higher altitudes had more negative population trend; upward shift brought more benefit to lower breeding species, suggesting that higher altitude species already have nowhere to shift.

This thesis brings enough evidence for the impact of climate on bird populations, which is most severe for montane species and long-distance migrants.

Abstrakt

Klimatická změna je jedním z nejdůležitějších faktorů ovlivňujících biodiverzitu. Pokud bude postupovat současným tempem, povede k homogenizaci a bude představovat závažnou hrozbu pro biodiverzitu. Ptáci, jakožto jedna z nejvíce probádaných taxonomických skupin, jsou úspěšně využíváni jako indikátor biodiverzity celých ekosystémů, a tudíž poskytují skvělou příležitost zkoumat celkový dopad klimatické změny. V této studii jsme využili údaje z Jednotného Programu Sčítání Ptáků (JPSP) v ČR, který je založen na bodovém sčítání, a Constant Effort Sites, programu spočívajícím v odchytu ptáků do sítí a kroužkování metodou konstantního úsilí. Zjistili jsme, že:

1. Populační růst šesti z celkem 37 rezidentních druhů reagoval negativně na sezónu s nižní teplotou v zimních měsících. to lower winter temperatures. Tento vztah byl výraznější u druhů konzumujících živočišnou potravu.
2. Hnízdní produktivita dálkových migrantů reagovala negativně na vyšší jarní teploty a časnější nástup jara, měřeno datumem rozvíjení listů u tří druhů dřevin. Rezidenti a migranti na krátké vzdálenosti reagovali naopak pozitivně. Tento kontrast přináší zřejmou podporu pro mismatch hypotézu.
3. Meziroční přežívání dospělých jedinců dálkových migrantů pozitivně reagovalo na vlhkost (AET/PET) v Sahelské části jejich zimujícího areálu. Efekt nebyl prokázán v jeho jižní části. Vliv carry-over efektu nebyl prokázán.
4. Jarní klima vysvětlilo 62% variability hnízdní produktivity dálkových migrantů, zatímco AET/PET v Sahelské části jejich zimujícího areálu vysvětlilo 20% variability meziročního přežívání dospělých ptáků. Klima na hnízdištích bylo tedy důležitější pro populace dálkových migrantů než klima na zimovištích. Nicméně, přežívání bylo více korelováno s populačním růstem než produktivita, což naznačuje důležitou nevysvětlenou komponentu variability přežívání dospělých ptáků, kterou se nepodařilo vysvětlit klimatem. Tato studije je pravděpodobně první, která klade důraz na porovnatelnost relativní důležitosti jednotlivých faktorů na širokém spektru druhů na delší časové škále.
5. Horské druhy ptáků posunuly areály do vyšších nadmořských výšek; tyto posuny areálů se více vyplatily druhům, jejichž areály byly níže položené, což naznačuje, že druhy s výše položenými areály se již nemají kam posouvat. Druhy hnízdící ve vyšších nadmořských výškách měly negativnější populační trend.

Tato práce přináší dostatek důkazů pro vliv klimatické změny na ptačí populace, který je extrémně závažný zejména pro horské druhy a pro ptáky migrující na dlouhé vzdálenosti.

Introduction

Human induced climate change is more and more urgent and alarming topic (King 2004). Climate change is one of the most important drivers of biodiversity (Pimm *et al.* 2014). If it proceeds at current pace, it will lead to homogenization and pose a serious threat to biodiversity (Thuiller *et al.* 2011). Birds, thanks to very good data availability and their position in the trophic pyramid, are great indicators of biodiversity of the whole ecosystems (Gregory *et al.* 2003, 2008; Lamb *et al.* 2009), and thus offer an excellent opportunity to study the overall impact of climate change.

Climate and it's changes in time and space have been shaping bird populations since their evolution birth. For example, bird migration evolved as an adaptation to climate variability in space and time (Louchart 2008). For this reason, we aim to focus on migration strategies and their challenges with changing climate. We also focus on a specific group, montane birds.

Winter temperature is amongst the most important predictors of bird distribution as shown by studies in Europe (Huntley *et al.* 2008) as well as in North America (Illan *et al.* 2014). Resident birds spend winter in their breeding ranges, so we might expect that their survival will be limited by climatic conditions in winter, namely temperature (Robinson, Baillie & Crick 2007).

Migratory species, from diverse taxonomic groups, ecoregions and habitats, are declining much more rapidly than residents (Wilcove & Wikelski 2008). In past decades, **long-distance migratory birds are experiencing consistent declines in Europe** (Berthold 1973; Sanderson *et al.* 2006; Heldbjerg & Fox 2008) and North America (Ballard *et al.* 2003). Migratory birds experience declines not present in residents and short-distance migratory birds to such an extent, as has been shown by multiple studies around the world (Lemoine *et al.* 2007; Heldbjerg & Fox 2008; Van Turnhout *et al.* 2010; Laaksonen & Lehikoinen 2013; Simmons *et al.* 2015).

Most discussed pressure on long-distance migratory birds is the **trophic mismatch hypothesis**. It is general phenomena present accross many taxa. Changing climate, in particular raising spring temperatures (Schwartz, Ahas & Aasa 2006), result in phenology shifts which differ among various trophic levels. In case of long-distance migratory birds, the mismatch occurs between the timing of peaks of their food (typically caterpillars) and timing of their breeding. Rising temperatures result in earlier onset of budburst and leaf unfolding and consequently earlier hatching of caterpillars, most important avian food source in breeding period. Bird phenology advanced as well, however, long-distance migrants are not able to adjust their phenology as much as short-distance migrants or residents (Saino *et al.* 2011; Kolarova & Adamik 2015). This trophic mismatch results in lower breeding productivity (Both & Visser 2005; Clausen & Clausen 2013) and subsequent population decline (Both *et al.* 2006; Møller, Rubolini & Lehikoinen 2008).

Long-distance (LD) migrants are also affected by on passage and wintering grounds. Famous is the **relationship between precipitation in the Sahel and survival of LD migrants**, which led to their severe population declines during the Sahel droughts in 70s and 80s (Winstanley, Spencer & Williamson 1974; Peach, Baillie & Underhill 1991). These conditions may also carry-over to affect the breeding season (Newton 2004; Norris & Marra 2007). Extent of the current impact on populations is, however, still unclear and also most of these studies come from western Europe, mostly UK; studies from other regions of Europe are still lacking (Ockendon, Johnston & Baillie 2014; Johnston *et al.* 2016).

Both major hypotheses sketched on what affects long-distance migrant populations have been pretty well described and confirmed. Unfortunatelly, very little is known on their relative importance and contribution to the general population changes of long-distance migrants (Pearce-Higgins *et al.* 2008; Norman & Peach 2013; Pöysä & Väänänen 2014). These studies, however, focus only on single species from very small geographical area. But in fact, general, multi-species studies focusing on the comparison of relative importance of major factors and mechanisms shaping species populations are critical for understanding the causes of declines (Vickery et al., 2014). This knowledge gap is filled by our **Paper IV.**

Climate change favors warm loving species, while cold-loving species decline (Lemoine *et al.* 2007; Gregory *et al.* 2009). This is also case of montane **species** (Lehikoinen *et al.* 2014). While cold-loving species can adapt by shifting their ranges northwards (La Sorte & Thompson 2007; Huntley *et al.* 2008), mountain species without access to higher elevations are especially vulnerable, since they have nowhere to shift (Şekercioğlu *et al.* 2008). Not only montane birds are threatened; the same pattern has also been described in butteflies (Forister *et al.* 2010) and plants (Lenoir *et al.* 2008). Although several studies predicted the impact of these threats according to future climate conditions (Chamberlain *et al.* 2013), empirical evidence for these impacts remains limited due to the lack of long-term data on species' distribution and abundance at high altitudes (Chamberlain *et al.* 2012). We fill this knowledge gap by our **Paper III.**

Aims

We set the following aims:

- Compare available monitoring schemes and determine most appropriate one for our purpose (**Paper I)**.
- Determine the impact of winter temperature on populations of resident birds (**Paper II).**
- Determine the key drivers that lead to the general decline of long-distance migratory birds (**Paper IV)**, in particular:
    - Test if long-distance migrant birds respond negatively to spring temperature and earlier spring onset, and if their response is more negative than in short-distance migrants and residents, as suggested by the *trophic mismatch hypothesis*.
    - Test if long-distance migrants suffer from droughts in their wintering grounds in sub-Saharan Africa, namely the Sahel region.
    - Compare the relative strength of both effects to be able to determine the key driver of long-distance migrant population changes.
- Determine how montane species cope with climate change:
    - Test if their population trend is dependent on altitude and life history traits.
    - Test if they adapt by shifting their altitudinal range and how much this adaptation actually helps them to improve their population trends.

Material and Methods

Our base dataset for **Papers I, II and III** is the data from Czech Breeding Bird Monitoring Programme (BBMP) between 1982 and 2007. BBMP is a large-scale generic bird monitoring scheme based on fieldwork of skilled volunteers. All 335 census sites are scattered throughout the whole territory of the country and they form a representative sample of the Czech landscape (Reif et al. 2008a). Standardized point counts are used as a field method with 20 points visited two times per breeding season (to detect both early and late breeding species) at each census site. During one visit, all birds seen or heard were recorded for five minutes on each census point. In **Paper I,** we compared these data with data from Czech Breeding Bird Atlas mapping.

In **Paper II,** we modelled the inter-annual population growth as a function of temperature in different winter months. We then analyzed the responses according to diet and body mass.

In **Paper III,** we have used a special set of point count data located in Giant Mountains, collected by Jiří Flousek. These data follow the same scheme as the Czech BBMP data. We ran a linear model, one species as one data point, trend as a response variable, with the following explanatory variables: mean altitude, altitudinal range shift, migration strategy, life history strategy (fast/slow resp. r-/K- strategy) and European climatic niche (Reif *et al.* 2013).

In **Paper IV**, we used data from the Constant Effort Sites (CES) mist-netting scheme in the Czech Republic from 2004 to 2014. This bird ringing programme is based on annual collecting of capture-mark-recapture data for numerous species of small passerines using a network of skilled volunteers under a standard protocol. At each of 43 sites scattered throughout the Czech Republic, birds were mist-netted during 9 visits in ca 10-day intervals covering the advanced breeding season (May - July) every year. During each visit of a given site, the ringer opened at least 70 m of mist nets for six hours and sampled the birds. Using these data allowed us to not only the population changes, but also key demographic parameters:

- **adult survival**: probability that adult resident bird will survive to the next year;
- **breeding productivity**: number of juveniles divided by number of adult population in a given year.

Our dataset provided results for 8 LD migrants, 8 SD migrants, 4 partial migrants and 1 resident species. Next, we used the following climatic variables:

- at the breeding grounds (Czech Republic):
  - mean monthly temperature in March – June;
  - GDD5 – Growing Degree Days – sum of daily temperatures above 5°C in March and April;
  - phenology of 3 tree species – Julian date of 10% leaf unfolding of *Tilia Cordata, Salix caprea* and *Sambucus nigra*;
- at the non-breeding grounds (sub-Saharan Africa):
  - AET/PET (actual to potential evapotranspiration) in species‘ individual non-breeding ranges. AET/PET ranges from 0 (no water at all) to 1 (100% saturation with water).

We did test the following hypotheses:

1. Breeding productivity of long-distance migratory birds will be negatively affected by spring temperature, GDD5, and earlier spring onset measured by leaf unfolding;
   a. for short-distance and resident birds we expect this effect to be neutral or opposite.
2. Adult survival will be positively affected by higher moisture (indicated by higher AET/PET ratio) in the non-breeding grounds. This effect will be stronger in the Sahelian part of their non-breeding range.
3. Breeding productivity will be positively affected by AET/PET in non-breeding grounds (carry-over effect).

Most importantly, we compared the strength of the above efects and their relative contribution to population changes.

Results and discussion

Paper I: Despite the fact that BBMP data cover much less area than the Atlas, thanks to the unified methodology performed constantly every year, the BBMP data are much more reliable information relative abundance changes than Atlas mapping. For this reason, we chose regular monitoring programmes for our further research.

Paper II: The effect of winter temperature is present, however, it is much weaker than we expected. This might be due to other influencing factors like land-use changes (Gregory *et al.* 2007; Reif & Hanzelka 2016), or due to the fact that, in contrast to e.g. Robinson, Baillie & Crick (2007) we did not study survival as a direct demographic parameter. For this reason, in our next study **(Paper IV)**, we focused on very detailed demographic analysis, which allows to disentangle various factors contributing to population changes.

Paper IV: Long-distance migrants' productivity indeed responds negatively to higher spring temperature and advanced plant phenology (see Figure 1). On the other hand, resident and short-distance (SD) migrant species responded significantly positively, partial migrants' response was also positive (though not significant). The distinct contrast between LD migrants and the other migratory strategies is a support for the trophic mismatch hypothesis.

Survival of adult individuals was significantly positively affected by AET/PET (moisture) – but only in the Sahelian part of their non-breeding ranges, not in the southern part. This might be due to the fact that Sahel is a first stop after the Sahara desert in the autumn migration (Tøttrup *et al.* 2012), and is also important refuelling station before crossing the Sahara desert in the spring migration (Risely, Blackburn & Cresswell 2015). Another reason could be that the Sahel region is very dry, so we can expect much more severe impact of water limitation on biota than in more moist regions of Africa (Hawkins *et al.* 2003). We did not see a significant carry-over effect; probably because this effect is much more indirect and complicated (Calvert, Walde & Taylor 2009).

Spring climate explained 62% variability of the breeding productivity (see Table 2 of Paper IV), whereas AET/PET (moisture) in Sahelian part of non-breeding ranges explains only 20% of the variability of the adult survival. As far as we know, our study is the first one to make such comparable measurement across wide spectre of long-distance migrant species, apart from few, very local studies (Pearce-Higgins *et al.* 2008; Norman & Peach 2013; Pöysä & Väänänen 2014). On the other hand, survival was more correlated with population growth than breeding productivity, possibly because it apparently contains large component that we have not explained by moisture in Africa – either due to poor localization of their wintering grounds, or other factors affecting adult or juvenile survival that come into play – land use change in sub-Saharan Africa (Zwarts *et al.* 2009) or more complex dynamic involving negative density dependence (Calvert, Walde & Taylor 2009).

Paper III Temperatures in the breeding season increased 0.04 – 0.08°C/year, depending on the station. Species moved upwards during the study period. Species breeding at higher altitudes had more negative trend. Moreover, the interaction of mean altitude and altitudinal range shift has shown that altitudinal range shift correlated with more positive trend in lower altitude species than higher altitude species. All these findings are in concordance with our expectations. Raising temperatures causes birds to track their climatic optima and shift upwards (Grytnes *et al.*; Chen *et al.* 2009). Species breeding at higher altitudes have nowhere to shift, which results in their declines. On the other hand, species breeding at lower altitudes, which shifted their range upwards, had more positive trend.

Our study thus brings an important evidence on a long-term, multi-species dataset, and confirms that if the climate change progresses at the current speed, montane birds are in urgent trouble. We suggest that conservation efforts should be made to protect their habitats in order not to add further pressure on their populations.

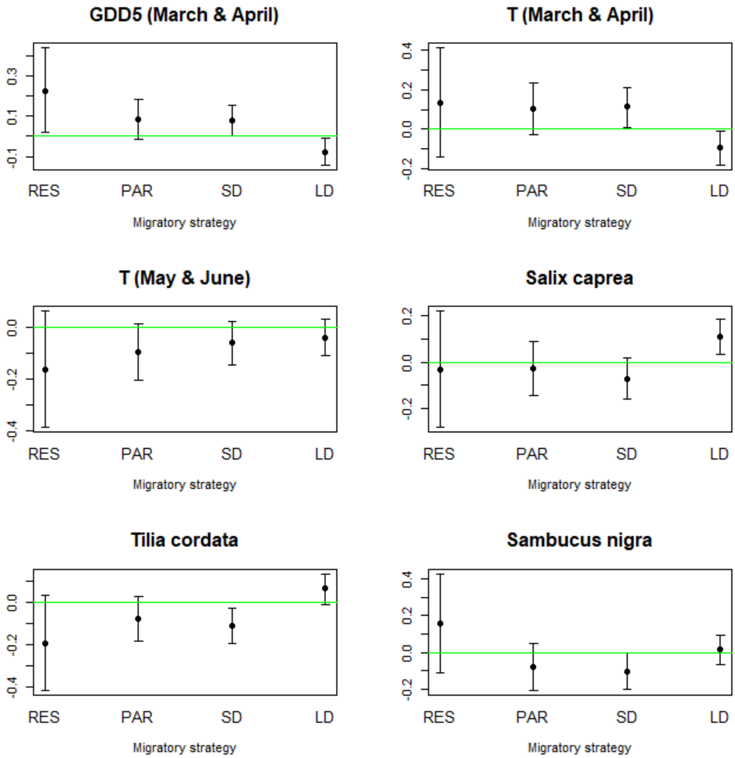

Figure 1 Relationships between breeding productivity of bird groups defined by different migratory strategies and climatic variables reflecting spring phenology at breeding grounds. Each variable was tested in a single model taking also the potential effect of population density into account (see Table S4 in Paper IV for full results of each model). The relationships are expressed as mean slopes across species sharing a given migratory strategy with 95% confidence intervals (y-axis). Climatic variables: GDD5 – growing degree days, i.e. accumulated temperature above 5°C; T – mean temperature; *Salix caprea, Tilia cordata, Sambucus nigra* – Julian date of 10% leaf unfolding for a given plant species. Migratory strategy: RES – resident, PAR – partial, SD – short-distance migrant, LD – long-distance migrant. See Paper IV for more details.

Conclusions

In **Paper I**, we have compared the data quality from the regular Breeding Bird Monitoring programme with the Atlas mapping. Despite the fact that BBMP data cover much less area than the Atlas, thanks to the unified methodology performed constantly every year, the BBMP delivered much more reliable information on relative abundance changes than Atlas mapping. For this reason, we chose regular monitoring programmes for our further research.

In **Paper II**, we found that six out of 37 resident species, for which the data was available, responded negatively to lower winter temperatures. The response was stronger in species feeding on animals, potentially due to lower availability of prey.

In **Paper IV,** we found that long-distance migrants' breeding productivity responds negatively to higher spring temperatures and advanced spring indicated by earlier leaf unfolding of three tree species. Residents and short-distance migrants responded positively. The distinct contrast between the response of long-distance migrants and the other migratory strategies brings a support for the trophic mismatch hypothesis. In other words, residents, short-distance and partial migrants can arrive earlier and thus can profit from earlier spring onset, whereas long-distance migrants, unable to advance their arrival to breeding grounds as much as residents, respond negatively.

We also found that survival of adult individuals of long-distance migrants was positively affected by moisture (AET/PET) in the Sahelian part of their non-breeding ranges. The effect was not present in the southern part. This suggest that the conditions in the Sahel have overall great importance on the populations of long-distance migrants, whether they actually do or do not spend whole winter in that region. We found no support for the carry-over effect.

We found that spring climate explained 62% variability of the breeding productivity, whereas AET/PET (moisture) in Sahelian part of non-breeding ranges explains 20% of the variability of the adult survival. Thus, climate on the breeding grounds is more important for migrant species than the climate on the non-breeding grounds. On the other hand, survival was more correlated with population growth than breeding productivity. This suggests that either the single unknown component of population dynamics – juvenile survival – is buffering the effect of productivity via density dependence, or is affected by other factors that we do not explain by climate, like land use change. As far as we know, our inovative study is the first one to make such comparable measurement across wide spectre of long-distance migrant species.

In **Paper III**, we found that montane species moved upwards to higher altitudes. Species breeding at higher altitudes had more negative population change. Moreover, the altitudinal range shift brought more positive population change to species living in lower altitudes. This suggests that species breeding at higher altitudes have nowhere to shift, which results in their declines.

Overall, our study, encompassing wide species spectrum and long-term dataset, confirms serious impact of climate change on populations of Czech birds. If the climate change progresses at the current speed, mountain birds and long-distance migrants will be in trouble. We suggest that conservation efforts should be made to protect their habitats in order not to add further pressure on their populations.

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Curriculum vitae - Mgr. Tomáš Telenský

Education

- 2009 – now: doctoral studies of population ecology at Faculty of Science, Charles University in Prague
- 2003: promoted to Mgr. degree, at Charles University in Prague, Faculty of Math and Physics, branch of Informatics

Business

- 2017 - 2018: Freelancer, bird Atlases, Faculty of Science, etc.
- 2015 - 2016: Institute of Vertebrate Biology, Academy of Science, Brno
- 2014 - 2015: Krkonoše Mountains National Park, publication of the book Breeding Bird Atlas of Krkonoše 2012-2014
- 2006 – 2014: Czech Society for Ornithology
- 2003 – 2006: CN Resources International (NetTest/Anritsu) - Telecommunications

Research Projects

- Od r. 2012: hlavním řešitelem dvouletého grantu GA UK: Zhodnocení vybraných mechanismů působení environmentálních faktorů na početnost ptačích populací
- 2009-2011: členem řešitelského kolektivu projektu GA AV (2009-2011, hlavní řešitel Jiří Reif): Zákonitosti v dlouhodobých změnách početnosti ptáků: od popisu nápadných jevů k odhalení nejdůležitějších působících procesů

Pedagogical activity

- 2010 - 2016: education of the field methods of bird monitoring at Faculty of Science
- 2008 – 2016: organization of ornithological excursions for public – Dawn Chorus day, Bird Festival

Selected publications

Flousek J., Gramsz B., **Telenský T.** Atlas hnízdního rozšíření ptáků Krkonoš 2012-2014. Breeding Bird Atlas of Krkonoše Mountains 2012 – 2014.

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Presentations at international conferences

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