CZECH UNIVERSITY OF LIFE SCIENCES FACULTY OF LIFE SCIENCES

Department of Ecology

Vliv hlukového a světelného znečištění na hlasovou aktivitu kosa černého (*Turdus merula*)

The impact of traffic noise and artificial light on vocal activity of Blackbird (*Turdus merula*)

Bachelor thesis

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CZECH UNIVERSITY OF LIFE SCIENCES PRAGUE

Faculty of Environmental Sciences

BACHELOR THESIS ASSIGNMENT

Tamar Balgiashvili

Applied Ecology

Thesis title

The impact of traffic noise and artificial light on vocal activity of Blackbird (Turdus merula)

Objectives of thesis

The bachelor thesis aims to study the influence of the light and noise pollution on the vocal activity of the lackbird (*Turdus merula*). More specifically, it will analyze the intensity of the song during the 60 mins after the sunrise.

Methodology

Research will be conducted on 4 types of locations – with light pollution, with noise pollution, with both types of pollutions and locations without any disturbing factors.

During the research will be analysed recordings from the year 2014 and 2015. The intensity of the Blackbird vocalization will be monitored on each of the 40 recordings with the help of Avisoft software.

The proposed extent of the thesis

25- 30 pages + attachments

Keywords

light pollution, noise pollution, vocal activity, Common Blackbird

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Recommended information sources

Dominoni, D.M., Carmona–Wagner, E.O., Hofmann, M., Kranstauber, B. & Partecke, J. 2014: Individual–based measurements of light intensity provide new insights into the effects of artificial light at night on daily rhythms of urban–dwelling songbirds. Journal of Animal Ecology, 83(3): 681-692.

Fuller R.A., Warren P.H. & Gaston K.J. 2007: Daytime noise predicts nocturnal singing in urban robins. Biology Leters vol. 3: 368-370.

Kempenaers, B., Borgstrom, P., Loes, P., Schlicht, E. & Valcu, M. 2010: Artificial Night Lighting Affects Dawn Song, Extra-Pair Siring Success, and Lay Date in Songbirds. Current Biology, Vol. 20: 1735-1739.

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Nordt A. & Klenke R. 2013: Sleepless in Town – Drivers of the Temporal Shift in Dawn Song in Urban European Blackbirds. PLoS ONE 8(8).

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Declaration

I confirm that this paper, devoted to the research of the artificial light and the traffic noise pollution affects on the vocal activity in Common Blackbird (*Turdus merula*), I have elaborated with the help of referred sources and information

Prague, 25.04.2018 Signature:

Acknowledgement

I would like to thank my supervisor Ing. Petr Zasadil, Ph.D for willing to lead my thesis, to be always there to advise and support.

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Prague, 25.04.2018 Signature:

Devoted to my dad ☺

Abstract

The increasing number of studies devoted to the urbanization effects on the different animal and bird population are identifying 2 main pollution factors having the increasing trend and what is the most important – big impact of the environment – artificial light and urban noise pollution. Artificial light is suspected to cause a shift in timing and increase the song length together with the song intensity in most songbirds' vocal activity. Urban noise can mask the part of the acoustical signals, change the melody and also affect the timing and intensity of the song.

The aim of the below paper is to find out the statistically significant effect of the light and noise pollution on Common Blackbird`s vocal activity in the morning during the dawn chorus. The recordings from 2014 were analyzed from 4 types of localities - 1. With a light pollution, 2. With the noise pollution, 3. With the both light and noise pollution and 4. Control localities with no significant light or noise pollution. Avisoft SASLab and R statistical software were used for analyzing and evaluating recordings.

The artificial light pollution was found as main cause in the earlier onset on the Blackbird`s dawn chorus as well as resulting significantly increased length and intensity of the song. According to the below results noise can not cause the statistically significant shift, nor affect the length and the intensity of the song. Nevertheless, with the combination with other independent variables (here artificial light) strengtheners the effect – Blackbirds on the localities effected by the combo of noise and light pollution start singing much earlier (some of them even 3 hours earlier) then the sunrise. The Combination of light and noise pollution also seem to decidedly contribute to prolonged dawn chorus song and maintenance of high intensity throughout the whole singing period.

Key words

Blackbird (*Turdus merula*), Dawn Chorus, Light pollution, Noise Pollution, Urbanization.

Used shortcuts

Blackbird, Common Blackbird, C. Blackbird, European Blackbird – all refer to *Turdus merula* in this paper

Contents

1. Introduction

Increasing Urbanization is one of the predominant trends of our time with 54 percent of the world's urban population to be increased to 66 % projected by 2050 (United Nations, 2015). By pushing the boarders of the nature, we increase the spaces of interaction (United Nations, 2015). Except numerous environmental impacts including air, water pollution, changes in patterns of precipitation and water streams, worsening the land quality and creation of the "heat Island" (Uttara, Bhuvandas, & Aggarwal, 2012), urbanized areas are also affecting the environment via anthropogenic light (Spoelstra & Visser, 2013) (Rich & Longcore, 2006) and noise pollution (Madadi, et al., 2017).

All these affects cumulate and modify habitats for all the species living in and around the urbanized areas affecting change in their morphology (Biard, et al., 2017) and physiology (Dominoni, Quetting, & Partecke, 2013; Miranda, Schielzeth, Sonntag, & Partecke, 2013) together with fitness and behavior – particularly daily activity (Riley, et al., 2003; Rich & Longcore, 2006) for example in songbirds - reflecting is the shifts in their circadian clock (Dominoni, Esther, Hofmann, Kranstauber, & Partecke, 2013).

The effects of the light and noise pollution on vocal activity of common blackbird (*Turdus merula*) was a subject of numerous studies (Dominoni, Esther, Hofmann, Kranstauber, & Partecke, 2013; Kamplenauer, Borgstrom, Loes, Schlicht, & Valcu, 2010; Nemeth, et al., 2013), but most of them focus only on the before sunrise vocal activity – more specifically when the bird starts to sing. Hereby bachelor thesis aims to analyze the vocal activity of common blackbird and evaluate the following hypotheses:

Ha: Anthropogenic light and noise pollution shifts the start of the song of Common blackbird (*Turdus merula*) song in the morning;

Hb: anthropogenic light and noise pollution affects the length of the Common blackbird (*Turdus merula*) song in the morning;

Hc: Anthropogenic light and noise pollution affects the intensity of the Common blackbird (*Turdus merula*) song in the morning (Hc1: maximum intensity and Hc2: mean intensity);

Hd: Anthropogenic light and noise pollution affects the length of the Common blackbird (*Turdus merula*) song after the sunrise.

2. Background theory research

2.1. Urbanization and vocal activity

Increasing Urbanization is one of the predominant trends of our time with 54 percent of the world's population that lives in urban areas (United Nations, 2015). The idea that urbanization creates a shift in coping styles by changing the stress physiology of animals was confirmed by the research conducted by Partecke, Schwabl & Gwinner (2006). The recent study in Czech Republic shows on a large geographic scale that despite strict European air pollution regulations and regular monitoring that have allowed general improvements in atmospheric contamination, non-degradable heavy metals persistently contaminate animal blood and feathers in anthropogenic environments at levels that may have subclinical yet physiological effects with varied influence on health (Bauerová, et al., 2017).

When coming back to the song birds, besides all above listed affects, the urban environment decreases the effectivity of the spreading the vocal signal. As urban birds often experience very noisy conditions while singing, the acoustic signals (that are crucially important for life functions - mating, defend territory, warnings, socializing, bringing up the new generations) are weakened and deformed because of the numerous walls and constructions in cities (Slabbekoorn & Boer-Visser, 2006).

As my thesis is specifically focused on the light and noise pollution, the remaining 2 subchapters are devoted to the scientific research background beyond the referred topics and its effect on the vocal activity of Common blackbird.

a. The influence of noise pollution on the vocal activity

Noise pollution among other effects on the physiology and psychology of birds and animals, is also considered as an obstacle in vocal communication by interfering with the low frequency acoustical signals (Madadi, et al., 2017). This obstacle can cause the severe damages in the species where acoustical communication is predominant, especially singing birds. Studies (Slabbekoorn & Peet, 2003; Nameth, et al., 2013) suggest that the city blackbirds had adapted their singing frequency (to higher amplitudes) that enables them to differentiate their song from the urban noise pollution.

Blackbirds *(Turdus merula*) are one such species that sings at lower frequencies (Cramp & Perrins, 1994). For urban noise it is characteristic to have high volume acoustics on the low frequencies (Slabbekoorn & Ripmeester), there a logical consequence above all that these 2 frequencies are overlapping that could limit blackbirds communication that is crucial for singing birds in many life aspects, especially for reproductive success (see paragraph 2.2 a. Acoustics and song).

Multiple studies conducted on comparing the song of the C. blackbirds living in Urban areas and ones that live in forests, underline the birds have learned how to avoid masking their songs with the urban noise – they learned to evade low frequencies. Researchers Nemeth and Brumm (2009) compared the songs of blackbirds, *Turdus merula*, from the city center of Vienna and the Vienna Woods and found that forest birds sang at lower frequencies and with longer intervals between song. Multiple studies conducted on comparing the song of the C. blackbirds living in Urban areas and ones that live in forests, underline the birds have learned how to avoid masking their songs with the urban noise – they learned to evade low frequencies (Nemeth & Brumm, 2009; Solange Mendes & Peris, 2011). The statistically significant change was found also when studying other singing birds living in the city - Great tit *Parus Major* (Mockford & Marshall, 2009; Halfwerk, Bot, & Slabbekoorn, 2012) European robin *Erithacus rubecula* (Mclaughlin & Kunc, 2013; Montague, Danek-Gontard, Kunc, & Kunc, 2013).

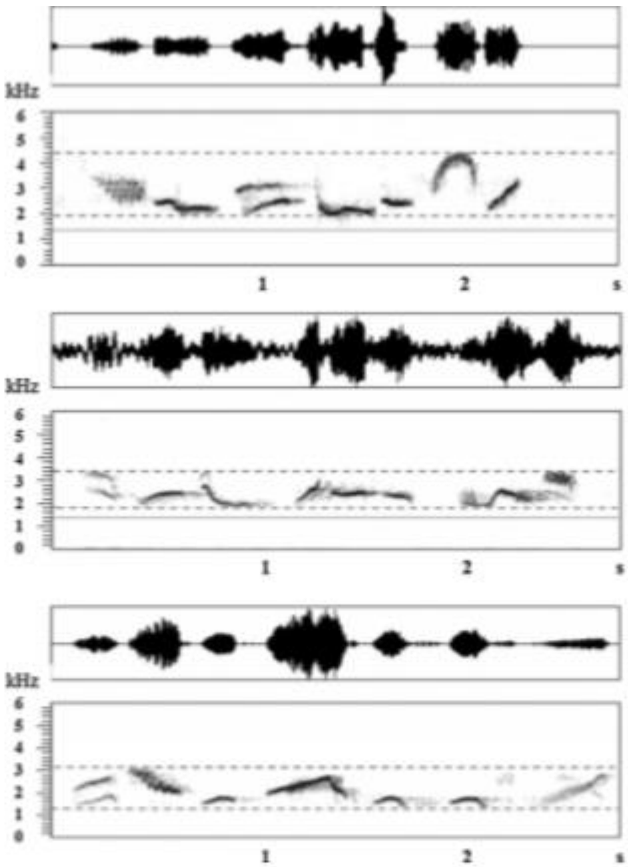


Figure 1Examples of sonograms recorded in the three areas. The upper song belongs to an urban bird, the second to a periurban one, and the bottom one to a rural blackbird. Urban bird songs reach the highest minimum frequencies but also the highest maximum ones (2–5kHz). The periurban sonogram occupies an intermediate position (1.9–3.5kHz). The rural sonogram shows the lowest frequencies (1.3–2.9kHz). (Solange Mendes & Peris, 2011)

There is also a line of studies that crack the theory of adapted acoustic frequencies and state increased song pitch might not be the adaptation to reduce signal masking, but a physiological side effect of urbanization, as they found out the frequency changes is not very effective in mitigating masking from the traffic environment – they suggested the use of amplitude instead (Nemeth & Brumm, 2010; Nameth, et al., 2013). The study conducted by the collective of authors lead by Nemeth later found out the strong correlation between *Turdus merula* acoustic frequency and amplitude (Nemeth, et al., 2013). By this notion the theory about C. blackbirds singing in urban environment with higher frequency elements and at the same time also can gain intensity and be less masked in low – frequency traffic noise was solidified.

The change of frequency is not the only option how to avoid the masking. Songbirds are capable to change volume (Brumm & Hultsch, 2001; Nemeth, et al., 2013) and timing when they usually sing. Most of singing birds have a higher peak in singing activity before sunrise and a lower peak before sunset (Bruni, Mennill, & Foote, 2014)

Across the prevalent number of studies devoted to the change in timing, 2 major hypotheses were established:

1. **Shift is caused by the urban noise** - Songbirds need to avoid masking their songs by noise. As Urban noise peaks during the day and is significantly decreasing during the night, it may cause the alteration of the song to the late hours (Fuller, Warren, & Gaston, 2007; Arroyo-Solís, Castillo, Figueroa, López-Sánchez, & Slabbekoorn, 2013; Ruß & Klenke, 2013; Cartwright, Taylor, Wilson, & Chow-Fraser, 2014).
2. **Shift is caused by the anthropogenic light** – Songbirds living in the area highly affected by the artificial light start the dawn chorus earlier than their counterparts less affected by this anthropogenic factor (Miller, 2006; Kamplenauer, Borgstrom, Loes, Schlicht, & Valcu, 2010; Silva, Valcu, & Kempenaers, 2015; Dominoni, Esther, Hofmann, Kranstauber, & Partecke, 2013).

b. The influence of light pollution on the vocal activity

The advance of urbanization and the increase in the standard of living involves a progressive, worldwide expansion in nocturnal illumination. The presence of artificial light extends to all areas with human activities;

The new world atlas of artificial night sky brightness shows that more than 80% of the world and more than 99% of the U.S. and European populations live under light-polluted skies (Falchi, et al., 2016). The increasing coverage is affecting all areas all over the planet - terrestrial habitats are illuminated by street lights and by a variety of lights for the illumination of structures, as well as with the lighted vehicles; marine habitats are disturbed by light from oil rigs, wind turbines, ships and light houses. Natural habitat is not only polluted by direct light (glare), but—in most cases— indirectly by reflection (sky glow) of light (Spoelstra & Visser, 2013).

Ecological light pollution is defined as light which disrupts ecosystems (Longcore & Rich, 2004). Photoperiod is an important cue for many bird species and this makes light pollution potentially an important ecological trap (Schlaepfer, Runge, & Sherman, 2002) as it may no longer be a reliable indicator in the presence of artificial light. In illuminated areas, the response to day length may lead to non-adaptive behavior (Spoelstra & Visser, 2013).

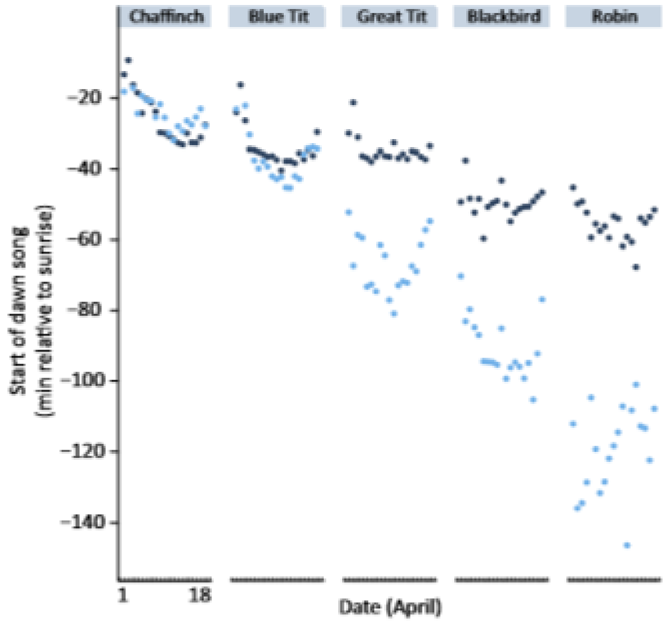


Figure 2 Effect of artificial night Lighting on the Start of the Dawn Chorus in Five Songbird Species, relative to sunrise between April 1-18. (Kamplenauer, Borgstrom, Loes, Schlicht, & Valcu, 2010)

After investigating effects of artificial night lighting on a dawn song in five common forest breeding songbirds, researchers Kampenauer and his colleagues (Kamplenauer, Borgstrom, Loes, Schlicht, & Valcu, 2010) found out the significant differences in the timing of the down songs (in 4 species, males near street lights first, started singing earlier than their peers not affected with the direct light). The results are displayed on Figure 2, where dark dots indicate the onset of dawn song in dark territories, light dots indicate dawn song onset in illuminated territories. It shows that species which start dawn song relatively early under normal (including C. Blackbird), tend to shift the dawn chorus much more then species that start later (Chaffinch, Blue tit).

Above mentioned results were confirmed by a line of studies. Research group of Dominoni and his colleagues (2013) while trying to highlight the relationship between light exposure at night and timing of daily activity in songbirds, found out blackbirds exposed to higher light intensities were active earlier in the morning. Scholars explained it with the notion, that Individuals exposed to light pollution might perceive a longer day than birds under natural night conditions (Dominoni, Quetting, & Partecke, 2013) & Partecke 2013), which could lead to production of steroid hormones and ultimately expression of mating behaviours, such as territorial defence and dawn song (Dominoni, Esther, Hofmann, Kranstauber, & Partecke, 2013).

This result followed many other research results about artificial light affecting and shifting the circadian clock for the songbirds (Nemeth & Brumm, 2009; Miller, 2006; Kamplenauer, Borgstrom, Loes, Schlicht, & Valcu, 2010). These effects are in line with the observation that birds can change their timing of song activity under natural light level fluctuations. For example, birds sang earlier in the morning during moonlit nights compared to mornings with a cloud covered sky (Miller, 2006)

The early onset of dawn song has potentially negative consequences such as reduction of energy levels, exhaustion (Kempenaers et al., 2010; Longcore & Rich, 2004), and the attraction of predators (Miller, 2006) but may also have positive effects.

An example of fitness consequences of a change in daily timing is the paternity gain by male blue tits that occupy illuminated territories as reported by Kempenaers and his colleagues (2010). Males that have a territory under street lights sired more extra-pair offspring in other nests than males that had a territory further away from the artificial light (Kamplenauer, Borgstrom, Loes, Schlicht, & Valcu, 2010). The males near the light posts are potentially more attractive to females in adjacent, dark territories because of their early onset of dawn song. This is in line with earlier observations of female preference for early singing males (Poesel, Kunc, Foerster, Johnsen, & Kempenaers, 2006). However, the effect may also relate to differences in male quality and needs to be verified in an experimental setup (Spoelstra & Visser, 2013).

Miller (2006) showed that light also affected the timing of singing at dusk (birds stopped singing later when there was artificial light nearby), also the continuation of song activity by artificial light after dusk has been reported in urban blackbirds (Stephan 1999, cited in Spoeltra & Visser (2013). But nobody ever studied the continuation of the vocal activity after sunrise – how long does it takes for Blackbird to stop the vocal activity? It its length also affected with the voice and light pollution? This is one of the statements (Hd) that will be tested in this paper.

2.2. Common blackbird

Kingdom	Phylum	Class	Order	Family
Animalia	Chordata	Aves	Passeriformes	Turdidae

Figure 3 Taxonomy of Common blackbird Turdus merula (BirdLife International, 2016)

The common blackbird *Turdus merula* is 23.5 to 29 centimeters in length, has a long tail, and weighs 80–125 grams (Mullarney, Svensson, & Grant, 2001). The adult male has glossy black plumage, blackish-brown legs, a yellow eye-ring and an orange-yellow bill. The bill darkens somewhat in winter (Mullarney, Svensson, & Grant, 2001). The adult female is sooty-brown with a dull yellowish-brownish bill, a brownish-white throat and some weak mottling on the breast. The juvenile is similar to the female, but has pale spots on the upperparts, and the very young juvenile also has a speckled breast (Mullarney, Svensson, & Grant, 2001)

According the BirdLife International (2016) *Turdus merula* inhabits a very wide range of habitats. Its main and original habitat is relatively open broadleaf, coniferous, mixed and deciduous forests (Luniak, Mulsow, & Walasz, 1990) but it is also found in tree plantations, orchards, farmland, gardens and parks and commonly in open grassy areas so long as vegetation cover is within a short distance (Evans, et al., 2012).

In Europe it breeds from mid-March to early September. The nest is a large cup of dry grass stems and small twigs, packed with mud and lined with fine grass and stems. It is generally sited 0,5–15 meters off the ground in a bush or tree or in a climbing plant against a wall, and frequently in or on a wall, outside or inside a building. Common blackbird`s eggs are Sub-elliptical usually pale greenish-blue, mottled and speckled light red-brown, smooth and glossy; usually pale greenish-blue, mottled and speckled light red-brown. Usual clutch is 3–5 eggs (varies within season), Incubation period is 12-14 days and fledging period usually lasts 13,6 days.

Turdus merula is a highly flexible and adaptive forager and feeds principally on invertebrates, mainly earthworms and insects and their larvae but will also take fruits and seeds and, occasionally, small vertebrates (BirdLife International, 2016). Recorded diet includes many unusual items, such as small fish, newts, and lizards; also, wide variety of fruits, wild and cultivated (Cramp & Perrins, 1994).

The species is sedentary, partially migratory and fully migratory, depending mainly on latitude (Collar, 2015). Native in Czech Republic and most of the countries in Europe, Asia and part of Africa. Lives 5,4 years in average. Dues to the classification LC – least There are currently no known conservation measures for this species within its European range.

Mating system is monogamous, though a few exceptional cases of bigamy recorded. In areas with resident populations, established pairs usually remain together in successive breeding seasons if both partners survive. Most new pairs formed in late winter and early spring. Song (by male only) delivered from perch; occasionally sings in flight between perches. Song-period several months, from late winter to end of breeding season; time of onset much dependent on weather, stimulated by mild and damp conditions. In northern Europe, may start late December if weather mild, rarely even earlier.

Habitat is usually exceptionally diverse, including dense woodland, varied types of farmland, heaths, moors, some wetlands, and settled sites including inner cities. Found in middle and overlapping to lower middle and upper latitudes of west Palearctic, including oceanic islands and coasts as well as milder boreal and temperate continental regions. Given shelter, will tolerate wet, windy, and cool situations better than very warm and dry ones; prefers moisture and shade, with ample access to bare ground, layers of dead leaves or short grass and herbage, even where overshadowed by low bushes and shrubs or tree canopy; avoids distances from cover exceeding *c*. 100–200 m. (Heath, Borggreve, & Peet, 2000)

a. Acoustics and song patterns

Bird vocal activity is one of the most important part of communication as it plays a crucial role not only in mating and finding partner, guarding the one`s own territory, but also warning for any danger and creating social boundaries (Catchpole & Slater, 2008).

Occurrence and intensity of the vocal activity depends not only on a season, weather conditions and circadian time, but also the reproduction period (Amrhein, Johannessen, Kristiansen, & Slagsvold, 2008) on the spectral capabilities of the individual (Catchpole & Slater, 2008). The group of researchers Nana Hesler, Roger Mundry, Thomas Sacher, Timothy Coppack, Franz Bairlein and Torben Dabelsteen even suggest that for Common blackbird singing repertoire depends in the body size (Hesler, et al., 2012).

The vocal signals are heard in big distances, are spread in all directions and can go through various materials. Even though, it can be changed with the dense vegetation in the forest and with the disadvantageous location of the singing bird (Mathevon, Aubin, Dabelsteen, & Vielliar, 2004).

Common blackbird (*Turdus merula*) has beautiful low- pitched song mostly delivered, with fluted quality. Each adult male has large repertoire of song-phrases exhibiting great individual variation. However, each song starts with a low-frequency motif followed by a twitter, which is of higher frequency and wider bandwidth (Solange Mendes & Peris, 2011). Call is loud and varied: most distinctive are low ‘pook’ and ‘chook’ sounds often given in warning and half-alarm situations (and accompanied by simultaneous tail-cocking and wing-flicking), and hysterical chatter and screaming rattle in full alarm. Groups join in distinctive ‘chink’-ing chorus at dawn and dusk. (Heath, Borggreve, & Peet, 2000), (Cramp & Perrins, 1994).

Common blackbird delivers a song mostly from a highly placed (Hall-Craggs, 1962); occasionally sings in flight between perches. Song is delivered exclusively by male blackbirds during establishment and maintenance of territory and as advertisement for females also after loss of mate (Snow, 1958).

The mating song-period lasts several months, from late winter to end of breeding season; the starting time depends on weather, stimulated by mild and damp conditions). Early in season – last third of February or the beginning of March, the song starts mainly in late afternoon gradually extending back into earlier part of day; By time passes and mating period - dawn song typically begins 1 hour before sunrise, and evening song ends around sunset (Bruni, Mennill, & Foote, 2014).

Except already mentioned anthropogenic factors discussed in paragraph 2 (urban noise and artificial light), there are also environmental factors that influence the start and timing of the songbird vocalization.

The most important element is sunshine (Bruni, Mennill, & Foote, 2014), that is stimulating hormones playing a dominant role in reproductive behavior and affectivity (The injection of male hormones into male birds in mid-winter will start them singing (Wilson & Watts, 2006).

Weather conditions also play a significant role: Harsh weather conditions can cause stress in birds. Birds produce cortisone in response to this stress that might trigger physiological and behavioral changes to ameliorate these effects (Romero, Reed, & Wingfield, 2000)

- Temperature - Both cool and hot weather will decrease the amount of singing, as do rain and wind (Catchpole & Slater, 2008; Hasan, 2010)
- Cloudiness - in the morning can delay singing (Hill, Copenhaver, Gangler, & Whaley, 2005)

For most species, hormones, stimulated by photoperiod, probably play a dominant role in determining the time of year a bird sings. The injection of male hormones into male birds in mid-winter will start them singing (Wilson & Watts, 2006)

Dawn chorus is also shown to be a reliable indicator of male quality and social interactions (Amrhein & Erne, 2006). Several studies found that physical condition of the individual birds also play role in timing of the morning chorus - birds in better health condition start singing earlier (Murphy, Sexton, Dolan, & Redmond, 2008) and are more attractive to females (Poesel, Kunc, Foerster, Johnsen, & Kempenaers, 2006).

3. Methodology

3.1. The studied localities

With the help of the strategic noise map (geoportal INSPIRE) the consistence was secured – on the localities polluted only with light, the noise intensity was not higher than 55 dB. In addition to this, every locality was minimum 300 meters far from each other. On every selected place artificial light pollution was emitted by the street lamps and urban noise – by cars passing by on the highways. The sound recordings were collected from 4 types of localities:

1. Sites with the artificial light, but without the noise pollution (n = 9) – data was collected in Prague urban area, where there is plenty of areas affected artificial light without significant level of urban noise. More specifically, the recorgings were gathered in park Stromovka (4 recordings), on Pertrin (3 recordings) and in Park Hostivar (2 recordings). Each recording is from different location.
2. Sites with noise pollution – mainly highways without artificial lights (n = 9) – forest areas close to highways without artificial lights, close from Prague in the area of 20 – 40 kms). Data was collected in Radosovice (1 recording), Ricansky les (2 recordings), Kersko (5 recordings) and Klanovice (1 recording).
3. Sites with both light and noise pollution (n = 11) – small parks close to the noisy streets in Prague. Park Pratelstvi (3 recordings), Letna (6 recordings), Kinskeho zahrady (1 recording), Hostivar (1 recording).
4. Control localities - calm areas without artificial light pollution (n = 10) – calm areas not affected with the anthropogenic noise and light - Radosovice (3 recordings), Kersko (4 recordings), Olsanske hrbitovy (1 recording) and Klanovice (2 recordings).

3.2. Collecting the data

The vocalization material was recorded in 2014 (from 08.04 till 05.06) Sony ICD-PX333 and saved in MP3 format. The song was recorded always in a week interval to map the seasonal change in vocal activity. Recording were made only when weather conditions were favorable (without strong wind and rain).

The data was collected according the following procedure - the recorder was left nearby the singing blackbird 2 hours before the sunset and was taken 3 hours after the sunrise the next day. On the localities with the light pollution, the recorder was places in 2 meters distant as maximum from the street light lamp. For this paper, I analyzed 40 recordings of the Blackbirds song 1 hour after the sunrise.

3.3. Analyzing the recordings

For processing and analyzing the data Avisoft SASLab Pro software (Raimund Spetch, Berlin) was used. For better detection of the song and reducing the background noise, a low pass (1kHz) and a high-pass (10kHz) filters were used. During this phase, we found out 10 recordings without the Blackbird singing and that is why only 30 recordings were used in the statistical analysis.

As the analyzed recordings were all after the sunrise and for the testing of the suggested statements data before the sunrise was also needed, we decided to take advantage of the database already created regarding this study and use information available also from before the sunrise recordings from the same locality (after 2 a.m. till the sunrise).

4. Statistical analysis

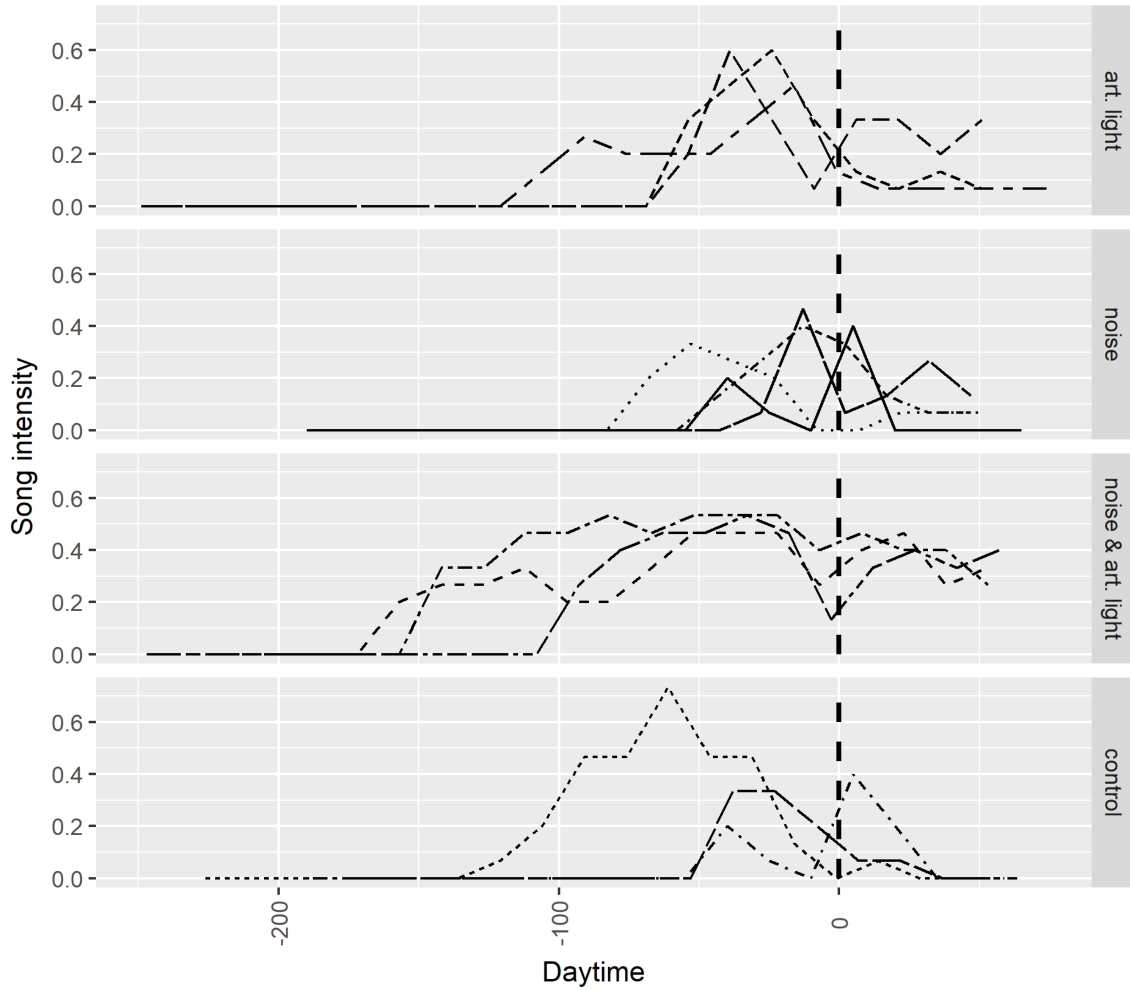
The effect of artificial light and noise pollution was assessed on the morning timing and intensity of blackbird singing using linear models. the separate analysis was conducted for the following factors:

1. The timing of the start of the Blackbirds song (minutes before the sunrise);
2. Total length of the song both before and after the sunrise (minutes);
3. Maximum reached intensity in each song including the recordings both before and after the sunrise (minutes);
4. Average intensity (how frequently Blackbird vocalized during singing both before and after the sunrise in the morning (minutes);
5. The length of the song in 1-hour recording after the sunrise (minutes).

For statistical analysis, data manipulation and plot creation R statistical software was used (R Core Team, 2018). The following R packages were used: ***car*** for analyzing variance ***plyr*** for data manipulations and ***ggplot2*** for graphics. Data is fulfilling both normality and homogenic variances assumptions for the statistical testing (see the attachments).

5. Results

The exploratory analysis outlined the obvious differences between the affected and control localities. The most observable was the course of the song intensities on the spots exposed to both – artificial light and urban noise pollution (noise & art. Light). Blackbirds here were not only started singing earlier, but also were maintaining the high intensity even after the sunrise (Daytime "0" on the graph). Noise pollution does not seem to effect timing and intensity of the blackbird song, while light significantly causes the shift of the start to the earlier hours.



Graph 1 Song timing and intensity (vocalization frequency) visualization across all studies types of localities according the time with the relation of the sunrise (Daytime in minutes, sunrise is visualized with the vertical spaced line = 0), gglot2 (R Core Team, 2018).

Hypotheses	Adjusted R^2	Model parameters	Intercept	art. light	noise	art. light & noise
Ha: **Start** of the singing (total)	0.3931	Estimate[1]	-55.00	-10.50 **	17.20	-50.59 *
		SE[2]	9.137	12.92	14.73	19.36
		% of explained variance	-	45,35%	6,17%	26,27%
Hb: **Length** of the song (total)	0.4351	Estimate	26.63	4.13 **	-10.23	34.14 **
		SE	5.398	7.634	8.704	11.44
		% of explained variance	-	44,51%	11,00%	34,28%
Hc1: Maximum **intensity** (total)	0.06	Estimate	0.458	0.025 .	-0.0983	0.1187
		SE	0.043	0.061	0.069	0.0907
		% of explained variance	-	11,48%	1,68%	6,59%
Hc2: Mean intensity (total)	0.4365	Estimate	17.37	5.500 **	-7.575 .	30.81 *
		SE	5.254	7.431	8.472	11.13
		% of explained variance	-	46,45%	13,43%	29,46%
He: The song **length** after sunrise	0.2357	Estimate	7.625	0.125 .	-1.225 .	9.475 .
		SE	2.228	3.151	3.593	4.721
		% of explained variance	-	13,20%	12,87%	15,50%

Table 1 Results of ANOVA test for all tested hypotheses (Ha, Hb, Hc, Hd). Own calculations in R (R Core Team, 2018)

Above observations were used to form studied hypotheses in the next steps in statistical analyze and results were displayed on the below summary plot (Graph 1).

The research statements were tested with ANOVA – analysis of variances with the following results:

> Ha: Anthropogenic light and noise pollution shifts the start of the song of Common blackbird (*Turdus merula*) song in the morning.

Created Model is well fitted – that is confirmed with the explained variance of 39,31 % (adjusted R^2). As we already anticipated from the boxplot (Graph 2), the H0 hypothesis about light pollution having zero effect on the start of the Blackbird vocalization was rejected on 99% confidence level (Artificial light in fact explained 45,35% of the variance between the localities).

The second significant parameter appeared the combination of both – light and noise pollution (explained 26% of the variance). The hypothesis about this factor not effecting the start of the song was rejected with 95% confidence level. As assumed, noise does not have any effect on the dawn song timing (Table 1).

> Hb: Anthropogenic light and noise pollution affects the length of the Common blackbird (*Turdus merula*) song in the morning (full song – before and after the sunrise).

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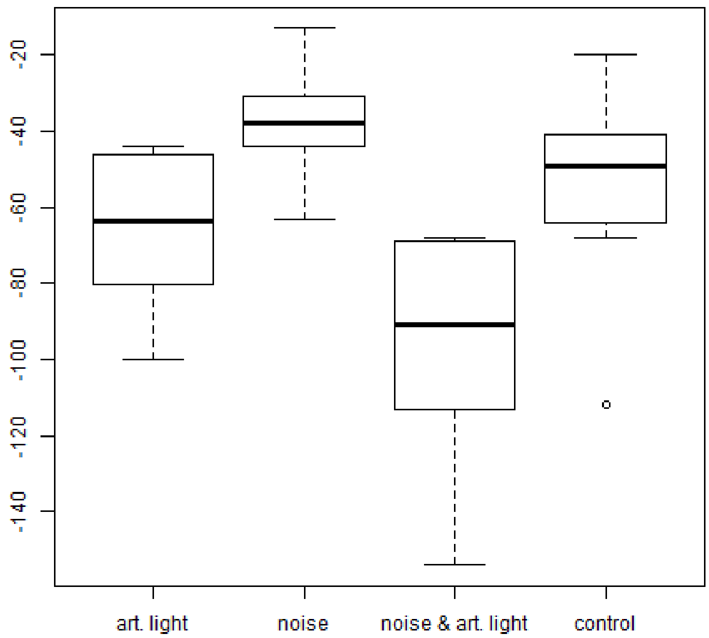
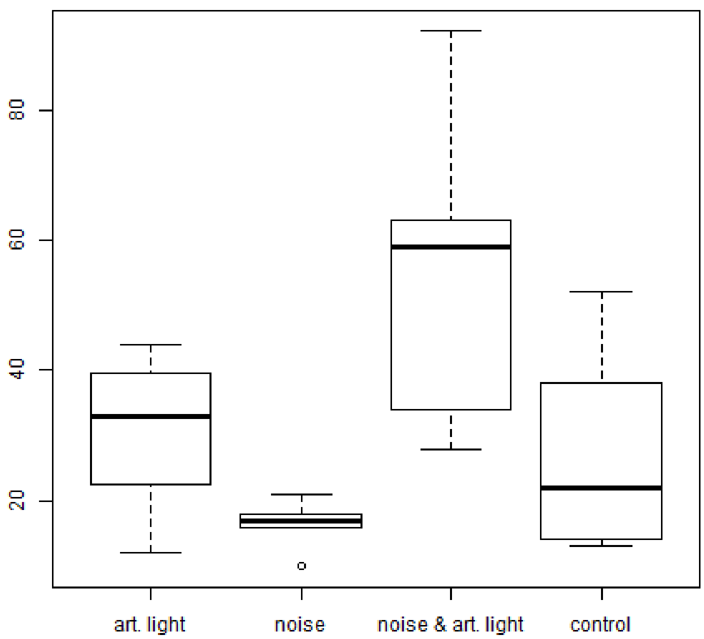
[1] Parameter estimates are based on ordinal least squires. Its significance is assessed with the following codes: " *** " – parameter is significant on the 99,9% confidence level (p<0,001); " ** " – parameter is significant on the 99% confidence level (p<0,01); parameter is significant on the 95% confidence level (p<0,05); ' . " - parameter is significant on the 90% confidence level (p<0,1);
[2] Standard error estimated with the model



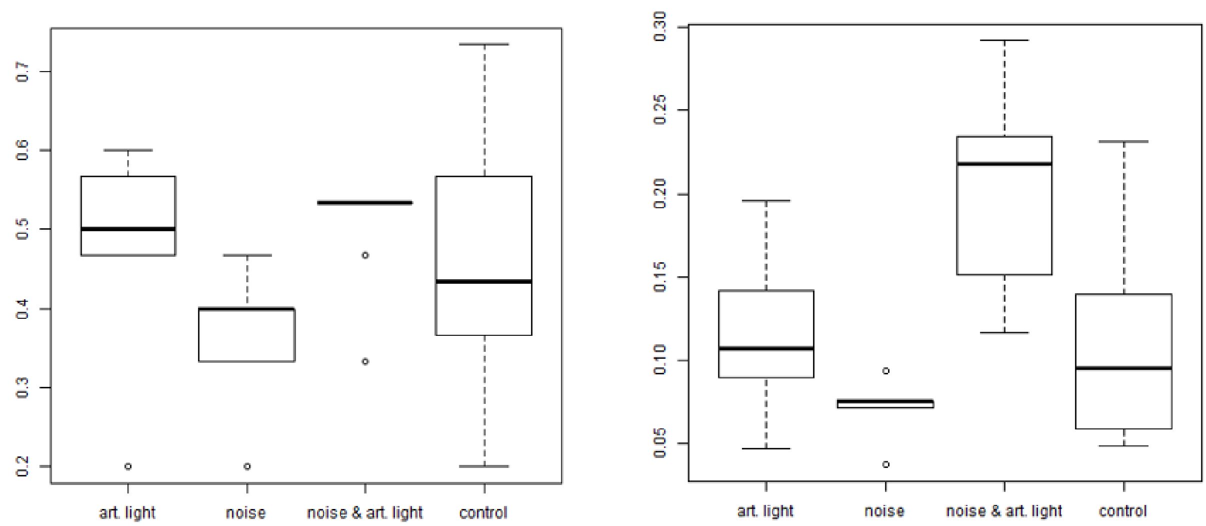
Graph 2 Distribution of the start of the singing across 4 studied localities (Ha: Start of the singing), export from R



Graph 3 Distribution of the song length across 4 studied localities (Hb: Length of the song), exported from R;

The length of the song appeared to be significantly affected with the following parameters: art. light (H0 rejected with the confidence level 99%, explains 44,51% variance) and art. Light & noise (H0 rejected with the confidence level 99%, explains 34,28% variance). Also, the model is well fitted and explains 43,51 % of the total variance. The results go in line with our preliminary observations (see Graph 3).

> Hc: Anthropogenic light and noise pollution affects the intensity of the Common blackbird (*Turdus merula*) song in the morning before and after the sunrise (Hc1: maximum intensity and Hc2: mean intensity);



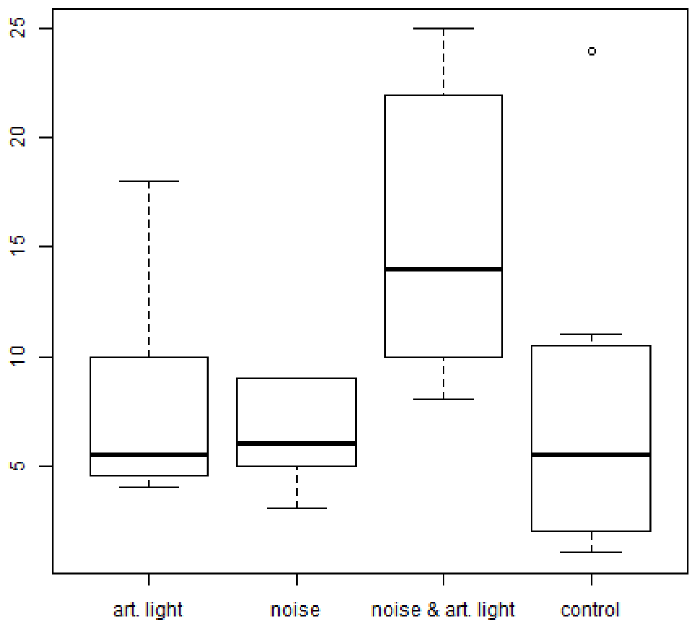
Graph 4 boxplot on the left - Distribution of maximum intensity across 4 studied localities (Hc1: Maximum intensity), boxplot on the right – Distribution of mean intensity across 4 studied localities (Hc2: Mean intensity), in R.

When testing Hc1 statement the model appeared to be badly fitted – it explained only 6% of the variability. As it was forecasted form the descriptive visualization (see Graph 4) That is not true for the statements Hc2, where the model explained 43,65 % of the data variability and highlighted the importance of “art. Light” and “art. light & noise” pollution.

The H0 hypothesis about Artificial light not affecting the mean intensity on the song was rejected on 99 % confidence level and this factor explained 46,45% of the variability in length of the songs in our recordings. With 95% confidence level, we also rejected the hypothesis about “art. Light & noise” not affecting the Blackbird song intensity. In fact, it explained 29,46% of the variance how intensely Blackbirds were singing in our sample.

Hd: Anthropogenic light and noise pollution affects the length of the Common blackbird (*Turdus merula*) song after the sunrise.

The last model was somehow weak – suggested parameters explained only 23,57 % of the variance in song length after the sunrise. The H0 hypothesis seems to be rejectable on 90 % confidence level for all three suggested predictors – seems the data is insufficient for the test to decide, even though the difference was obvious from the visualization (see Graph 1 and Graph 5).



Graph 5 Boxplot Hd: The song length after the sunrise, exported from R.

6. Discussion

When analyzing the start of the song results not only go in line with the existing research (see 2.1) regarding the light pollution predicting the earlier song onset, but also highlighted the significant contribution that the combination of both light and nose pollution has on the shift – as we see from the Graph 1 (Song timing and intensity (vocalization frequency) visualization across all studies types of localities according the time with the relation of the sunrise (Daytime in minutes, sunrise is visualized with the vertical spaced line = 0), gglot2.) Blackbirds on such locations in fact started the earliest of all other locations. The results indicate light as the significant cause and with the tandem with noise causes the morning chorus to start even 2 hours before the sunrise.

We also looked at the length (Hb) and the intensity (Hc1 and Hc2) of the song. Artificial light appears to affect both length (44,51% of explained variance) and average intensity of the song (46,45% percent of explained variance). The tandem Art. Light & noise was also highly significant causing Blackbirds to sing longer (34,28% of the explained variance) and with higher tenure (29,46% of explained variance in intensity).these findings go hand in hand with the other studies - Songbirds living in the area highly affected by the artificial light start the dawn chorus earlier than their counterparts less affected by this anthropogenic factor (Miller, 2006; Kamplenauer, Borgstrom, Loes, Schlicht, & Valcu, 2010; Dominoni, Esther, Hofmann, Kranstauber, & Partecke, 2013; Silva, Valcu, & Kempenaers, 2015).

Noise pollution in our study stayed outside the league and with this result the assumption about Blackbird avoiding masking their songs by noise by alteration of the song to the late hours (Fuller, Warren, & Gaston, 2007; Arroyo-Solís, Castillo, Figueroa, López-Sánchez, & Slabbekoorn, 2013; Ruß & Klenke, 2013; Cartwright, Taylor, Wilson, & Chow-Fraser, 2014) was not confirmed.

Noise appears not causing any independent statistical effect on neither length, not intensity (articulating frequencies discussed in theory part was not the subject of our study), but when combined with light pollution seemingly increases the intensity levels. Many questions arise in connection with this phenomenon especially when we connect it with already confirmed statement that light & noise combo causes the significant shift of the song to the earlier hours. Why art. Light & noise pollution causes the length and intensity to increase? Is it because of increased stress levels? What are the effects of these outcomes on the health and fitness of the male Blackbirds? How stress is affecting the individual Blackbird`s life spam?

The early onset of dawn song has potentially negative consequences such as reduction of energy levels, exhaustion (Kamplenauer, Borgstrom, Loes, Schlicht, & Valcu, 2010; Rich & Longcore, 2006), and the attraction of predators (Miller, 2006) but may also have positive effects – such as increased paternity gain together with the extra-pair gain by male blue tits reported by Kempenaers and his colleagues (Kamplenauer, Borgstrom, Loes, Schlicht, & Valcu, 2010). However, first, the effect may also relate to differences in male quality (Spoelstra & Visser, 2013), second, more specific study conducted on the Blackbirds is needed to find out the real answers as they are not provided with the current research.

The results from the last Hd statement are also interesting. Although the data visualization indicated the clear connection between the length of the song and the art. light & noise pollution, F test could not support this statement. All predictors appeared to be weakly significant (90 % confidence level – statistically is below acceptable) and test failed to be effective probably because of the relatively small sample (30 recordings). Further research with the bigger sample would be extremely beneficial as the length of the song after the sunrise would help the further research to study the true effects of the light & noise pollution on offspring, physical, psychical wellbeing and in general - life spam of our beloved Common Blackbird.

7. Conclusion

In the first part the theory background research is presented. The second part is devoted to the methodology (localities, data and tools used) and statistical analysis (including results and discussion). 40 recording were analysed from the breeding season in 2014 (March – June). The 30 out of 40 recording were valid for the further statistical analysis. The results can be summarized as below:

Ha: Anthropogenic light and noise pollution shifts the start of the song of Common blackbird (*Turdus merula*) song in the morning;

This statement was confirmed for the anthropogenic light pollution – it explains 45,35% of the variability in the shift in starting time in morning chorus of *Turdus merula*. Urban noise does not have the significant impact individually, but in a tandem with the light pollution explaines 26,27% of the variance.

Hb: anthropogenic light and noise pollution affects the length of the Common blackbird (*Turdus merula*) song in the morning;

The light pollution appears to be meaningful for the length of the song as well (factor explained 44,51 % of variance). Again, the combination of the both light and noise has a statistically significant effect on the Blackbird song duration (34,28% fo the explained variance).

Hc: Anthropogenic light and noise pollution affects the intensity of the Common blackbird (*Turdus merula*) song in the morning (Hc1: maximum intensity and Hc2: mean intensity);

The first statement stands for the maximum reached intensity during the individual song. Neither artificial light pollution, neither urban noise is inducing the peak of intensity. Nevertheless, the average intensity seems to be affected. 46,45 % of the variance was explained by the light pollution and 29,46% was cause by combination of light and noise. Again, the intensity also seems to be increased by combining different types of pollutions. One of the intermediates can be increased stress level, but we would leave this suggestion to the future research.

Hd: Anthropogenic light and noise pollution affects the length of the Common blackbird (*Turdus merula*) song after the sunrise.

We were unable to confirm or reject this statement. Nevertheless, the effects is obvious from the data visualization (Graph 1 Song timing and intensity (vocalization frequency) visualization across all studies types of localities according the time with the relation of the sunrise (Daytime in minutes, sunrise is visualized with the vertical spaced line = 0), gglot2.) and certainly is worth of future examination.

How can the research continue?

As already mentioned above because of the small study sample we could not fully answer if the pollution factors (light and noise) had influence on the length of the Blackbird`s song after the sunrise. This direction could be interesting for the future research especially studying the pollution effects on the energy levels and life spam of *Turdus merula*. After verifying the causal dependence on the bigger sample, the possible directions could be:

- How much the singing hours are prolonged in total?
- What effect it does have on the Blackbird?

Noise appears not causing any independent statistical effect on neither length, not intensity (articulating frequencies discussed in theory part was not the subject of our study), but when combined with light pollution seemingly increases the intensity levels. Many questions arise in connection with this phenomenon especially when we connect it with already confirmed statement that light & noise combo causes the significant shift of the song to the earlier hours.

- Why art. Light & noise pollution causes the length and intensity to increase?
- Is it because of increased stress levels?
- What are the effects of these outcomes on the health and fitness of the male Blackbirds?
- How stress is affecting the individual Blackbird`s life spam?

8. Table of figures

Graphs

Tables

Figures

Attachments

9. Works Cited

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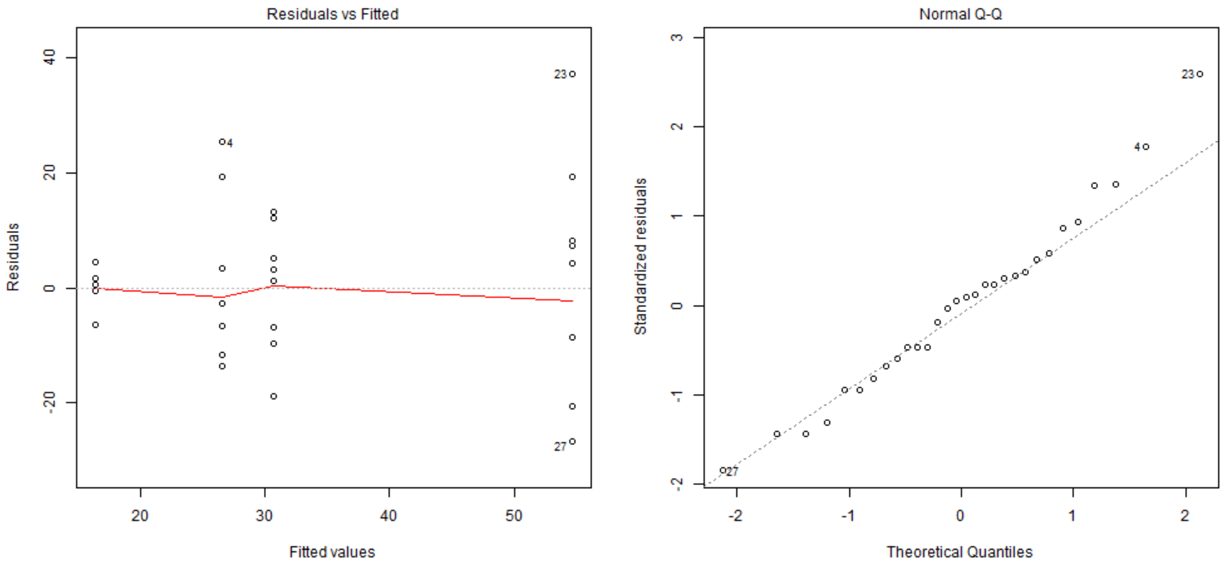
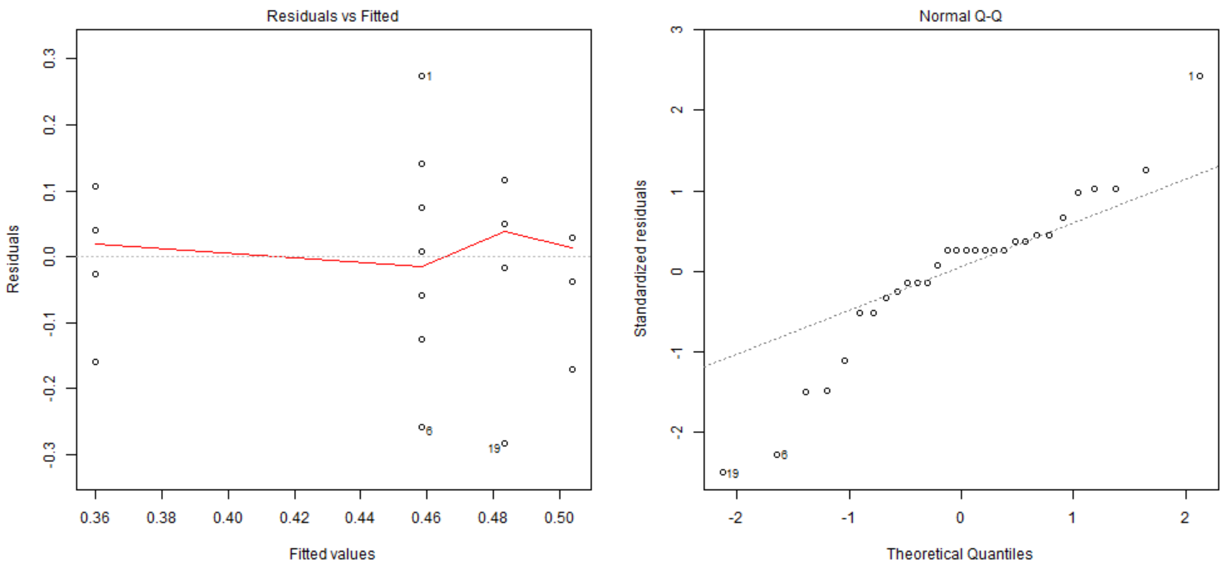
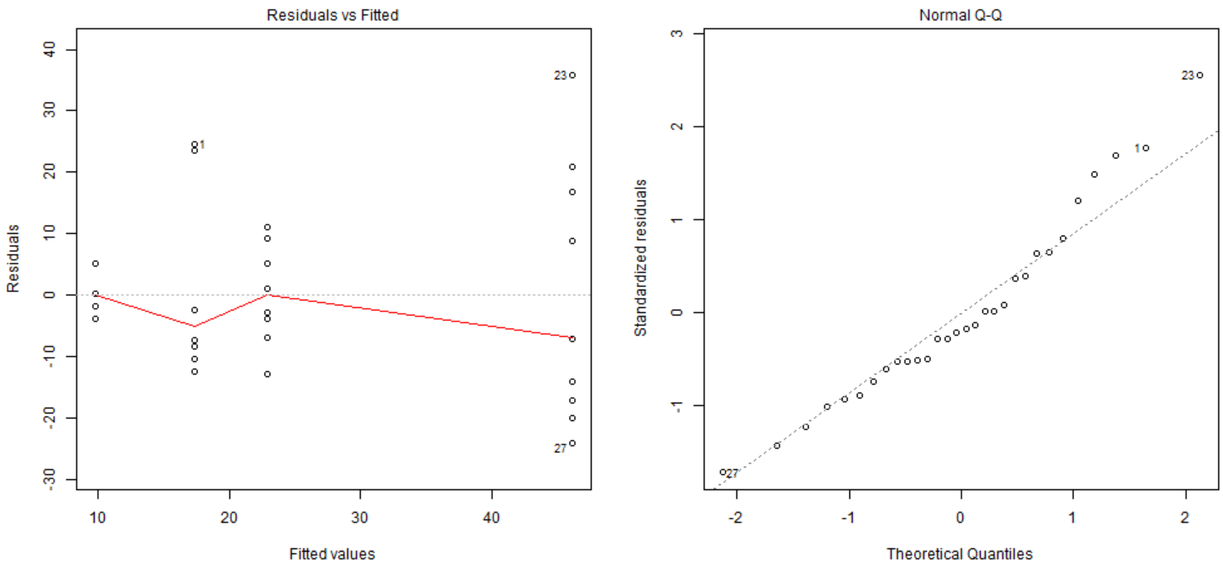
10. Attachments



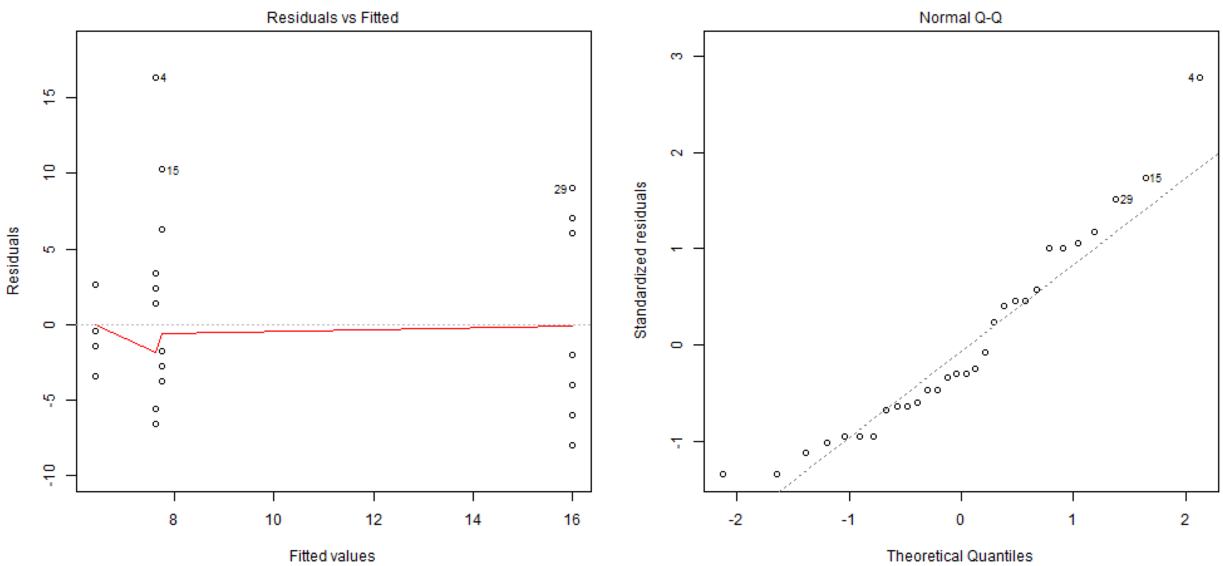
Attachment 1 testing of the data normality and fit - Total length of the song



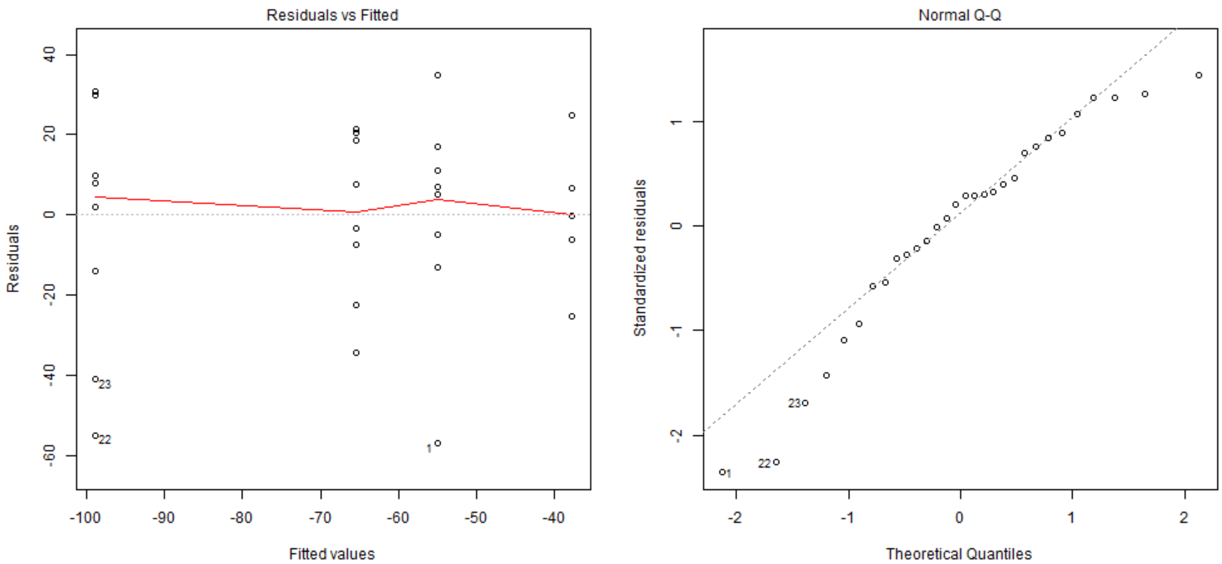
Attachment 2 testing of the data normality and fit - Maximum intensity



Attachment 3 testing of the data normality and fit - Mean intensity



Attachment 4 testing of the data normality and fit - song length after the sunrise.



Attachment 5 Testing of the data normality and fit - start of the song.