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Yellowhammer dialects and citizen science
Dialekty strnada obecného a občanská věda

Doctoral Dissertation

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Declaration

I declare that this thesis has not been submitted for the purpose of obtaining the same or any other academic degree earlier or at another institution. My involvement in the research presented in this thesis is expressed through the authorship order of the included publications. Its extent is specified in the statements of contribution from my supervisor and co-authors. All literature sources I used when writing this thesis have been appropriately cited.

Prague, 31. 1. 2023

Prohlašuji, že jsem závěrečnou práci zpracovala samostatně a že jsem uvedla všechny použité informační zdroje a literaturu. Tato práce ani její významná část nebyla předložena k získání jiného nebo stejného akademického titulu.

V Praze, 31. 1. 2023

Lucie Diblíková

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Abstract

Bird dialects, the cultural phenomena that can be linked to migration, gene flow, speciation and cultural evolution, have been studied extensively. The yellowhammer *Emberiza citrinella*, a common European bird with a simple song and long singing season, has been a model species for studying dialects for decades. In this thesis, I collate several studies that benefited from citizen science approaches to push this field forward. First, we have compiled and unified information on yellowhammer dialect distribution scattered in numerous publications, and unified different dialect nomenclatures used in the past. We supplemented this with data available thanks to volunteers contributing to public databases and other online sources, and demonstrated that the continental distribution patterns of yellowhammer dialects do not support the existence of broad, geographically distinct macrodialect groups as previously believed. In 2011, as part of the Bird of the Year campaign of the Czech Society of Ornithology, we launched a year-long public awareness project "Dialects of Czech Yellowhammers". Its first year's results exceeded expectations in quality and quantity, so a one-year, conservation-focused citizen science project became a long-term, investigative one. In subsequent years, improvements to the web user interface have been prioritised (with a focus on interactivity, fast feedback and gamification for more even sampling effort) resulting of recordings of yellowhammer song from 191 people from 4100 locations, covering 90% of the country. To our knowledge, this makes Czechia the best-mapped country in any bird dialect research. Like in some other parts of Europe, dialects in Czechia are distributed in a mosaic-like fashion. Detailed analyses nevertheless revealed that not all previously recognized song variants have distributional patterns expected from true dialects, so we performed a quantitative study that resulted in simpler and more consistent dialect boundaries. In 2013, we launched a sister citizen science project 'Yellowhammer Dialects' that had broad international coverage but primarily focused on comparison of Great Britain and New Zealand, to which yellowhammer had been introduced in the 19th century. Using archive and recent recordings (including those provided by citizen science volunteers) we compared the distribution of dialects of in its native source (GB) and invaded region (NZ). Unexpectedly, NZ hosted more dialects, which we interpreted as a result of severe loss of suitable habitats accompanied with yellowhammer decline in the second half of the 20th century in Great Britain. Our citizen science projects proved that it is not only possible to collect data of sufficient quality for scientific research with the help of unexperienced volunteers, but also taught us – by trial and error – the best practices to involve the public.

Abstrakt

Ptačí dialekty, jsou již dlouho zkoumány z hlediska migrace, toku genů, speciace a kulturní evoluce. Strnad obecný, *Emberiza citrinella*, běžný evropský pěvec s jednoduchým zpěvem a dlouhým obdobím zpěvné aktivity, je po desetiletí modelovým druhem pro studium dialektů. V této práci shromažďuji několik studií, které těžily z projektů občanské vědy. Nejprve jsme shromáždili a sjednotili informace o distribuci dialektů strnada obecného rozptýlené v mnoha publikacích a sjednotili nomenklaturu používanou pro různé typy dialektů v minulosti. Dataset jsme doplnili o nahrávky dostupné díky dobrovolníkům přispívajícím do veřejných databází a dalších online zdrojů a prokázali jsme, že kontinentální distribuce strnadích dialektů nepodporuje existenci širokých, geograficky odlišných makrodialektových skupin, jak se dříve věřilo. V roce 2011 jsme v rámci kampaně Pták roku České společnosti ornitologické zahájili projekt občanské vědy „Nářečí českých strnadů". Výsledky za první rok předčily naše očekávání co do kvality i kvantity, a tak se z jednoletého projektu zaměřeného na ochranu přírody stal dlouhodobý, vědecky zaměřený projekt. V následujících letech byly vylepšeny webové stránky projektu (se zaměřením na interaktivitu, rychlou zpětnou vazbu a gamifikaci) a výsledkem byly nahrávky strnadího zpěvu od 191 dobrovolníků ze 4100 lokalit, které pokrývají 90 % našeho území. Česko je tak nejlépe zmapovanou zemí z hlediska ptačích dialektů. Podobně jako v některých jiných částech Evropy jsou i v Česku dialekty rozmístěny mozaikovitě. Podrobné analýzy nicméně odhalily, že ne všechny dříve rozpoznané varianty dialektů dávají v širším měřítku smysl, a proto jsme provedli kvantitativní studii, která vedla k jednodušším a konzistentnějším dialektovým hranicím. V roce 2013 jsme zahájili sesterský projekt občanské vědy ‚Yellowhammer Dialects", který měl široké mezinárodní pokrytí, ale primárně se soustředil na srovnání Velké Británie a Nového Zélandu, kam byl strnad zavlečen v 19. století. Pomocí archivních a recentních nahrávek (včetně těch, které poskytli dobrovolníci z projektu) jsme porovnali distribuci dialektů v zemi původu (GB) a invadované oblasti (NZ). NZ neočekávaně hostil více dialektů, což jsme interpretovali jako výsledek velké ztráty vhodných biotopů doprovázené úbytkem strnada obecného ve druhé polovině 20. století ve Velké Británii. Naše projekty občanské vědy prokázaly, že s pomocí i nezkušených dobrovolníků je možné nejen sbírat data dostatečně kvalitní pro vědecký výzkum, ale také nás metodou pokusů a omylů naučily postupy, jak efektivně zapojit veřejnost.

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Figure 1: *Photo of male Yellowhammer (Emberiza citrinella). Photo taken by Petr Jan Juračka.*

Introduction

This thesis presents a comprehensive study of the geographic distribution of dialects of the Yellowhammer (*Emberiza citrinella*) in Czechia and other parts of the world. The Yellowhammer is a common bird with simple dialects and a long singing season, making it an ideal model species to study bird dialects, their origins, and their persistence in time and space (Cramp & Perrins 1994). However, the Yellowhammer also has other qualities that make it suitable for research with active participation of the general public, the so-called citizen science. These include its commonness in open agricultural landscapes, ease of recognition, and frequent singing throughout the day. All five chapters of this thesis focus on Yellowhammer dialects, with some or all data obtained through the participation of the general public. This includes data from already published studies or available on on-line databases (**Chapter 2**) as well as two citizen science projects created and organized by our team: the Dialects of Czech Yellowhammers (focusing on Czechia) and the international Yellowhammer Dialects project (**Chapters 1, 3, 4**, and **5**).

Citizen science and its progress in recent decades

Citizen science generally refers to a form of public participation in scientific research, in which members of the public collaborate with professional scientists to collect, analyse, and/or interpret data (Vohland et al. 2021). Currently, volunteers are participating in a broad range of projects, from astronomical research to bird watching and weather monitoring (Hunter et al. 2013). However, citizen science involves activities in many scientific fields, from simple observations to more complex research projects, allowing the public to make meaningful contributions to scientific knowledge.

The North American Bird Phenology Program, initiated by the ornithologist Wells W. Cooke in the 1881, is widely regarded as the first genuine citizen science project. This program persisted until the 1970s, and at had its peak 3,000 participants who documented the dates of migratory arrivals in both spring and autumn (Droege 2007, Mayer 2010). Despite the fact that initiatives with the public involvement have been in existence for over a century, the term 'citizen science' itself has only been in use since the 1990s (Silvertown 2009, Vohland et al. 2021). In fact, the term is so young that in 2011, when I got involved in my research on yellowhammer dialects and our first project started, there was no Czech equivalent of this term. Ultimately, 'občanská věda' (literal translation of the English term) was adopted and used since in the Czech language. Citizen science has become increasingly popular in recent decades, with scientists and members of the public collaborating on finding solutions to

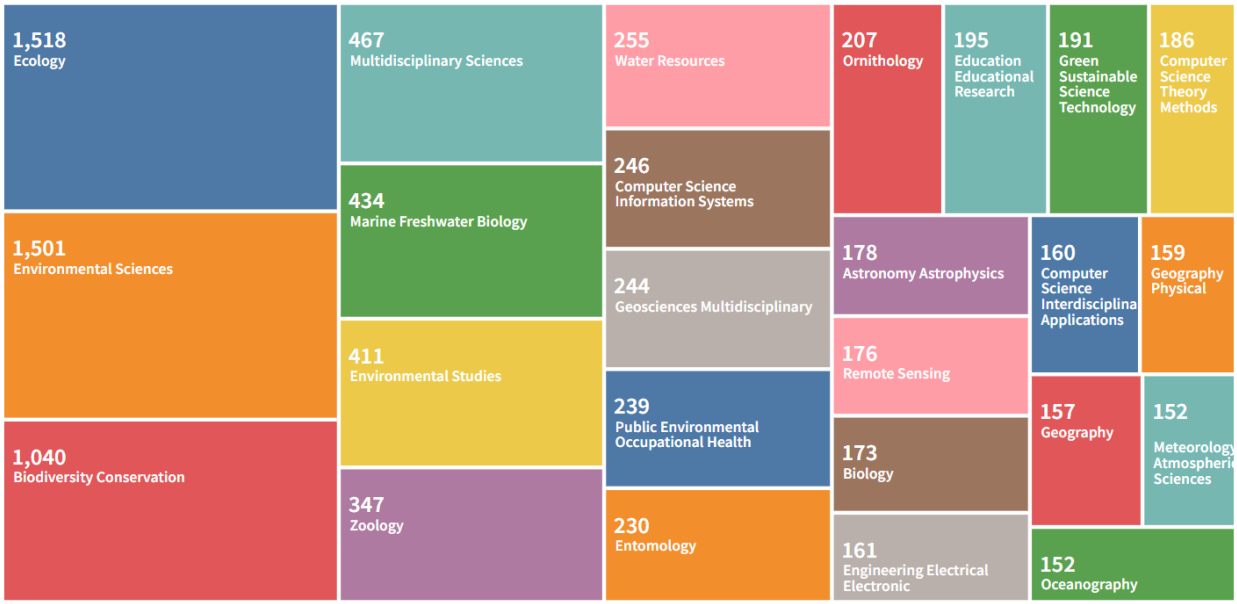

Figure 2: TreeMap chart visualization of records for the topic 'citizen science' published before 1st January 2023 and their respective Web of Science Categories, retrieved from Web of Science, 21st January 2023.

scientific and social problems (Hodgkinson et al. 2021). It is particularly popular in natural science fields such as ecology, environmental sciences, biodiversity research, marine and freshwater biology, and zoology. Other notable fields include nature and landscape conservation, meteorology, and education (Fig. 2). The growing interest of the scientific community in citizen science is illustrated by the frequency of the term 'citizen science' in the topic indexes of articles in the Web of Science database. In 2009, when Jonathan Silvertown wrote his highly cited article 'A new dawn for citizen science' (Silvertown 2009), the database contained 56 papers explicitly dealing with 'citizen science', 80% of which were published during 5 years before the publication. Less than 3 years later, when I wrote my bachelor thesis on yellowhammer dialects, the same database already contained 149 articles. This trend has continued, as seen in Figure 3. Vohland et al. (2021) mentioned a total of 2625 publications for the topic 'citizen science' by the end of 2019 (November 8th). By the end of 2022, the number of such indexed articles already exceeded 7300.

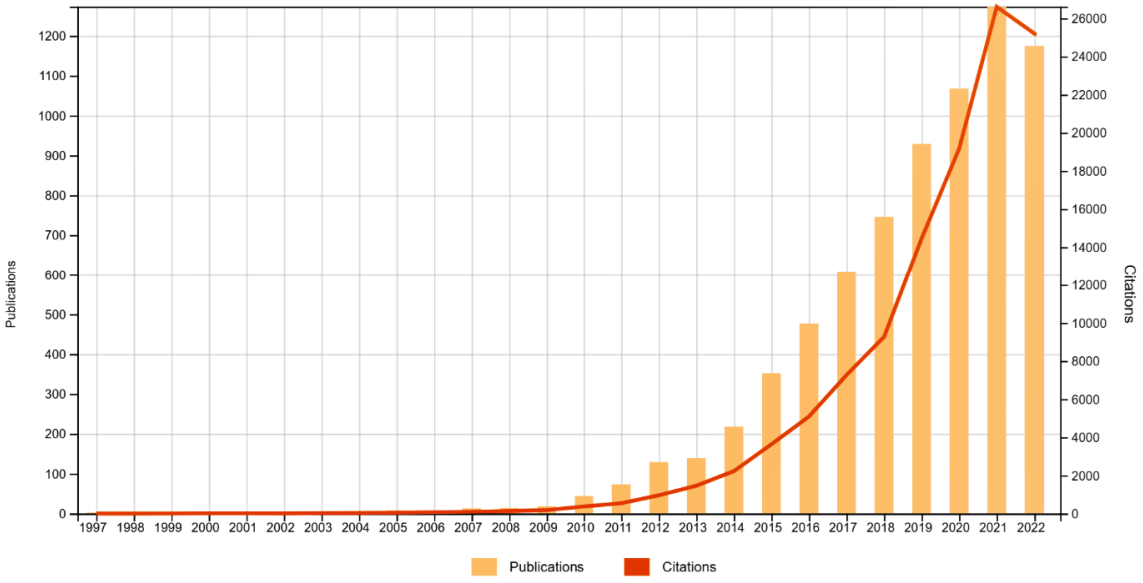

Figure 3: Number of articles for the topic 'citizen science' published before 1st January 2023 (n = 7313), retrieved from Web of Science, 21st January 2023.

Citizen science is now increasingly recognised in science, policy, education, social innovation, and non-governmental organisations (Vohland et al. 2021). Whereas previously it was mainly associated with natural sciences, it has now spread to encompass all disciplines, including social sciences and medicine (Fig. 2). The increase of citizen science in recent decade can been attributed to a range of causes. These include an increased inclination among the public to use their leisure time for meaningful activities (Kragh 2016), a more educated population, the development of data collection and processing

technologies (e.g., availability of internet-connect home computers with substantial computing power, the widespread use of smartphones allowing precise localization and high-quality audio-visual documentation). Also, an in case of biodiversity observations particularly in recent years, the crucial was the development of AI technologies that enable rapid and reasonably accurate species recognition on mobile devices, which not only assist in validation of the records but also has a great learning potential (Vohland et al. 2021). In this thesis, my main focus is on citizen science projects in the field biology and environmental sciences and the majority of the text below will be devoted to them.

Data collected by volunteers appeared in the scientific literature long before the term 'citizen science' appeared in the 1990s. The information about active involvement of motivated volunteers can be recognised (often retrospectively), for example through acknowledgements, methods and sometimes co-authorship, without using the term citizen science. Also, there are many organizations that have a long history of public involvement in research and conservation, such as the Cornell Lab of Ornithology (founded in 1915) or BirdLife International (founded in 1922), whose official partner is also the Czech Society for Ornithology (founded in 1926). In recent decades, there has been a marked increase in the use of citizen science practices, leading to the formation of several associations devoted to supporting and consolidating such activities (Göbel et al. 2017). For example, the Citizen Science Association (founded in the USA 2013), the European Citizen Science Association (ECSA) (founded in 2014), and Citizen Science Association of Aotearoa New Zealand (founded in 2019) were all established within the last decade.

With the growing number of citizen science projects and programmes, the need for a quality infrastructure to support such activities has grown as well. Thus, web-based platforms for citizen science are emerging that showcase and aggregate specific ongoing citizen science projects and activities. Moreover, they provide tools that can be useful for such projects. There are several types of such platforms (Vohland et al. 2021). For example, those dedicated to specific projects (including our websites strnadi.cz and yellowhammers.net), platforms bringing together several projects with similar aims (for example, najdije.cz, searching for selected invasive species in the Czech Republic), or national and transnational ones bringing together different citizen science projects (for example, eu-citizen.science bringing together European projects). Some platforms, such as iNaturalist, Zooniverse (www.zooniverse.org), or Epicolect5 (five.epicollect.net), provide free infrastructure for data collection and analysis for dozens of various projects, which thus do not need to develop their own (See **Chapter 1**).

As citizen science has established itself as a robust area of research and practice, many challenges have emerged. There is a growing need (Kullenberg & Kasperowski 2016, Eitzel et al. 2017, Bowser et al. 2020) to develop principles, standards, codes of ethics, guidelines and even a vocabulary or classification to improve citizen science practice. For instance, Wiggins & Crowston (2011) proposed a basic categorization of citizen science initiatives into activist, conservative, investigative, virtual, and educational categories based on their main goals (See **Chapter 1**). In 2015, ECSA's Working Group on 'Sharing Best Practice and Building Capacity for Citizen Science' produced a document entitled 'Ten Principles of Citizen Science'. These are the basic principles that ECSA members believe underpin good practice in citizen science. It is used internationally and is currently available in 35 languages (according to ECSA website, accessed January 2023), including Czech. The Ten Principles of Citizen Science are a good starting point for any new citizen science activity, and they challenge existing practices to pursue high quality activities in citizen (Robinson et al. 2018).

In the early days of citizen science, concerns were raised about the quality and scientific validity of volunteer-collected data (Hunter et al. 2013). Despite these concerns, the trends to involve the public in research continued to grow. Data collected by volunteers has long been an essential part of research in a variety of disciplines. For example, only less than 14% of information on biodiversity in Europe was collected by professionals, while the majority, i.e., more than 86%, was collected by volunteers (Schmeller et al. 2009). In case of bioacoustics, the work of volunteers is priceless. There are even databases with audio recordings of thousands of species (e.g., xeno-canto.org), that can be directly used in scientific research. Without contribution of volunteers worldwide, global comparative studies, such as Mikula et al. (2020) would not be possible. Even our research on yellowhammer dialects (see **Chapter 2** and **4**) benefits from recordings collected by people not specifically for our project, but stored either in the databases, archives on social media. Actually, citizen science project relying on recording of song of specific species by public are still very rare. In fact, I am aware only of our yellowhammer projects (**Chapters 1, 3** and **4**), old project of Hasen (1985) and recent study on song of common nightingales, *Luscinia megarhynchos* (Jäckel et al., 2023).

While it is important to be aware of the potential challenges associated with citizen science and data quality, the efforts should now be directed towards addressing and preventing these problems. This requires developing and implementing specific guidelines addressing not only these issues, but other areas such as legal, ethical, and educational considerations. Numerous organisations, associations and platforms have been working on developing such guidelines over the last decade (Vohland et al. 2021).

It is worth noting that our first citizen science project, Dialects of Czech Yellowhammers, started in 2011, well before most of the general guidelines for the field were formulated. Therefore, now that the discipline of citizen science is established, it might be interesting to evaluate how our 2011 citizen science project compares to current quality standards. However, to be ready for such comparison, I must first describe our DCY project and its development.

Citizen Science and Yellowhammer dialects: from local to global perspective

The origin of the citizen science project Dialect of the Czech Yellowhammers (DCY) is closely linked to the Bird of the Year, the most successful and popular campaign of the Czech Society for Ornithology (CSO). Its aim is to draw attention to interesting bird species living around us and to encourage public participation in their observation and conservation. The CSO committee annually selects a particular bird species as the Bird of the Year. Such species need to be charismatic for the broader audience. However, the elected species are often declining or represent a particular habitat of conservation concern. The campaign is supported by various events in which the public can take part, and thus learn more about the selected species as well as the troubles it faces, and ideally contribute to its protection. Citizens are frequently informed about the outcomes of these activities through different types of media (Stejskalová 2004).

In 2011, the Yellowhammer (*Emberiza citrinella*) was chosen as Bird of the Year. Although the Yellowhammer is a typical and common species in Europe an agricultural landscapes, it has declined in many areas in recent decades (e.g., Staneva & Burfield 2017). In the Czech Republic, the Yellowhammer is one of the most common birds of the open agricultural landscape and it represents about 10% of the whole European population. However, the 'Breeding Bird Census Programme' in the Czech Republic showed a 20% decline in abundance between 1982 and 2009. The decline in Western Europe is more severe, at around 50% (Procházka 2011). Many other farmland birds have shown a similar downward trend. This decline has been caused primarily by changes in land use in most of Europe, including the consolidation, intensification and chemicalisation of agriculture (Procházka 2011). By selecting the Yellowhammer as the Bird of the Year 2011, the Czech Ornithological Society aimed to raise public awareness of the continuing decline of many farmland bird species and their habitats (Procházka 2011). In order to raise even more awareness of the species chosen for the year, the CSO prepares an accompanying activity each year in which the volunteers can

get involved, such as monitoring its arrival from wintering grounds. However, in 2011 it was not possible to apply the same approach to this (common and non-migratory) species.

Petr Procházka proposed to draw attention to the Yellowhammer song. The Yellowhammer is very easy to recognise, not only by its distinctive yellow colouration, but also by listening to its characteristic song. The song is very simple and so typical that even a complete beginner can learn to recognise it very quickly with a little effort. In addition, male Yellowhammers have a very long singing season, from early spring to late summer or later (Cramp & Perrins 1994) and often sing throughout the day, at a time when anyone can encounter them (Hiett & Catchpole 1982). In addition, it has been known for more than a century that yellowhammers have distinct song dialects (see Fig. 4) (Oppel 1869, Röse 1869).

Bird dialects are an example of a geographical variation in learned vocalization where songs have regionally specific traits and the boundaries between dialect areas are quite distinct, even when there are no obvious physical or environmental barriers (e.g., Bjerke & Bjerke 1981, Kroodsma 2004). They have been studied extensively over the last seventy years (e.g., Poulsen 1958, Lemon 1975, Mundinger 1982). However, many of more recent papers (MacDougall-Shackleton & MacDougall-Shackleton 2001, Foote & Barber 2007, Petrusková et al. 2010, Wilkins et al. 2013,Bistel et al. 2022, see **Chapter 2-5**) show that it is still a topic worth scientific attention. This interest stems in part from the fact that bird dialects are a cultural phenomenon that lends itself to addressing more general questions that are not only species- or songbird-specific. Research on dialects, their distribution, origin, and evolution can be well linked to questions of migration, gene flow, speciation, habitat or cultural evolution (e.g., Hansen 1985, Lang & Barlow 1997, Panov et al. 2003, Soha et al. 2004, Tracy et al. 2009). However, large-scale dialect studies, require large amounts of data from large areas, which are costly and time consuming to obtain (Silvertown 2009, Diblíková 2011). However, these complications can be avoided by involving citizen scientists in research (Silvertown 2009, Diblíková 2011, 2013, see **Chapter 1-5**).

The Yellowhammer dialects geographical distribution has been studied by many authors in different parts of Europe, often showing mosaic-like patterns even at relatively limited spatial scales. It has also been suggested on a number of occasions (Kaiser 1965, 1983, Cramp & Perrins 1994) that the Yellowhammer dialects can be divided into two groups with a macro-geographical distribution pattern (the Eastern group and the Western group), with the border running through Central Europe (see **Chapter 2**), possibly even through the territory of today's Czech Republic. However, so far there has been no in-depth study of yellowhammer dialects in this country. Finding out whether the presumed

macrodialect boundary runs through the Czech Republic was a simple but attractive research question for the planned accompanying activity for the public.

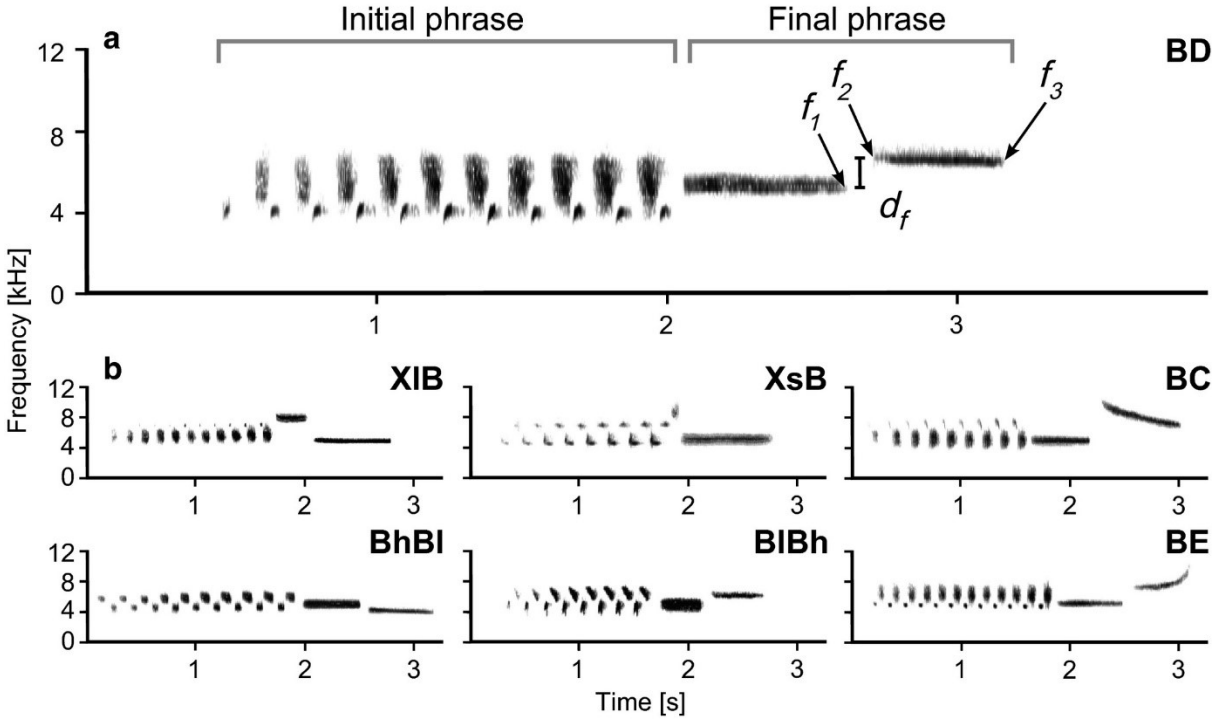

Figure 4: Sonograms of the Yellowhammer song and some of the local dialects heard in the Czech Republic (see Chapter 3). The typical structure of the Yellowhammer song is shown in detail in (a), highlighting the initial and final (dialect) parts. Frequency and temporal characteristics (f1, f2, f3, df) are used to quantify the variation of the dialects BlBh, BD and BE to see whether these dialects form a distinct dialect category or rather a continuous gradient (see Chapter 5). Terminal elements (dialects) are labelled according to Hansen's (1985) nomenclature (see Chapter 2). Figure from Chapter 3.

However, it was first necessary to determine whether it would be possible to identify dialects from recordings made with commonly available electronic devices in 2010s (e.g., digital cameras and camcorders, mobile phones, first smart phones or voice recorders). Petr Procházka therefore contacted Tereza Petrusková who focuses her research on songbird vocalisations, and she confirmed that there appear to be many widely available devices capable of recording sounds between 1 and 10 kHz, which is the range needed to capture the entire song of the Yellowhammer, including the dialect. Therefore, a core project team was formed in 2010 to develop a year-long planned citizen science project, Dialects of the Czech Yellowhammer (DCY), and to produce all the guidelines, protocols and training materials,

including a test for device suitability, needed to launch this activity. The initial project team consisted of:

- Petr Procházka (Institute of Vertebrate Biology, The Czech Academy of Sciences)
- Tereza Petrusková (Department of Ecology, Faculty of Science, Charles University)
- Adam Petrusek (Department of Ecology, Faculty of Science, Charles University)
- Jiří Svoboda (Department of Ecology, Faculty of Science, Charles University)
- Zdeněk Vermouzek (Czech Society for Ornithology)

The three main aims of the project were:

1. To map the dialects of the Yellowhammer (*Emberiza citrinella*) in Czechia with the help of general public and commonly available devices.
2. Determine whether the border between the Eastern and Western European macrodialect group of dialects crosses the Czech Republic.
3. To help raise awareness of the declining populations of farmland birds and the habitats they inhabit.

The CSO traditionally announces the Bird of the Year at a press conference in early February. On 1 February 2011, a press release announcing the naming of the Yellowhammer as Bird of the Year was published on the CSO website (www.birdlife.cz). Several articles on the species and an electronic version of the annual information brochure 'Yellowhammer, Bird of the Year 2011' (Procházka 2011) accompanied the news. All materials, protocols, and instructions for participation in the project were also published. The entire organisational team prepared these materials and articles, but the main part of the work was done by Jiří Svoboda, who developed the materials as part of his pedagogical thesis (Svoboda 2011). Two different sets of guidelines were created. The main set of instructions essential for participating in the project and a bonus set for extra motivated volunteers. The main set included information on how and why to get involved, how to find out if your recording device is suitable for recording dialects, how to record a yellowhammer in the field, what information to record and where to send the recordings. A bonus set included information on how to extract the audio track of a recording for further processing, how to identify the dialect, and how to use the program to analyse sounds and create spectrograms. In addition, the project created and distributed special materials for teachers to use in the classroom.

The DCY project was designed from the start as a citizen science project (Procházka 2011). Although general detailed guidelines for the design and running of citizen science projects have mainly been developed over the last 10 years, by 2010 there were already several recommendations (largely based on best practice) on how to run such projects (e.g., Bonney et al. 2009). From the start of the project, it was clear that the project would not work without strong promotion and prompt feedback to the volunteers who would be recording songs.

The promotion of the whole project was facilitated by the fact that it was created as part of the already very popular Bird of the Year campaign. The CSO has a lot of experience in the promotion of its activities in many types of media and furthermore the society itself had over 2000 active members in 2011 (CSO 2011), who were in 2011 the project's primary audience. The project was also advertised through press releases and articles in newspapers, as well as through social media (Facebook), television and radio broadcast.

Particularly important was the promotion on the radio programme Meteor on the Czech Radio focusing on science popularization, hosted by Marek Janáč. This radio programme has been an official partner of the DCY project from the very beginning and regularly provided information on its progress, making it a key factor in promoting the project and reaching a wide audience.

As mentioned above, communication with participants (feedback) should play a key role in citizen science projects (Bonney et al. 2009). Rapid feedback is a unique way to motivate volunteers to participate and collaborate in the long term (Tweddle et al. 2012). However, this requires considerable human capacity. Very early in the project, it became clear that interest in the project exceeded the expectations and that the project team would need to be expanded. At the beginning of March 2011, I, as a bachelor student of biology joined the team. My role was to ensure communication with participants during the project and to collect and analyse recordings. Participants were able to send recordings and additional information by email, post or via the free cloud storages available at the time (mostly Uschovna.cz or Uloz.to). The recordings were then stored and backed up on external drives. The recording database with additional information about the recordings (e.g., date and time of recording, GPS coordinates, nearest municipality, membership of CSO, recording device) was stored as well. Most communication with the volunteers was by email. An online Google map was created and continuously updated to give volunteers and the project team an overview of which locations had already been mapped and whether it was possible to identify the dialect.

The first results of the project were published in mid-2011 in the form of a web article and a press release on the CSO website. The results for the whole season were then presented at the CSO

Ornithological Conference in Mikulov, where the theme was citizen science, which was gaining in popularity. The overall results of the 2011 season were then published on the CSO website (article, press release) and featured on the Meteor radio show.

In 2011, 50 volunteers (62% were CSO members) provided recordings from 754 different sites. This provided enough data to determine that the border between two putative macrodialect groups indeed runs through the Czech Republic. The DCY project, originally planned for one year, could thus be completed and considered a success. However, the project was not finished, quite the opposite. After the successful completion of the 2011 DCY season, the project team could appreciate the results of such cooperation between scientists and volunteers. In addition to achieving good scientific outcomes, surpassing original expectations, new scientific questions arose. The project also received very good feedback from the participants, many of whom wanted to continue recording Yellowhammer dialects next season.

There has also been a slight shift in the focus of the project. The project, which in its first year had elements of citizen science focused on nature conservation, shifted its focus to scientific investigation in 2012 and became primarily an investigation type of citizen science project (according to Wiggins & Crowston 2011, see **Chapter 1**).

As the project was extended until 2012, when yellowhammer was no longer Bird of the Year, we decided to create a new project website outside the CSO website but using the CSO database. Members of the project team were already aware during 2011 that the project would benefit from faster feedbacks to volunteers. However, to do this would require a complete change in the way recordings are uploaded, published and stored. The creation of the new project website made these changes possible. Because Jiří Svoboda left the team after successfully defending his pedagogical work, it was necessary to expand the team with someone who could handle the creation of a new website that would meet the new requirements. So, in 2012, Pavel Pipek, a PhD student of invasion ecology, joined the DCY project team. Initially only for the purpose of helping with web development, as his research focus was unrelated to birdsong. Nevertheless, this changed over the course of the project, as can be seen mostly in **Chapter 4**, but we'll get to that later.

The newly expanded team therefore decided to create the DCY project website and subsequently link it to the CSO Faunistic Database and servers (for storing the audio recordings). The planned website would not only contain all the necessary instructions and information, but most importantly, it would link to a simple and uniform online form, that would allow submitting recordings and information about them directly to the CSO Faunistic Database, thus providing much faster, clearer, and more

transparent feedback for the volunteers. Vice versa, it would display the data stored in the CSO database in user-friendly way. To ensure a smooth connection between the website and the CSO database, Tomáš Telenský, one of the CSO web and database administrators at the time, became involved in the project.

In March 2012, a brand-new website accessible at http://strnadi.cz was launched. Initially, this contained the same instructions and methods for submitting recordings as in the previous year. This was due to the fact that connecting the new website to the official CSO faunistic database required significant modifications of the database and the associated infrastructure. The unified online upload of recordings to the database and the new interactive dynamic map were available from July 2012. After each recording was analysed by researchers from Charles University in Prague (mostly by me), it changed from appearing as a map point with a question mark symbol to the symbol a particular dialect (Fig. 5). This was a big improvement that enhanced the user experience. The volunteers received real-time feedback on the development of the CS research from the interactive map (Diblíková 2013 and **Chapter 1**).

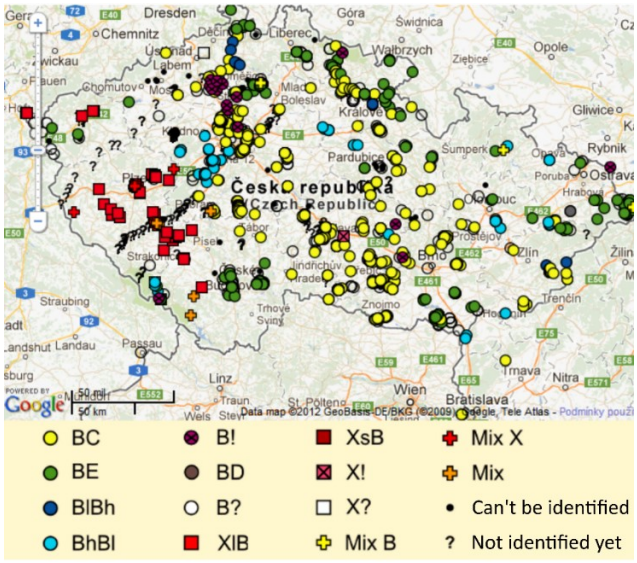

Figure 5: Preview of the new dynamic online map from 12 July 2012 (strnadi.cz).

In 2012, the promotion project DCY was similar to the previous year. Information on the continuation of the project was sent to all CSO members by email. Several lectures were held at Czech scientific universities. The project was also promoted during the popular Prague Museum Night event and University Night event. The general public could even get to know the project as part of the entertainment programme at the Rock for People summer music festival. During the promotion in

2012, we tried to motivate volunteers to obtain recordings from previously unexplored sites. This year, as part of our promotional strategy, we have deliberately avoided encouraging people to look for the macrodialect boundary between dialects and where exactly it crosses the Czech territory.

This was partly because I wrote bachelor's thesis on 'Yellowhammer as a model species for studies on passerine dialects' in 2011, which was basically a review of past research on the topic. Based on this review, it became clear that although some authors refer to the occurrence of macro-geographical variations (macro-dialects) in the yellowhammer song (e.g., Kaiser 1965, 1983, Glaubrecht 1991, Cramp & Perrins 1994), there is a lack of evidence for this (see Chapter 2). On the contrary, when I pooled together data from literature on yellowhammer dialects, the existence of such a macrodialects did not seem to be supported (Diblíková 2011). The next step was to supplement the published data with recordings that were freely available online (e.g., from Youtube.com or the citizen science bird sounds database Xeno-canto.org) and those stored in archives (such as British Library or BBC Nature Sound Effects Library). This showed (more in **Chapter 2**) that the patterns of yellowhammer dialect distribution in Europe do not support the existence of geographically distinct macrodialects.

Even without targeted promotion of the macrodialect boundary search and with the delay in the transition to the new website, 41 volunteers joined the project in 2012 (59% of whom were again CSO members). 17 of them uploaded for the second year in a row. This year, volunteers submitted recordings from 578 different sites.

The results of the first two years far exceeded initial expectations. The numbers of recordings were growing, and it was clear from the feedback from those who had recorded that the creation of the new website and the new dynamic online map was a right step. However, one of the main challenges of the project was the increasingly uneven sampling effort (see **Chapter 1**). Typically, when a new volunteer joined the project and decided to continue recording, they would map in detail the areas where they occurred most frequently. In some places this led to a nice and important refinement of dialect boundaries. However, some large areas remained completely unexplored.

In 2013, to encourage volunteers to record in largely unexplored areas, an online game called Diacaching was created, inspired by geocaching (an outdoor recreational activity in which participants use GPS devices to hide and seek containers called 'geocaches'). For the purposes of the game, used the KFME mapping grid (Kartierung der Flora Mitteleuropas), which splits the region of Central Europe into blocks 10' of longitude wide and 6' of latitude long (c. 12 × 11.1 km, henceforth 'squares'). This way, the territory of the Czech Republic can be divided into 679 squares. Squares from the previous two years of mapping that already contained recordings with an identifiable dialect were

marked as occupied. The remaining squares could be newly "conquered". To do so, the recorder had be the first person to make a recording from a given square from which a dialect could be determined. The square was then marked as 'conquered' and the name of the 'conqueror' could be read off the map. In addition, "bonus" squares, whose location was not known to the public, were randomly selected by the computer. After conquering them, the uploader received a small prize. When the square was captured by a member of the research team, the prize was randomly assigned to a new square. The names of the winners, as well as other news and interesting facts from the Diacaching game (e.g., number of newly occupied squares, number of new recordings, percentage of the Czech territory covered, tips for successful recordings, stories from recordings) have been published regularly (about every 14 days) in the radio programme Meteor in and on the programme and project website since April 2013. Thanks to the cooperation with the radio show Meteor, the game Diacaching became very popular. And it has produced significant results. The 22 volunteers who had already recorded in previous years were joined by 69 new volunteers (Fig. 6).

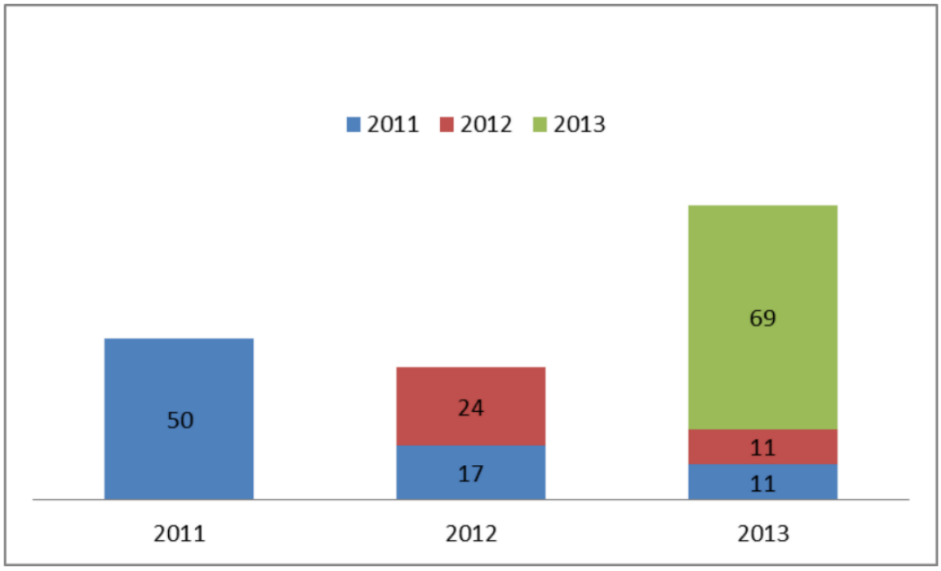

Figure 6: Number of volunteers and their persistence in the project in the years 2011 - 2013

All 91 volunteers (only 30% of CSO members) sent recordings from 1015 sites, the most in the whole history (up to now) of the project. A large part of them came from completely new and unexplored localities. At the end of 2012 we had records from 30% of the area (111 from 2011, 93 from 2012; 204 squares in total). During the year 2013 Diacaching added 287 new sites. In total, after three years of the project, we had recordings from 72% of the area (489 of the 679 sites). The 2013 season was the most successful season of all the seasons (past and future) when the DYC project was running.

The last major change in the design of the project was in 2014. From previous years we had a good idea of the distribution of dialects in the Czech Republic from many localities. In many places we had mapped them in enough detail to even allow further scientific research (e.g., playback experiments on/outside dialect boundaries, mapping the role of habitats in dialects, see Bílková, 2015). However, there were still many very interesting localities (e.g., areas of dialect boundaries and areas with rare dialects) that deserved to be mapped in more detail. We wanted to draw attention to such localities by using miniDiacaching, which is based on the same principles as Diacaching, except that in more scientifically attractive localities the original squares were divided into 4 smaller ones and the "conquering of the squares" started again in such localities, but in more detail.

During the six years of the project (2011-2016), the Czech Republic became one of the most thoroughly researched countries, and we learned about the distribution of dialects for almost 90% of its territory. To my knowledge, the Czech Republic is currently the most extensively mapped (in scale and detail) country in terms of dialect, as well as public participation in research on the song of a particular bird species (see **Chapter 3**). Most of the dialect types that are widespread in Europe have been discovered in the Czechia, and they are distributed in a mosaic-like pattern. In addition, localities with a number of unusual and rare dialects were found (see **Chapter 3**). With this amount of data from a large area, we were able to test whether the traditionally recognised Yellowhammer dialects could be considered distinct, or whether they formed a continuous gradient that, at least in our area, should not be further subdivided (see **Chapter 5**).

Since the 2017 season, we have decided not to promote the project anymore and naturally to phase it out to have more time for follow-up research and projects. Although the project has not been promoted since 2017, there is still the opportunity to send us recordings via the project website, and this is still happening, but on a much smaller scale. To date (January 2023), almost 191 people (included core team) have taken part, you can see their names in the acknowledgements. They sent recordings from over 4100 sites in the country, from 609 squares (90% Czechia) (Fig. 7).

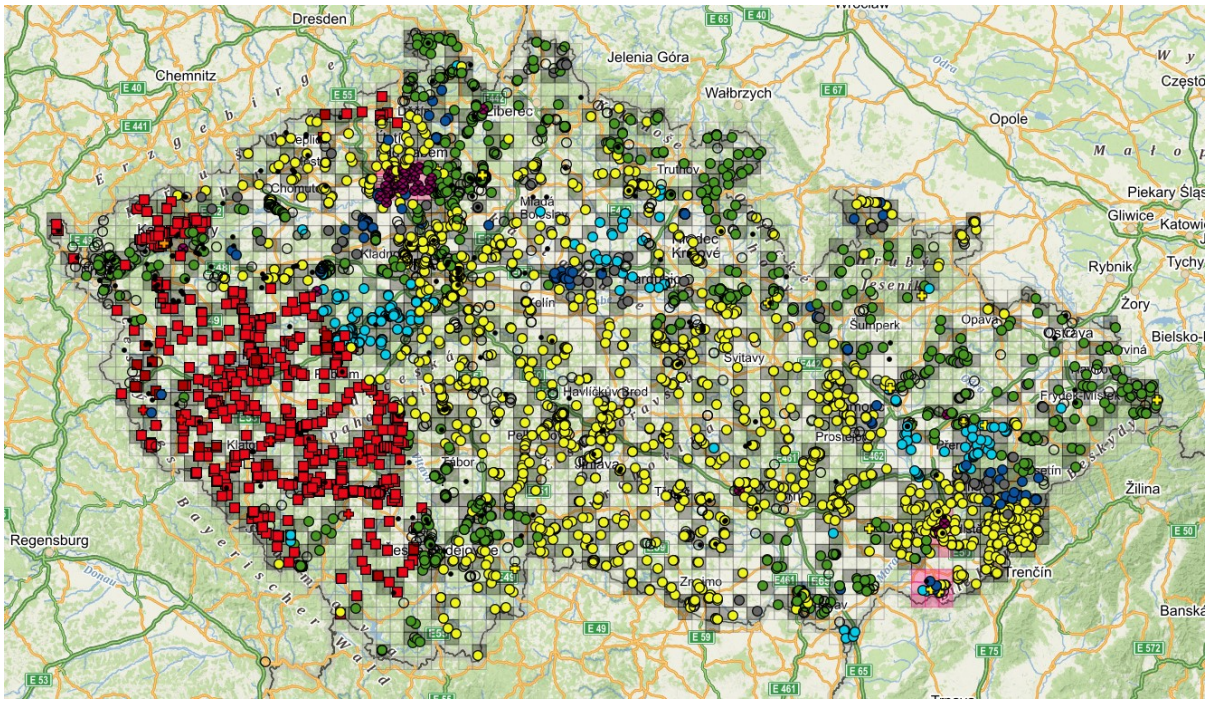

Figure 7: The interactive map of Yellowhammer dialects in the Czechia (January 2023, www.strnadi.cz)

However, revealing distribution of yellowhammer dialects in our country is still not the end of our research. DCY served as an inspiring example for similar CS projects in other countries. First, we started a new sister project - Yellowhammer Dialects (http://www.yellowhammers.net). Its initiator and main organiser was Pavel Pipek. Soon after helping to develop the website for the Czech project, Pavel realised that Yellowhammers had much more in common with his field of research, invasion ecology, than it might first appear. Yellowhammers were intentionally introduced from Great Britain to New Zealand in the 19th century, where they quickly became an unwelcome pest. Up till now, New Zealand is the only country in the world with established population of yellowhammers. The fact that the introduction was carried out on purpose by New Zealand acclimatisation societies meant that sufficiently accurate data was available, for some of the introduction events including details about the localities of capture in Britain and release in New Zealand (Pipek et al., 2015). This made it possible to compare the dialect distribution of yellowhammers in their native and exotic range (Great Britain and New Zealand) 140 years after complete isolation (see **Chapter 4**). Even though the project brought interesting results, when it comes to public engagement, it was not as successful as the Czech project. A lot of the data were collected by members of our team or extracted from sound archives and sound databases (such as xeno-canto). We did not test this in scrutinous way, but it can be explained by

several factors. First, in the Czech Republic we had the advantage of the already established network of birdwatchers, members of Czech Society for Ornithology. Although we were supported by several institutions in the UK/ New Zealand, and the information was spread through some media, there was not a direct partnership with the local ornithological society. This is something that could be planned more carefully. Second, the model species was not the best for the two countries. In the UK, yellowhammers are much less common and thus not as frequently observed by the public. In New Zealand, yellowhammer is everywhere, of no conservation concern, however, the interest of the public and the researchers is targeted towards threatened endemic species.

Since then, other countries have participated in the recording of yellowhammer dialects, including Poland, Latvia, Croatia and Switzerland (Ambühl et al., 2017). The Polish, Swiss and Latvian projects are hosted on the 'Yellowhammer Dialects' project website. The same website can be used by other countries for their own citizen science initiatives with Yellowhammer dialects (for more information, see https://yellowhammer.net or https://eu-citizen.science/). In addition, we have been extracting individual recordings of yellowhammer birdsongs, which have been uploaded to servers such as "xeno-canto" and others. These efforts have resulted in unprecedented coverage of the species' range and will help us to understand how dialects are formed and maintained at a deeper level.

Comparison of Dialects of Czech Yellowhammers with citizen science standards

Let's take a quick look at how our project, created without proper guidelines and intended primarily as a public engagement activity during the Bird of the Year campaign, would have turned out if we had had the guidelines to hand back in 2010. There are many guidelines to support the successful implementation of citizen science projects, covering different aspects of the process, including setting up a project, recruiting and retaining participants, storing and managing data, and influencing policy. These guidelines take different forms, such as handbooks, checklists or examples of best practice (Vohland et. al 2021). I have chosen to compare our project with the guide 'Citizen Science for All. A Guide for Citizen Science Practitioners' (Pettibone et al. 2016). This publication is a good example of a general guide that covers aspects common to all citizen science projects. It describes how citizen science can be used in different areas, including education, conservation and the arts and humanities, and includes a project task list and checklist for planning a citizen science project from start to finish (Vohland et al. 2021).

The first good news is that, despite the somewhat hectic start to the project, we have gone through all the correct phases of the project, from formulating proper research questions to publishing and presenting results (Fig. 6). We also completed all the tasks, although not necessarily in any meaningful order, but that is not a requirement. In general, I can say that most of the questions listed in the guide as those that practitioners should consider before starting a project have been answered and the other recommendations listed in the guide "Citizen science for all A guide for citizen science practitioners" (Pettibone et al., 2016) have been followed (Fig. 8).

Most of the steps and considerations we took in the project were fully in line with the tasks and recommendations in the guide (marked in green). We came to them independently, without their knowledge, during the creation of the project. There are a few recommendations from the guide that would be nice to follow and know earlier on (marked in yellow), as they may have reduced some of the challenges we encountered during the project. First, when considering benefits of using citizen science, we should define benefits for all sides - scientists, participants and society. However, I feel that we could have focused more on the benefits for society, and the project could have had an even greater impact in disseminating the knowledge about the problems of the birds in the countryside. Secondly, data collection and storage proved more difficult than we had anticipated, and this could be better planned in advance., so that the data would still be relevant and easily accessible for follow-up research in the future. Finally, more resources could have been put into providing feedback to participants. Although we put a lot of effort into providing quality feedback as quickly as possible, we were limited by (wo)manpower as the core team consisted for the most of the time of only two, occasionally three people (students). Despite these limitations, I believe the project meets the standards of high-quality citizen science projects.

Project phase	Project task	Done
Before beginning	1. *Define the research question based on a hypothesis or social problem*	
	2. *Define the benefits of using citizen science*	
First steps	3. Establish the project team	
	4. Develop concreate project goals	
Planning phase	5. Determine the research design	
	6. Determine methods	
	7. Types of participants	
	8. Calculate resource requirements	
	9. Develop a communication strategy	
	10. Develop data protocols	
	11. Develop training material	
Data collection	12. Collect, visualise and analyse of data	
	13. Give feedback to participants	
Communication and discussion	14. Publish and present results	
Publish and present results	15. Evaluate the quality of the scientific results	
	16. Evaluate the process and benefits for all	

Figure 8: Modified project task list adapted from guideline "Citizen science for all A guide for citizen science practitioners" (Pettibone et al. 2016). Green birds symbolise tasks that have been completed according to the guidelines. Yellow birds symbolise tasks that would benefit from some minor improvements (commented in the text).

Conclusions and future research

With our Yellowhammer dialects citizen science projects, we have shown that it is possible to motivate the public to get involved in a very specific task of bioacoustics research – recording of songs of a particular bird species. Moreover, with the help of many volunteers, we were able to obtain valuable data from a large area in a sufficient quality to answer our research questions. That does not mean that involving the public is an easy or cheap way to get such data. It is probably not easier than going to the field and recording the data by a small dedicated team, and certainly it needs different skills than a scientific work usually does.

Running a citizen science project requires swift and clear communication with the public, it involves a large management burden and coordination of many people. Despite all the efforts, it is not always a success. For example, when we tried to get volunteers from the UK and NZ involved, our efforts were not rewarded as much as we expected. One of the likely reasons could have been that despite a huge community of bird-watchers in the UK, many projects already competed for their attention and participation. Moreover, there was no specific contact person in the UK and NZ who was as motivated to creatively develop the project further and to take care of its smooth progress as was the core DCY team in Czechia.

The success of the DCY project highlights that it pays off to invest time into the "non-research" activities of citizen science projects – communication with the volunteers, public outreach, gamification, etc. The data we have obtained thanks to volunteers should eventually allow us to study more phenomena than we expected when launching the project. First, not only were we able to map the dialect distribution in various regions and across multiple spatial scales (**Chapters 2-4**) but we could also re-evaluate the boundaries of traditionally recognized dialects (**Chapter 5**). This highlighted that not all song variants recognized in the seminal work of Hansen (1985) are relevant for our Central European conditions.

The discovery of numerous replicated borders of the same dialect types in Czechia provide ideal grounds to study what lies behind the emergence and maintenance of dialect borders. Pilot playback studies testing the hypothesis that male territorial response against singers of local vs. foreign dialects differs, already have been done (Bílková 2015). However, the results are ambiguous, and more experiments need to be performed in the peak of the breeding season in at least two dialect regions. It

is also just a question of time when we complete a comprehensive dataset to prove that there is no consistent relationship between the yellowhammer dialects and habitats.

Moreover, and to our surprise, many recordings from various devices used by the volunteers were of a quality comparable to recordings from professional equipment used by some of the core team members (Petrusková unpbl. data). This opened a new perspectives, as we could focus not only on the dialect part of the song but also on its initial phrase, which remains understudied in yellowhammers. Examining variation of the first phrase song types within and between different areas may add to current knowledge of song evolution in space. Unfortunately, we had to retract the already published study focusing on this aspect of yellowhammer vocalization (van Boheemen et al. 2019), as the dataset got mixed up beyond repair by a fellow student sometimes during the analysis.

There are numerous directions in which the future research of yellowhammer vocalization may go. Even the topic of the dialect distribution itself is far from explored. We should eventually get the public involved again to collect new recordings from the same regions, so we can focus on the stability or dynamics of the dialects in time and space. Although the rapid development of passive recorders and automated analyses of large-volume acoustic data may eventually provide the researchers the means to collect data on large spatial scales, we have shown that material obtained through a citizen science project may be sufficient even for quantitative analyses. Last but not least, involving the public in such projects is beneficial not only for the research. Yellowhammer is a convenient flagship species of "healthy farmlands" (e.g., Whittingham et al., 2005) and collecting the recording of this pretty bird may attract the attention of the public to nature conservation, and boost the awareness of the importance of landscape heterogeneity around citizen scientists' homes.

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