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EFFECTS OF URBAN NOISE ON SINGING OF THE WHITETHROAT SYLVIA COMMUNIS

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Abstract

Acoustic signals of birds have two basic functions: mate attraction and territory defense, which are interrelated. Noise waves interact with bird's song, resulting in reinforcement and interference or reverberations, i.e. noise hinders clear sound transmission. It forces birds to either adapt to high noise levels or to move to another area. Earlier studies showed that some bird species increase the frequency or amplitude of their songs, change the time of singing, and reduce song length to cope with urban noise. However, the Whitethroat *(Sylvia communis)* was not among the studied species in that topic.

The aim of this research was to study the effects of urban noise on singing of the Whitethroat, based on nine selected parameters: minimum element frequency, maximum element frequency, maximum spectral frequency of an element, length of elements, song length, total number of elements in a song, number of different elements in a song, singing activity, and length of pauses between songs. Singing males were recorded for ten minutes per male in two study areas: Sebezh city (urban) and Sebezhsky National Park (rural). Songs from both study areas were compared using song spectrograms on the nine study parameters.

The study showed that acoustic communication of the Whitethroats is also affected by noise. Recorded males in urban area had shorter song elements and shorter pauses between songs than in National Park. Other parameters were not statistically different. However, several aspects that could affect the results were not included in this research, such as level of noise, age of the male, mating status, presence of singing neighbors, developmental history, and resource abundance. Besides, larger sample sizes could provide more reliable conclusions. Despite the fact that the difference in singing of the Whitethroats in urban and rural areas was found, further studies would provide a better understanding of the effects of urban noise on singing of the species.

Keywords

Urban noise, Sylvia communis, Whitethroat, Common Whitethroat, singing, elements, frequency, singing activity, pauses

CONTENTS

LIST OF ABBREVIATIONS

NP – rural sampling area of the Sebezhsky National Park nearby Osyno Lake
CITY – urban sampling area, Sebezh city
Min freq – minimum frequency of an element (Hz)
Max freq – maximum frequency of an element (Hz)
Max spectral freq – maximum spectral frequency; frequency with maximum energy in an element (Hz)
Element length – length of an element (s)
Song length – length of a song (s)
Total elements – total number of elements in a song (#)
Different elements – number of different elements in a song (#); repertoire size
Singing activity – number of songs sang in 10 minutes (#)
Pauses – length of the pauses between songs (s)

1 INTRODUCTION

Birds are social animals, and acoustic signals are essential for their communication. Besides communication itself, avian acoustic signals have two basic functions: mate attraction and territory defense (Slabbekoorn & Ripmeester, 2007), which are interrelated. Most birds are territorial, and territory defense is important for successful mating, nesting, and foraging. Several studies pointed that song reflects the male quality and is among the major factors that influence female choice (Eens et al. 1991, Balsby 2000a, Searcy et al. 2010). Female choice may be affected by both physical properties of the song and by male signals, such as female-directed song performances (Dunning, et al., 2014).

Sound transmission strongly depends on environmental conditions such as wind, temperature, humidity, and noise. Temperature and humidity determine the amount of absorption of wave energy of sound (Stephen, 2017). Wind refracts sound waves by binding them away from warm grounds (Acoustics by design, 2008). Noise causes interactions of sound waves of the noise source and the bird, resulting in reinforcement and interference or reverberations (Lemon, et al., 1980). Wind, temperature, and humidity in some cases may lead to sound attenuation with distance, while noise is always a barrier for a clear sound transmission.

Several studies showed that birds in the areas with high noise levels had lower reproduction success, and, therefore, population decline. For example, Halfwerk et al. (2010) found that females of the Great tit *(Parus major)* in traffic areas laid smaller clutches and had less fledglings, than their mates in quiet areas. House sparrows *(Passer domesticus)* had lower fledgling success in suburban areas than in rural, and suburban nestlings had a smaller body size compare to the nestlings in rural areas (Seress, et al., 2012). Noise also interrupts communication between chicks and their parents by masking the calls of the chicks. The study by Shroeder from Sheffield University (2012) showed that House sparrows *(Passer domesticus)* in urban areas fed the nestlings less than parents of the same species did in rural areas. Contrary to the negative impacts of noise on birds, Francis, et al. (2009) found that noise may indirectly increase reproductive success of individuals nesting in noisy areas by altering predator-prey interactions.

Environmental conditions historically have predetermined the voices of different bird species, giving to each species its acoustic niche, or forcing birds to adapt to the acoustic niche by changing song frequency and intensity (Malchevskiy & Pukinskiy, 1980). However, physiological capabilities and behavioral flexibility determines the ability of birds to adapt to changing environment (Hardman, 2015).

Increasing the frequency or amplitude (Schuster, et al., 2012), changing the timing of singing (Dominoni, et al., 2016), or reducing the songs length (Gentry, et al., 2017) were found to be among the adaptations of birds to high noise levels. The background noise in cities has low frequency of about 2 kHz, and it masks the frequencies at which many birds sing (Hardman, 2015). Several species increase song frequency in noisy areas: Great tits *Parus major* (e.g. Hamao, et al. 2011, Slabbekoorn et al. 2013), Blackbirds *Turdus merula* (Nemeth, et al., 2012), European robins *Erithacus rubecula* (McLaughlin & Kunc, 2013), Song sparrows *Melospiza melodia* (Wood & Yezerinac, 2006), Serins *Serinus serinus* (Diaz, et al., 2011), White-crowned Sparrows *Zonotrichia leucophrys* (Derryberry, et al., 2016). Lemon et al. (1980) suggested that Warblers adjust their song frequency and structure by either increasing or decreasing the frequency to communicate with the most biologically significant for them individuals. Erwin Nemeth and Henrik Brumm (2010) of the Max Planck Institute for Ornithology found that birds increase both frequency and amplitude in response to high noise levels, and increased frequency is just a side-effect of increased volume of the song, known as Lombard effect.

This research aims at determination of the effects of urban noise on singing of the Whitethroat *(Sylvia communis)*. The Whitethroat is a mixed singer, i.e. it copies vocal patterns of an alien species in its song (Helb, et al., 1985), and it makes the species interesting for studying the adaptations of the song to the anthropogenic noises. Besides, no studies on the effects on noise on the Whitethroat have been carried out yet. The working hypothesis (H_1) is based on the findings of the previous years on bird’s adaptations to high noise levels by increasing the frequency and adjusting the duration of singing. It is suggested that the Whitethroat would show similar tendencies in coping with urban noise. Two study questions were formulated:

1. Does the singing of the Whitethroat *Sylvia communis* in the city differ from singing of the same species in rural area?
2. What is the difference in singing of the Whitethroat *Sylvia communis* in urban and rural areas?

2 STUDY SPECIES AND STUDY AREA

2.1 Description and distribution

The Whitethroat *(Sylvia communis),* also known as the Common Whitethroat or the Greater Whitethroat, is a species of the *Sylviidae* family, order – *Passeriformes*. It is a medium-sized Old World warbler of 14-17 g weight and 14 cm in length (Aymí & Gargallo, 2017). The adult male has a distinctive grey head and a white throat (Figure 1, left). The back is grey brown or brown, and the wings are rufous. The tail is relatively long and brown or rufous in color with thin white stripes on the edges. The underparts are beige or whitish-brown. The legs are brownish-yellow. The eyes are brown with thin white-greyish eyeing. The upper part of the bill is dark brown, and the lower – is yellowish. Females are duller and have brownish heads (Figure 1, middle). Juveniles are more uniform brownish in color (Figure 1, right).

Figure 1. Adult male (left), adult female (middle), and juvenile (right) of the Whitethroat. Photos were kindly provided by Mattias Hofstede, Beat Rüegger, and John Caddick, respectively.

There are two differentiated groups of *S.communis*: Western and Eastern Whitethroat. Some ornithologists allocate four subspecies of the Whitethroat, based on their geographical distribution: *S.c.communis* and *S.c.volgensis* (of the Western group) and *S.c.rubicola* and *S.c.icterops* (of the Eastern group). *S.c.volgensis* and *S.c.rubicola* were identified only in the beginning of 20th century (Aymí & Gargallo, 2017). The subspecies have small variations in their phenotypes. Thus, *S.c.volgensis* is slightly larger, paler, has greyer upperparts and more white on the underparts than *S.c.communis*. *S.c.icterops* is darker than other subspecies. *S.c.rubicola* has more grey on the upperparts than *S.c.icterops*, and is a bit lighter overall (Bouglouan, n.d.).

The Whitethroat is highly migratory and has a very wide distribution range, from mid Scandinavia to the south of Africa, and from the west of Europe (Portugal and Ireland) to Mongolia (Figure 2). The total occupied area is 25 100 000 km^2 (BirdLife International, 2017). Subspecies have differences in distribution (Aymí & Gargallo, 2017):

- *S.c.communis.*
  Breeding: Europe, North-East Russia, Ukraine, North Turkey, North-West Africa.
  Non-breeding: West and Central Africa.

- *S.c.volgensis.*
  Breeding: South Russia, South Siberia, Kazakhstan.
  Non-breeding: North, Central and East Africa.

- *S.c.icterops.*
  Breeding: North-West and South England, Scandinavia, South Germany, North Greece, Turkey, Middle East, Caucasus, Transcaucasia, North Iran, Turkmenistan.
  Non-breeding: South-East Africa.

- *S.c.rubicola.*
  Breeding: Central Asian Mountains, Uzbekistan, Mongolia, South Transcaucasia.
  Non-breeding: South-East Africa.

Figure 2. Distribution map of the Whitethroat *(S.communis)*. Bright yellow-mustard – native and breeding (Eurasia), yellow – native non-breeding (Central and East Africa), pale yellow – passage (North Africa, Somalia and East Ethiopia) (IUCN Red List, 2016).

According to the IUCN Red List, the population size of *S.communis* is increasing, and is between 53 and 86 millions of mature individuals. The species belongs to the Least Concern group, meaning “the widespread and abundant taxa, not belonging to Critically Endangered, Endangered, Vulnerable, or Near Threatened species”. Habitat loss, desertification, and severe winters are the major threats to the species, based on the previous years (IUCN Red List, 2016). A dramatic decline in population size occurred in 1968-1975 due to the drought in Sahel region of West Africa because of the human activities, mainly because of the overgrazing and slash and burn agriculture (IUCN Red List, 2016, Schmidt, 2001). Intensive agriculture in Europe is also leading to habitat loss.

2.2 Habitat and ecology

The Whitethroat lives in a variety of habitats, but the presence of bushes and shrubs or tall blades of grass on the field are essential (IUCN Red List, 2016). It can often be found on the edges between forests and open fields (Figure 3).

The Whitethroat does not occupy densely vegetated areas such as woods (Bouglouan, n.d.). However, the nest is located in dense grasses or at the lower part of the bushes. It is made of dry grass, fiber, and wool; the outside parts are covered with cobweb, fluff, and lichen (Dementyev, et al., 1954).

Figure 3. Typical habitat of the Whitethroat. The area is represented by open fields, bushes, tall blades of grass, and trees on the edge. Photo was made by E. Karabanina in Sebezhsky National Park 10.06.2017.

Male starts singing immediately after arrival from wintering grounds and in 10-14 days builds several nests on his area (Fertikova, 2000). These nests are not finished at first, but if a male does not have a female for a long time, he may finish one of the nests himself (Nadtochiy & Krapivniy, 2016). A female either chooses and completes one of them or a pair builds a new nest (Matantseva, 2017). The breeding period generally starts in April and ends in July, slightly varying in birds from north and south areas. (Aymí & Gargallo, 2017).

A pair normally has one clutch per season, but may also have two. One of the reasons for another clutch is destruction of the first one, while the breeding period has not ended yet (Matantseva, 2017). The female lays one egg every day during 3-6 days, resulting in 3-6 eggs per clutch (most often – five), which both parents incubate for 11-13 days (NatureGate Promotions Finland LTD, 2017). However, only females incubate eggs during the night (Paevskiy, 2010). The eggs are variable in color for subspecies: from yellowish to olive or green-grey with noticeable dark markings (Dementyev, et al., 1954).

S.c.communis has olive eggs with dark markings. Fledglings leave the nest at the age of 10-12 days, but parents keep looking after them and feeding for the first 12-14 days (Dementyev, et al., 1954).

On the following year, birds tend to come to the same breeding place (Bouglouan, n.d.). Generally, the Whitethroat is monogamous, but shows polygamic tendencies: some males may have more than one female: either at the same territory or at two different territories belonging to the same male (Matantseva, 2017).

During the breeding season the Whitethroat feeds on invertebrates with addition of some fruits, but at wintering mostly consumes berries (IUCN Red List, 2016). The invertebrate diet mainly consists of beetles, caterpillars and bugs, varying in proportion of species depending on the geographical region. Thus, the Whitethroat in Ryazan (Central part of European Russia) predominantly fed on the insects with soft chitinous cover: *Diptera, Homoptera*, caterpillars, larvae of sawfly, and larva of beetles (Ivanov & Baranovskiy, 2003). The major natural threat is predation of the nestlings and eggs by snakes, ravens, crows, magpies, carnivorous mammals, dogs. Besides, the ground location of the nest increases the risk of being crushed and trampled by humans and medium/large mammals.

2.3 Song and call

The male Whitethroat starts singing right after the arrival on breeding areas and sings almost constantly (Fertikova, 2000). Singing begins with the sunrise and continues until the “hot hours” of the day (12:00 – 15:00). Before the evening, when the heat is gone, the singing resumes (Dementyev, et al., 1954). While the male is not mated, he may sing even at night in the northern counties, when the day length is around 20 hours (Simonov, 2017).

Whitethroats perform three types of songs: perch, flight, and diving of which perch song is the most often, and diving – the rarest types of songs (Balsby, 2000b). Males sings perch songs sitting on the top of the tree or a bush (Figure 4). Based on the song structure, Balsby (2000b) has determined two types of perch songs: motif and variable. Motif songs have a stereotyped beginning and a variable end, while variable songs do not have any specific sequence of elements and are typically longer, with more elements represented (Balsby, 2000b). Usually, a perch song consists of a main part and a subsong. The main part includes separate and relatively clear elements, while the subsong is softer, more uniform, and reminds twitting. The main part often remains the same for the male, while the subsong has more variations. Flight songs are similar to variable perch songs and are more chirping (Figure 5). Nadtochiy et al. (2016) found that the Whitethroat sings approximately 15-20% of songs in flight. Diving songs are aimed at attracting a female in most cases, or driving away the intruder either of the same species or of another (Petersen B., 1984, Balsby, 2000b, cited in Balsby T., 2000). A male may sing a diving song for a female nearby one of the preliminary nests that he has built (Nadtochiy & Krapivniy, 2016), or performing short flights between the branches towards a female or an intruder (Balsby, 2000b).

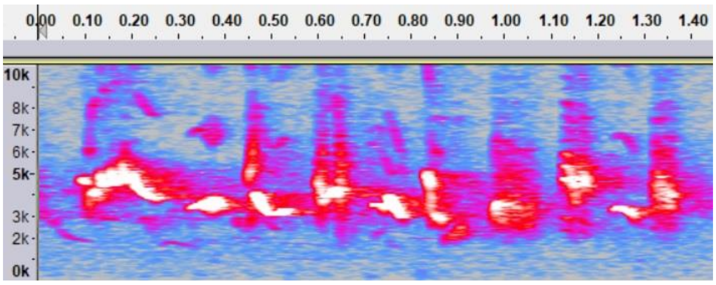

Figure 4. Spectrogram of the Whitethroat perch song recorded by E. Karabanina in Sebezh city on 09.06.2017. The horizontal axis represents time is seconds, and the vertical axis stands for frequency in Hz. The brighter the color is, the higher the intensity of the song.

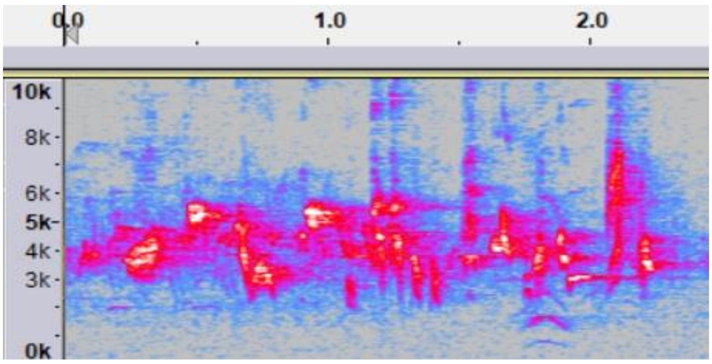

Figure 5. Spectrogram of the Whitethroat flight song recoded by E. Karabanina in Sebezh city 31.05.2017. The horizontal axis represents time is seconds, and the vertical axis stands for frequency in Hz. The brighter the color is, the higher the intensity of the song.

During the three phases of breeding cycle (unmated, pre-incubation, and post-fertile periods), perch and flight singing activity change, while diving singing remains constant. Singing activity decreases by 30-40 % after a pair has been formed, and the songs become shorter (Nadtochiy & Krapivniy, 2016). The remaining function of the song is territory marking. Males sing perch songs more actively in pre-incubation period than during the post-fertile period (Balsby, 2000b). Flight singing activity of the unmated males does not differ from pre-incubation, but becomes much lower in post-fertile period (Balsby, 2000b). Besides the first-year males have higher perch and flight singing activity than males of two years and older (Balsby, 2000a).

Song element repertoire, or number of different elements in a song, of the Whitethroat increases with age: first year males have smaller repertoire than males of two years and older (Balsby, 2000b). Repertoire size was found to reflect no only the age, but also some aspects of male quality: body condition and parasites (Balsby & Hansen, 2009). Thus, Spencer et al. (2016) found that “adult male canaries (*Serinus canaria*), infected with malaria (*Plasmodium relictum*) as juveniles, develop simpler songs as adults compared to uninfected individuals”. The fact that element repertoire size reflects the male quality may explain female preferences of males with elaborate songs, unless they arrived to the breeding areas later than males with more simple songs. Higher element repertoire also does not mean higher song length and higher number of different elements per one song (Balsby & Hansen, 2009).

The Whitethroat perform two types of calls: *woid* and *dscharp* (Figure 6). *Woild*-call is an alarm call, and often is produced by either a male or a female when and intruder comes close to the nest or somehow else makes a bird worry. *Dscharp*-call is typical for curious males as a reaction on intruders (Simonov, 2017).

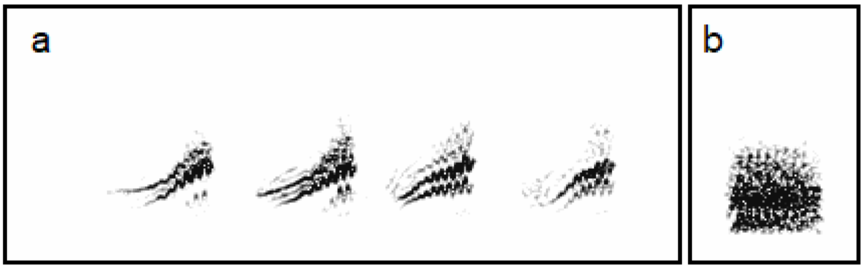

Figure 6. Spectrograms of the Whitethroat calls. *Woid*-call (a) and *dscharp*-call (b). The bandwidth is 129 Hz, time resolution is 2.9 ms. The spectrograms are kindly provided by T.J.S. Balsby.

2.4 Sebezhsky National Park

Sebezhsky National Park (56°11'N 28°27'E) is located in Pskov oblast, North-West Russia, on the Russian border with Belarus and Latvia. The total area of the park is 51 000 ha, and it consists of forest area, water reserves (lakes and rivers), agricultural lands, Sebezh city, and governmental and municipal lands (Ministry of Environment of the Russian Federation, 2011). Sebezhsky National Park was created on 01.07.1996 aiming at protection of historical monuments of culture such as human settlements of IV-II thousand BC (Ministry of Environment of the Russian Federation, 2011). Besides the historical value of the park, it represents indigenous or slightly modified landscapes with high flora and fauna biodiversity (Ministry of Environment of the Russian Federation, 2011). The park is located in the marine sector of the continent, meaning that there is no strong correlation between species distribution and natural zones. Specific flora and fauna composition is also related to the Pleistocene glaciation – the last ice age (Nikandrov, 2016a).

The major part of the National Park is covered with pine forests *(Pinus sp.)* due to a wide distribution of sandy soils (Nikandrov, 2016b). Small-leaved forests are also abundant, with dominating birch *(Betula sp.)*, grey alder *(Alnus incana)*, and aspen *(Populus tremula)* (Nikandrov, 2016c). Spruce forests *(Picea sp.)* exist in lesser extent than was in the past, and can be found nearby streams and on the plane territories (Nikandrov, 2016d). Broadleaf tree species are uncommon in the park. Rare for Pskov oblast sedges (*Carex sp.)* are found in broadleaf-spruce forests of the park (Nikandrov, 2016e). Black alder *(Alnus glutinosa)* is typical for floodplains, and together with birch, spruce, and ash *(Fraxinus sp.)* represent alder carrs. Except for the forests and lakes, the park is rich with low and high bogs, and dry and floodplain meadows. There are several villages on the edges of the park.

Fauna of the Sebezhsky National Park is very diverse, and is related to the presence of different types of habitats of various natural areas: tundra, taiga, undercut and broad-leaved forests, and steppes. However, more research is needed to give a full representation of the species, especially of invertebrates.

Most of the insects are common for North-West Russia, but several species have been found to be new or very rare for Pskov oblast, and/or Baltic region, and/or Russia in general (e.g. moths *Scopula corrivalaria* and *Acronicta tridens)*. The park is a habitat border for several day butterfly species: e.g. northern for *Lycaena tityrus,* southern for *Carterocephalus palaemon*, and eastern for *Odonestis pruni.* The vertebrate biodiversity is very high in the NP – 291 species, of which 202 birds (126 nesting), 49 mammals, 5 reptiles, 8 amphibians, 30 fish, and 2 lamprey (Nikandrov, 2016a). Three fish species have been reintroduced in the area: Peled *(Coregonus peled),* Common carp (*Cyprinus carpio*)*,* and Silver Prussian carp (*Carassius gibelio*) (Nikandrov, 2016a)*.* Most lakes in the park are either extensions of rivers' channels or have a strong connection with the rivers of Western Dvina basin. Therefore, freshwater fish species that occur in the lakes of the National Park, in other places can only be found in rivers (Nikandrov, 2016a). Several vertebrate species are included in the Russian Red Book (2017): e.g. Black stork *(Ciconia nigra),* Red kite *(Milvus milvus)*, Short-toed snake eagle (*Circaetus gallicus),* Golden eagle (*Aquila chrysaetos*), European bullhead (*Cottus gobio*)*.*

3 MATERIALS AND METHODS

3.1 Song recording and data collection

Songs of every singing Whitethroat *(Sylvia communis communis)* male were recorded for ten minutes with Olympus Linear PCM recorder LS-11 v.1.00. Singing activity was counted during the recording as the number of songs per ten minutes. Habitats of the sampled males were described as dominant tree and shrub species around the male. The data was collected during 17 days from 30 May until 15 June between 05:00 and 12:00. To mitigate biases related to the breeding season and mating status, the data was collected alternating the sampling areas. No records were done in rainy days, as rain would significantly worsen the record quality and affect the analysis. To obtain a better record and eliminate extraneous noise such as a buzzing mosquito near the hands, the recorder was placed on a hand-made stick with adjustable length. Oruxmaps v.6.5.0b smartphone application offline maps were used to register the exact location of each male recorded as the name of the record. It helped to avoid double recording of the same male. Any relevant information, such as movements, behavior, or nests was also marked in the application.

3.2 Sampling locations

To study the effects of urban noise on singing of the Whitethroat, songs of the males were recorded in two sampling locations: in Sebezh city (56°18'N 28°28'E) and nearby Osyno Lake (56°09'N 28°40'E) (Figure 7). Sebezh city (CITY) was the area with urban noise, while the Osyno area (NP) was a control location of rural environment, where birds were not affected by urban noise. Both areas were on the edges of the National Park, eliminating the biases related to the edge effect. The total number of recorded males in NP was 33, and in CITY – 31, and the location of each singing male was documented in Oruxmaps (Figures 8 and 9).

Figure 7. Map of the Sebezhsky National Park. Sampling locations are marked with arrows. Sebezh city is located on the north of the National Park (red arrow). The control location is on the South-East of the National Park – around the village Osyno and nearby the lake Osyno (violet arrow).

Figure 8. Locations of 31 Whitethroat males recorded in Sebezh city. The map was created in Google Earth pro using the metadata from Oruxmaps.

Figure 9. Locations of 33 Whitethroat males recorded nearby Osyno lake. Most birds were recorded nearby the Osyno Lake, and seven individuals – 4 km to the south-east from the Osyno Lake. The distance between the most northern and the most southern recorded males is approximately 8 km, between the most western and most eastern – 2 km. The map was created in Google Earth pro using the metadata from Oruxmaps.

3.3 Data analysis

In total, 64 Whitethroat males were recorded, of which 31 were in CITY and 33 in NP. Sound analysis and record processing were done in Audacity v.2.1.3, studying the spectrograms of the songs. To achieve a better representation of the song's spectrogram, the maximum frequency was set to be 10 000 Hz, and the color gain, range and frequency gain in most songs were 20 dB, 60 dB, and 12 dB, respectively. Several color adjustments were done for the songs with lower amplitude to improve the visualization. The output records were in WAV-format, meaning that they were reproduced in the analysis software accurately without the losses of some parts of the audio (Joe, 2013). Nine song parameters were chosen to compare singing of the Whitethroats in NP and CITY:

- song length (s);
- total number of elements in the song (#);
- number of different elements in a song (#);
- minimum element frequency (Hz);
- maximum element frequency (Hz);
- maximal spectral frequency of an element (Hz);
- element length (s);
- singing activity (#);
- lengths of the pauses between songs (s).

For simplicity, the whole analysis was split into four parts: general, elements, activity, and pauses.

General

General analysis included the parameters related to the whole song: song length, total number of elements in a song, and number of different elements in a song. First, 2-6 randomly chosen songs were cut out of the whole record for every male to simplify the further analysis. The target was to have three songs per male, but in some cases only two records could be taken, due to the low quality of the record related to additional noises (wind, songs of other species, humans, cars) or great recording distance leading to low sound amplitude. In order to compensate that, more songs were taken from other individuals from the same study group. To calculate the number of different elements, the catalogue of elements was prepared, representing the spectrograms the elements for both NP and CITY. Every new element received a numerical or a letter code. Based on visual and aural comparison with elements from the catalogue or previous songs, every following element got either an existing code or a new one if it had not been detected before.

Elements

Part “Elements” focused on the parameters related to the elements of the song: minimum and maximum element frequency, maximum spectral frequency of an elements, and the length of an element. If the same element was repeated two or more times in one song, only the first of them was included in the analysis. The songs used for the element analysis were the same as for the general analysis. Frequencies were measured from spectrum, plotted by Audacity (hamming window; window size – 4096; linear frequency). The peak value indicated the maximum spectral frequency (Hz), and the boundaries of the graph’s sublime part of an element represented the minimum and maximum frequencies (Hz). For some elements it was important to check the approximate frequency boundaries on the spectrogram, as presence of additional sounds at the same time period was also reflected on the spectrum.

Activity

Activity analysis aimed at comparison of singing activities as numbers of songs per ten minutes in NP and CITY. The activities were counted during the recording of singing. However, if there were uncertainties about the number of songs that a male had sung, it was counted again, checking the spectrograms in Audacity. To eliminate the biases related to the breeding period and couple formation birds from both study locations were recorded alternately during the field work, meaning that singing activity was supposed to gradually decrease over these days for rural and urban areas.

Pauses

The lengths of the pauses between 12 songs of the whole record were measured, resulting in ten pauses per record. The pause was a period of time between the end of the last element of one song and the beginning of the first element of the following song, measured in seconds. In cases when the male stopped singing, and then resumed again, the interval of silence was not considered a pause. If it was not possible to measure the pauses between 12 songs in a record, that record was removed from the analysis. For further statistical tests the medians of the lengths of the pauses per one record were calculated.

Statistical testing

Comparison between the parameters from NP and CITY was done by testing the null-hypothesis (H_0: $M_{NP} = M_{CITY}$, where M – median/mean) with either a non-parametric Mann-Whitney test (comparison of medians) or parametric unpaired two-tailed t-test (comparison of means). The confidence interval was 95 % for all tests ($\alpha = 0.05$). When the p-value was less than 0.05, the null-hypothesis was rejected, meaning that a significant difference between NP and CITY for the specific parameter was found, and vice versa: $p \geq 0.05$ – the medians/means could be considered equal for two sample groups.

Statistical analysis was done in Statgraphics Plus for Windows 2.1. and Maxstat Lite v.3.6. Maxstat had a limited number of rows for the data (254), so only those parameters, which sample size was less than 254 were tested in it. First, all parameters were tested on normality. For that Anderson-Darling (Maxstat) test and normality test based on standardized skewness and kurtosis (Statgraphics) were done. Anderson-Darling test is sensitive to the tails of distribution (Nornadiah & Yap , 2011) and is recommended by Maxstat. Standardized skewness and kurtosis values represent the deviation of the data's graph from its center on X and Y axes. According to Statgraphics, the values of standardized skewness and kurtosis belonging to the range from -2 to +2 are normally distributed. All normally distributed parameters were tested on variance with Bartlett's test for homogeneity of variances in order to use the unpaired t-test. Table 1 represents the principle of selecting a statistical test for the H_0 hypothesis testing.

Statistical test was chosen based on the normality and variance tests' results and fulfillment of required assumptions. Therefore, despite the fact that parametric tests perform more statistical power than non-parametric (Frost, 2015), they cannot be used if the assumptions for parametric tests are not met. In the study, all four required for the Mann-Whitney test assumptions were met (Lund Research Ltd, 2013): (1) dependent variables (parameters) were of continuous type (value for e.g. frequency, song length); (2) independent variables were two independent groups of the Whitethroat males in NP and CITY; (3) observations were independent as there were two remote sampling locations, and one male was not recorded twice; (4) the variables were not normally distributed. Unpaired t-test had three required assumptions that were also met (BBN, 1997): (1) independent and normally distributed variables; (2) independent samples of Whitethroats in NP and in CITY; (3) equal variances of the tested parameters from NP and CITY.

Pearson correlation coefficients were calculated for (1) song length, total number of elements, and number of different elements; and (2) singing activity, length of pauses, and song length. It was done to simplify the assessment of noise effects on singing of the Whitethroats. Thus, if one of the correlated parameters was significantly different between both study groups of the species, then others would show the same tendency, and vice versa.

Table 1. The principle of selecting a statistical test for hypothesis testing. First, the normality test, and if it is passed, then the variance of samplings is tested. The uppercase numbers indicate statistical software used for hypothesis testing.

Parameter	Statistical test
Song length[2]	Anderson-Darling: normal distribution AND Bartlett's variance: passed -> unpaired 2-tailed t-test
Total elements[2]	Anderson-Darling: normal distribution AND Bartlett's variance: passed -> unpaired 2-tailed t-test
Different elements[2]	Anderson-Darling: normal distribution AND Bartlett's variance: passed -> unpaired 2-tailed t-test
Min freq[1]	Skewness and kurtosis: not normal distribution -> Mann-Whitney test
Max freq[1]	Skewness and kurtosis: not normal distribution -> Mann-Whitney test
Max spectral freq[1]	Skewness and kurtosis: not normal distribution -> Mann-Whitney test
Element length[1]	Skewness and kurtosis: not normal distribution -> Mann-Whitney test
Activity[2]	Anderson-Darling: normal distribution AND Bartlett's variance: passed -> unpaired 2-tailed t-test
Pauses[2]	Anderson-Darling: normal distribution AND Bartlett's variance: not passed -> Mann-Whitney

[1] Statistical analysis was done in Statgraphics Plus for Windows 2.1
[2] Statistical analysis was done in Maxstat Lite v.3.6

4 RESULTS

4.1 Habitats

Willow *(Salix sp.)* dominated in the preferred by the Whitethroat habitats in both: NP (33 %) and CITY (30 %), followed by birch (*Betula pendula* and *B.pubescens*) – 22 % in NP, 16 % in CITY (Figure 10). The distribution of other vegetation species was relatively even in NP, while in CITY garden vegetation made up about 15 % of the total (Figure 10). Garden tree and shrub species were represented by Apple *(Malus domestica)*, Lilac *(Syringa* *vulgaris)*, Rose *(Rosa sp.)* and other garden bushes. Category "others" included any other non-dominant tree and shrub species: Ash *(Fraxinus sp.*), Horse Chestnut *(Aesculus hippocastanum)*, Linden *(Tilia sp.),* Field bindweed *(Convolvulus arvensis),* Pedunculate oak *(Quercus robur)*, Scots pine *(Pinus sylvestris)*, Raspberry *(Rubus idaeus)*, and Rowan (*Sorbus aucuparia)*. The amount of data was not sufficient for statistical testing of dominant vegetation for two sampling areas.

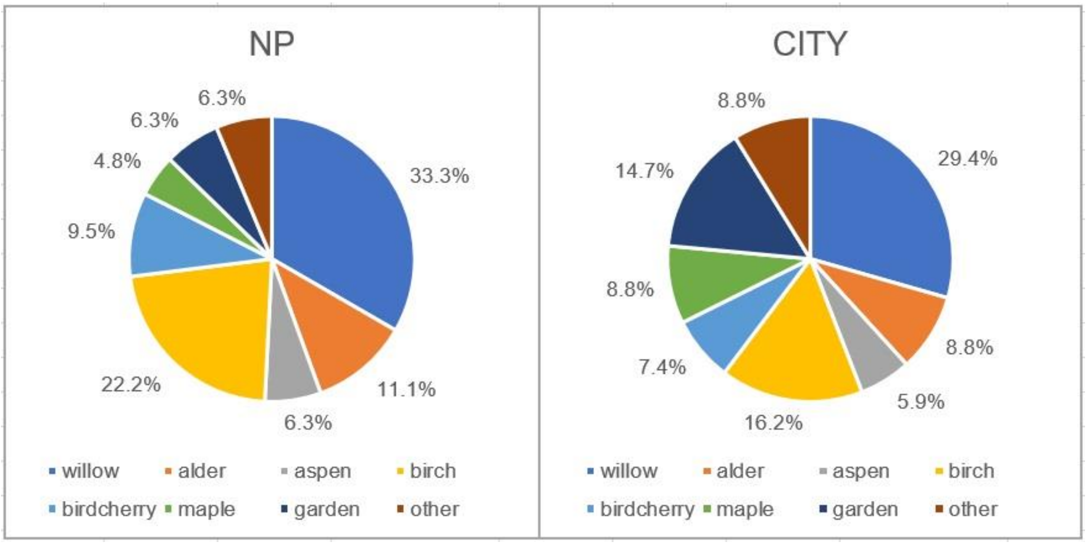

Figure 10. Distribution of tree and shrub species in the habitats of the recorded Whitethroats nearby Osyno Lake (NP) and in Sebezh city (CITY). Group "garden" includes Apple, Lilac, Rose, and other garden bushes. Group "others" includes Ash, Horse Chestnut, Linden, Field bindweed, Pedunculate oak, Scots pine, Raspberry, and Rowan.

4.2 General

Sample sizes (n) for parameters belonging to the general part of the analysis were 116 for NP and 96 for CITY. Song length ($p = 0.543$), number of total elements ($p = 0.968$), and number of different elements ($p = 0.220$) were not significantly different for NP and CITY (Appendix 1). Box-Whisker plots for the values of song length and total number were almost equal (Figure 11, a, b). Despite the fact that statistical tests did not find any difference between the means, the Whitethroats in CITY generally had more different elements in their songs than the Whitethroats in NP (Figure 11, c).

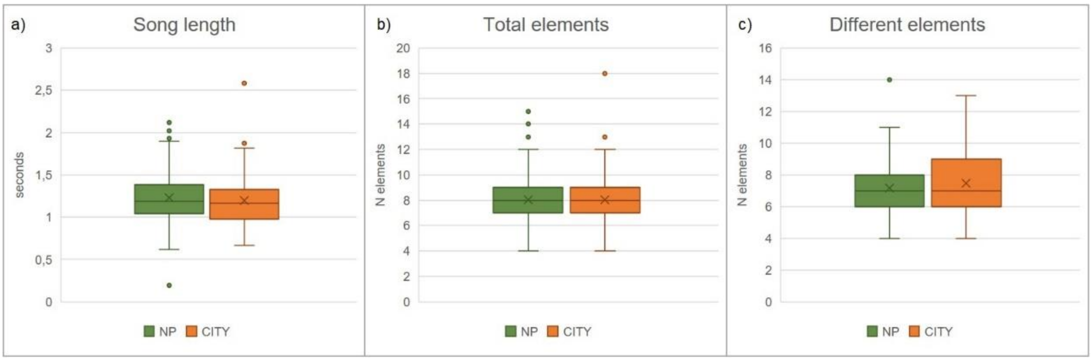

Figure 11. Box-Whisker plots for song length (a), number of total elements in a song (b), and number of different elements in a song (c). Green graphs are for the Whitethroats recorded nearby Osyno lake (NP), and orange – in Sebezh city (CITY). The vertical axes for total and different elements is the number (N) of elements per song. The crosses within the boxes represent the means, and the horizontal line – the medians. The width of the box is the interquartile range. The dots indicate outliers, which are 1.5 times bigger than the upper quartile. Upper whisker shows the highest value, and lower whisker – the lowest, excluding the outliers.

4.3 Elements

Among the four parameters of the “Elements” part of the analysis, only the lengths of the elements (Figure 12, d) had a significant difference for the Whitethroats in NP and CITY (Mann-Whitney test, $p < 0.001$, $M_{NP} = 0.137$ s, $M_{CITY} = 0.117$ s, where M – medians). Minimum ($p = 0.905$) and maximum element frequency ($p = 0.193$) and maximum spectral frequency ($p = 0.225$) were not different for NP and CITY (Figure 12 a, b, c; Appendix 1). Sample sizes were 824 for NP and 719 for CITY. Element length had a large data spread for NP with many outliers (Figure 12, d).

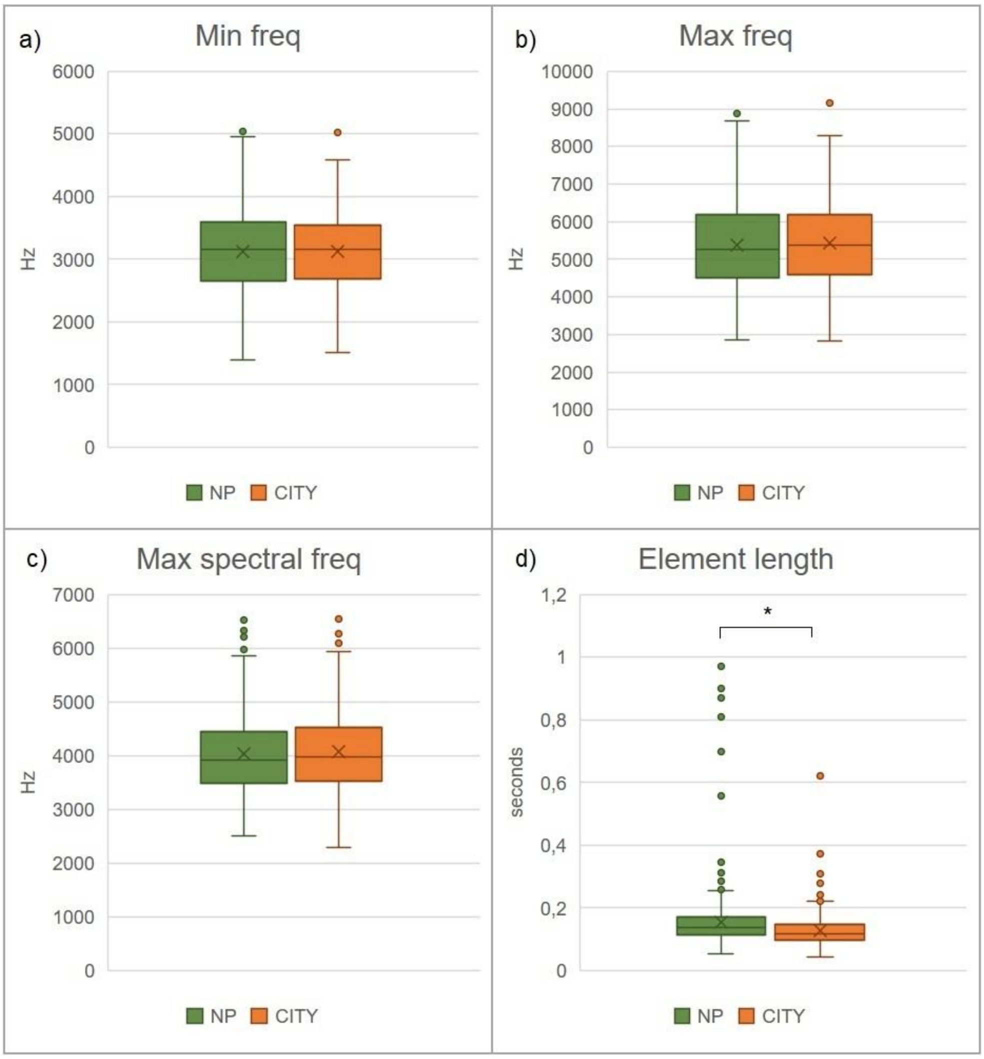

Figure 12. Box-Whisker plots for minimum element frequency (a), maximum element frequency (b), maximum spectral frequency of an element (c), and element length (d). Green graphs are for the Whitethroats recorded nearby Osyno lake (NP), and orange – in Sebezh city (CITY). Frequency unit for the vertical axes of graphs a, b, and c is Hertz (Hz). The crosses within the boxes represent the means, and the horizontal line – the medians. The width of the box is the interquartile range. The dots indicate outliers, which are 1.5 times bigger than the upper quartile. Upper whisker shows the highest value, and lower whisker – the lowest, excluding the outliers. Asterisk in the graph of element length indicate the significant difference ($p < 0.05$) of this parameter between two study areas.

4.4 Activity

Statistical testing did not find any difference between the means of singing activity in NP and CITY (unpaired 2-tailed t-test, $p = 0.341$). However, generally males in CITY sang more songs during ten minutes (Figure 13). Sample sizes were 33 and 31 for NP and CITY.

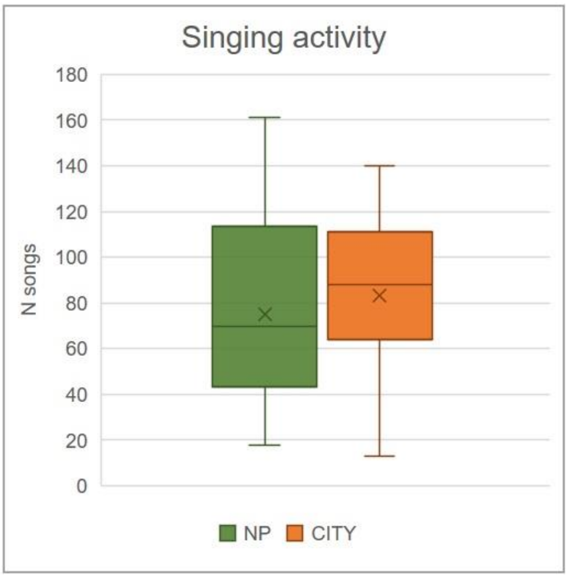

Figure 13. Box-Whisker plot for singing activity as the number of songs per ten minutes. Green graph is for the Whitethroats recorded nearby Osyno lake (NP), and orange – in Sebezh city (CITY). The vertical axis is the number (N) of songs sang per ten minutes. The crosses within the boxes represent the means, and the horizontal line – the medians. The width of the box is the interquartile range. The dots indicate outliers, which are 1.5 times bigger than the upper quartile. Upper whisker shows the highest value, and lower whisker – the lowest, excluding the outliers.

4.5 Pauses

The lengths of the pauses (Figure 14) between songs were significantly different in two sampling areas (Mann-Whitney test, $p = 0.0097$). Recorded males in NP had longer pauses between the songs than males in CITY (M_{NP} = 4.400 s, M_{CITY} = 3.765 s, where M – median). Sample sizes were 33 for NP and 30 for CITY.

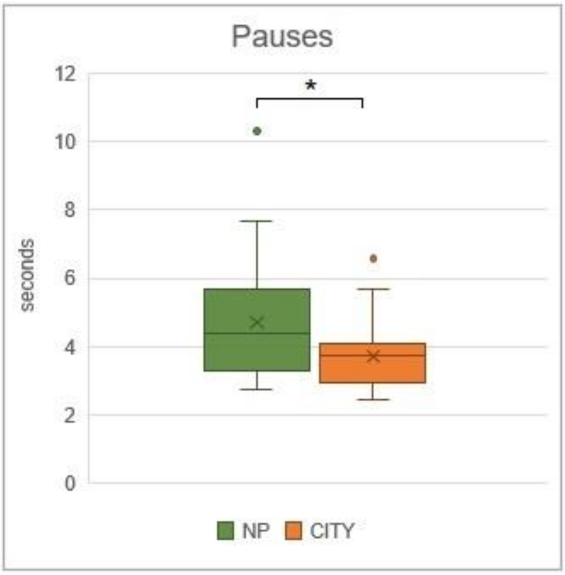

Figure 14. Box-Whisker plot for lengths of the pauses between songs. Green graph is for the Whitethroats recorded nearby Osyno lake (NP), and orange – in Sebezh city (CITY). The crosses within the boxes represent the means, and the horizontal line – the medians. The width of the box is the interquartile range. The dots indicate outliers, which are 1.5 times bigger than the upper quartile. Upper whisker shows the highest value, and lower whisker – the lowest, excluding the outliers. Asterisk in the graph indicate the significant difference ($p < 0.05$) of this parameter between two study areas.

4.6 Pearson correlation

Song length, total number of elements and number of different elements per song had strong positive correlations between each other for both study groups in NP and CITY (Table 2). Pearson correlation between singing activity and length of pauses was medium in NP and low in CITY, while song length was correlated neither with singing activity, nor with length of pauses between songs for both areas (Table 3). The guideline for interpreting the Pearson coefficient values is presented in Appendix 2.

Table 2. Pearson correlation coefficients (r) for songs length, total number of elements, and number of different elements for the recorded Whitethroats nearby Osyno Lake (NP) and in Sebezh city (CITY).

Parameters	Correlation coefficient, r	
	NP	CITY
Song length – Total elements	0.8213	0.8458
Total elements – Different elements	0.8351	0.9232
Song length – Different elements	0.7426	0.7123

Table 3. Pearson correlation coefficients (r) for song length, singing activity and length of pauses between songs for the recorded Whitethroats nearby Osyno Lake (NP) and in Sebezh city (CITY).

Parameters	Correlation coefficient, r	
	NP	CITY
Song length – Singing activity	0.0634	0.2410
Singing activity – Pauses	- 0.4858	- 0.1368
Song length – Pauses	0.1520	0.2171

5 DISCUSSION

Singing of the Whitethroats in the city was different from singing of the same species in rural area based on two parameters: length of elements and length of the pauses between songs. Other parameters were not statistically different for the two studied groups of the species.

The habitats of both study areas were similar in dominating tree and shrub species. Floral composition in the habitats of the recorded males fully complied with the required habitat for nesting and breeding of the Whitethroat. Prevalence of garden flora under the other deciduous species in CITY was expected in urban environment such as Sebezh, as many living places were detached houses with small gardens. The level of noise and its impacts on singing of the Whitethroats in Sebezh could be affected by the presence of noise barriers: fences, buildings (i.e. if the male lived in the yard behind the house), and groves. Most males were recorded in the areas remoted from the major noise sources such as main city roads and the railway. Presence of noise barriers in Sebezh city could reduce noise levels, so that birds did not have to change song frequency, singing activity, song length and number of total and different elements in their songs for successful communication.

Song length, total number of elements and number of different elements did not statistically differ between the males in urban and rural areas. Gentry et al.

(2017) studied the adaptations of suboscine birds to increased noise levels and decreased song length of the birds in noisy areas was among the finding of the researches. However, the Whitethroat belongs to oscine birds, which have a more complex song compare to suboscine, and the response of oscine birds to urban noise may be different from the findings of Gentry. Although, there was a small tendency of the males in NP to have longer songs than the males in CITY, more research is needed to prove this hypothesis.

Despite no statistical difference between the number of different elements, the Whitethroats in CITY had slightly higher repertoire size (number of different elements in a song) than in NP. Balsby (2000a) pointed that repertoire size reflected male quality of the Whitethroats: females preferred males with higher repertoire size. The uncertainty could arise due to the randomly chosen songs for the analysis and sample sizes. Probably, higher repertoire size in the noisy environment was an adaptation strategy of the male Whitethroats to increase the chances for successful mating. However, as the differences have not been supported statistically, this hypothesis still needs to be tested in further studies. Contrary to the findings of Balsby (2000a) song length, total number of elements and different number of elements of the studied Whitethroats had strong positive Pearson correlations. Eens et al. (1991) also found a direct correlation between the repertoire size and song bout length of European Starlings *(Strunus vulgaris).* Thus, if birds in urban environments change one of these parameters compare to the individual from rural areas, the effects of noise on the others would be as well.

Element length was one of the two significantly different singing parameters between the Whitethroats in the city and in the National Park. Recorded males in Sebezh had shorter song elements than the males in the National Park. For birds living in urban areas it may be costly to sing long-element songs, or less efficient in copying with noise. No previous studies focused on the effects of high noise levels on element length of the bird’s song, so more research is needed to give reliable conclusions on how birds change element length in response to urban noise.

Shorter song elements of the Whitethroats recorded in Sebezh could be also related to the lower air quality in the city, where the air is more polluted than in rural parts of the National Park. Air quality has a direct impact on bird’s health, as ozone and nitrogen oxides damage bird’s lungs (Zollinger, et al., 2017). Besides, chronic exposure to pollutants in air, water, and soil (via food) may worsen the physical condition of birds, which, in turn, may lead to changes on vocalization, such as inability to sing long-element songs.

In this study, the Whitethroats in both urban and rural areas had almost equal frequencies of song elements, while most studies had proved that birds increase minimum frequency of songs to cope with high noise levels (Nemeth & Brumm 2009, McLaughlin et al. 2013). Discrepancy with previous results may be explained by several reasons. First, the level of noise in Sebezh city was not high enough to cause changes in vocalizations. McLaughlin et al. (2013) proved that the level of noise pollution rather than the presence of noise determines the changes in birds’ behavior. The level of noise that causes changes may also be different for different bird species. Thus, Brumm (2004) discovered that Nightingales *(Luscinia megarhynchos*) increased the song frequency when the mean values of the background noise ranged from 40 to 64 dB. However, in this study the noise level in Sebezh city was not measured. The other reasons could be lack of food resources in Sebezh to compensate high costs for louder singing; already formed breeding pairs; and low activity of singing neighbors or only few singing neighbors.

No difference in song frequency between the study groups mean that the Whitethroats either do not change, or physically unable to change the frequency, or the level of urban noise in this study was not high enough to cause changes. Probably, the Whitethroats have chosen the strategy of decreasing the pauses between songs and singing short-element songs instead of increasing the song frequency to have a better communication under the noisy conditions as it is either more effective or less energy-demanding. This adaptation could be a micro evolutionary change on the population level of the Whitethroats in Sebezh region.

Singing activities of the males in CITY and NP were not statistically different. However, recorded Whitethroats in Sebezh city generally sang more songs during ten minutes of recording than the males from the National Park. As noise masks acoustic signals, the necessity of males to be heard by females could force the males in Sebezh to sing more actively than in quiet rural areas of the National Park. Higher sample size would make the conclusions about the effects of noise on singing activity of the species more certain.

The second parameter in this study that proved the effects on noise on singing of the Whitethroat was the length of pauses between songs, which was higher in NP than in CITY. Longer pauses between songs of the Whitethroats in rural area may be explained by the fact that birds do not need to sing as often as in noisy environment to be heard by mates. It also supports the findings of Nemeth et al. (2009) that forest birds have longer intervals between songs than birds in cities.

Several aspects that influence singing of males were not included in the research: age of the male, mating status, presence of singing neighbors, developmental history, and resource abundance. Older males (≥ 2 years) have more complex repertoires of their songs compare to the 1-year olds (Balsby & Hansen, 2009). Unmated males have higher singing activity (Balsby, 2000b), may have higher frequency and amplitude of the song (Lemon, et al., 1980), and sing longer songs (Nadtochiy & Krapivniy, 2016) than mated individuals. Presence of singing neighbors makes the male perform a better-quality song (repertoire size, length, frequency, and amplitude) to defend his territory and to hold down his female (Narango & Rodewald, 2016). Developmental history of species may be the reason for changes in singing of birds as a result of “cultural or microevolutionary shifts at the population level” (Zollinger, et al., 2017). Singing higher-quality songs is energetically expensive for males, and lack of food resources may lead to decreased signing activity, lower song amplitude and frequency, shorter songs, and less time singing in general (Searcy et al. 2010, Narango et al. 2016). Despite the uncertainties related to these aspects, the study has proved the effects of urban noise on singing of the Whitethroat.

6 CONCLUSION

Based on this research, the Whitethroats in urban areas have shorter song elements and shorter pauses between songs, than individuals in rural areas. Statistically, singing activities, lengths of pauses, repertoire size and frequencies are not different for both study groups. There is a visual tendency of some parameters (singing activity, song length, repertoire size) to show the difference between signing of the Whitethroats in the city and in the National Park, but more research is needed to have reliable conclusions.

This study proves that the Whitethroat replenish the list of bird species, on which noise has not only negative physical impacts, but also cause behavioural changes. In a long evolutionary term song modification in urban populations may lead to the selection of new subspecies of the Whitethroats. However, more research is needed to have a better understanding of the effects of urban noise on singing of the Whitethroats. Further studies could be related to:

- the level of urban noise that cause changes in singing of the Whitethroat;
- impacts of additional factors on the Whitethroat signing and adaptations to urban noise, such as age, mating status, singing neighbors, pollution, and food resources;
- different usage of song elements of individuals in city and forest, as some elements of lower frequency than urban noise (about 2-3 Hz) may not be sang in the city (Nemeth, et al., 2012);
- increasing the reliability of the findings by conducting the research in more study regions and analyzing larger sample sizes;
- studying the ability of the Whitethroats and energy demands to change song frequency and amplitude in response to urban noise.

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Appendix 1

Summary table of statistical testing. Confidence interval (CI) 95% (α = 0.05) for all tests.

Parameter	Statistical test	NP (n, M)	CITY (n, M)	p-value	Interpretation of the p-value
1. Song length (s)	2-tailed t-test (unpaired)	n = 116 mean ± sd = 1.226 ± 0.304	n = 96 mean ± sd = 1.200 ± 0.301	0.5428	No significant difference
2. Total elements (#)	2-tailed t-test (unpaired)	n = 116 mean ± sd = 8.043 ± 2.140	n = 96 mean ± sd = 8.031 ± 2.130	0.9679	No significant difference
3. Different elements (#)	2-tailed t-test (unpaired)	n = 116 mean ± sd = 7.181 ± 1.728	n = 96 mean ± sd = 7.490 ± 1.925	0.2204	No significant difference
4. Min freq (Hz)	Mann-Whitney	n = 824 median = 3152.0	n = 719 median = 3162.0	0.9054	No significant difference
5. Max freq (Hz)	Mann-Whitney	n = 824 median = 5277.5	n = 719 median = 5370.0	0.1929	No significant difference
6. Max spectral freq (Hz)	Mann-Whitney	n = 824 median = 3926.0	n = 719 median = 3971.0	0.2250	No significant difference
7. Element length (s)	Mann-Whitney	n = 824 median = 0.1365	n = 719 median = 0.117	<0.001	Significant difference
8. Activity (#)	2-tailed t-test (unpaired)	n = 33 mean ± sd = 75.121 ± 35.476	n = 31 mean ± sd = 83.387 ± 33.270	0.3408	No significant difference
9. Pauses (s)	Mann-Whitney	n = 33 median = 4.400	n = 30 median = 3.765	0.0097	Significant difference

n – sample/data size
M – median or mean
sd – standard deviation

Appendix 2

Interpretation of the Pearson correlation coefficients.

	Coefficient, *r*	
Correlation	Positive	Negative
Low	0.1 to 0.3	-0.1 to -0.3
Medium	0.3 to 0.5	-0.3 to -0.5
High	0.5 to 1.0	-0.5 to -1.0

Appendix 3

List of Figures and Tables.