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论文题目：城市噪音对喜鹊和灰喜鹊鸣叫结构的影响

The Impact of City Noise on Call Structure of Magpie *(Pica pica)* and Azure-winged Magpie (*Cyanopica cyanus)*

论文题目：**The Impact of City Noise on Call Structure of Magpie *(Pica pica)* and Azure-winged Magpie (*Cyanopica cyanus*)**

摘要：

Bird vocalization, a means of communication between birds, serves important functions in birds’ foraging, warning, territorial and mating behaviors. Generally, bird vocalization can be divided into two categories: bird song and bird call. Bird song represents the vocalization with complicated structure given off by birds during mating seasons as to attract mates, while bird call is the relatively simple vocalization emitted by both sexes of birds in daily-based occasions such as foraging or warning (Catchpole and Slater 2005).

Along with the accelerating urbanization, noise pollution gradually becomes a serious ecological issue in urban environments. Research shows that some bird species have modified their vocalization signals in order to cope with the urban environment they inhabit. Birds with high plasticity of vocalization modify their sound structures to adapt to environmental noises, while birds that fail to modify vocalization structures are unable to undergo effective communication, and therefore they fade away from the urban ecosystem. This process describes the modification of bird vocalization due to environmental factors and arouses wide attention from biologists and ecologists (Patricelli and Blickley 2006).

Research on *Melospiza melodia* and *Parus major* shows that minimum and peak frequency of an individual’s song exhibits positive correlation with noise intensity, which may be an adaptation to avoid their sounds being overlapped by low-frequency urban noises (Wood and Yezerinac 2006, Slabbekoorn and Peet 2003, Brumm 2004, Fernandez-Juricic et al. 2005). Other research shows that birds increase song intensity to ensure the effectiveness of communication; the observation was named as “Lombard Effect” (Rabin and Greene 2002, Warren et al. 2006). Researchers also found that some species of birds increase vocalization effectiveness by repeating or extending song length (Brumm and Slabbekoorn 2005), while other species choose a relatively quiet environment to emit songs (Popp 1989, Lohret al. 2003). However, the modifications mentioned above are restricted by birds' physiological structure, energy consumption, and heredity (Brumm 2004, Oberweger and Goller 2001).

The city in which we conducted research is located between the Northern China and Mongolia-Xinjiang zoogeographic zones and has an abundance of bird resources. Of all species recorded in the city, some are especially adapted to the urban ecosystem, among which *Pica pica* and *Cyanopica cyanus* are two primal examples. Researching how the vocalizations of these two species are influenced by urban noises can shed light on their adaptation to urban environment and offer new directions to environmental protection. Considering that most researchers focused on bird song and few investigation has been conducted on bird call, this experiment aims to investigate the correlation between call frequency, energy distribution and syllable time length of the two species and the environmental noise by synthesizing biologic, acoustic, and statistical techniques. The result offers advice to urban ecological planning.

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第三页为论文英文摘要（如果是中文论文，此页为英文摘要。否则，留空白。）

Title:

Abstract

第四页为创新性申明

本参赛团队声明所提交的论文是在指导老师下进行的研究工作和取得的研究成果。尽本团队所知，除了文中特别加以标注和致谢中所罗列的内容以外，论文中不包含其他人或本团队已经发表或撰写过的研究成果。若有不实之处，本人愿意承担一切相关责任。

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日 期：

论文题目：**The Impact of City Noise on Call Structure of Magpie *(Pica pica)* and Azure-winged Magpie (*Cyanopica cyanus*)**

论文正文：

1 Background Introduction (See as the Abstract Section)

See the Abstract Section

2 Materials and Methodology

2.1 Research Objects

The research objects of this experiment were the calls of magpies and azure-winged magpies randomly selected and the intensity of ambient noises where the birds were recorded.

2.2 Sampling Sites

The bird calls were recorded at four different locations with various noise types and noise intensities to reflect the diverse microenvironments within the city. As illustrated in Figure 1, Sampling Site 1 is located on the periphery of the city with relatively low artificial noise. Sampling Site 2 is sited next to a major highway and suffered heavy traffic noise. Sampling Site 3 and Sampling Site 4 lie next to downtown areas and are more influenced by noises caused by visitors.

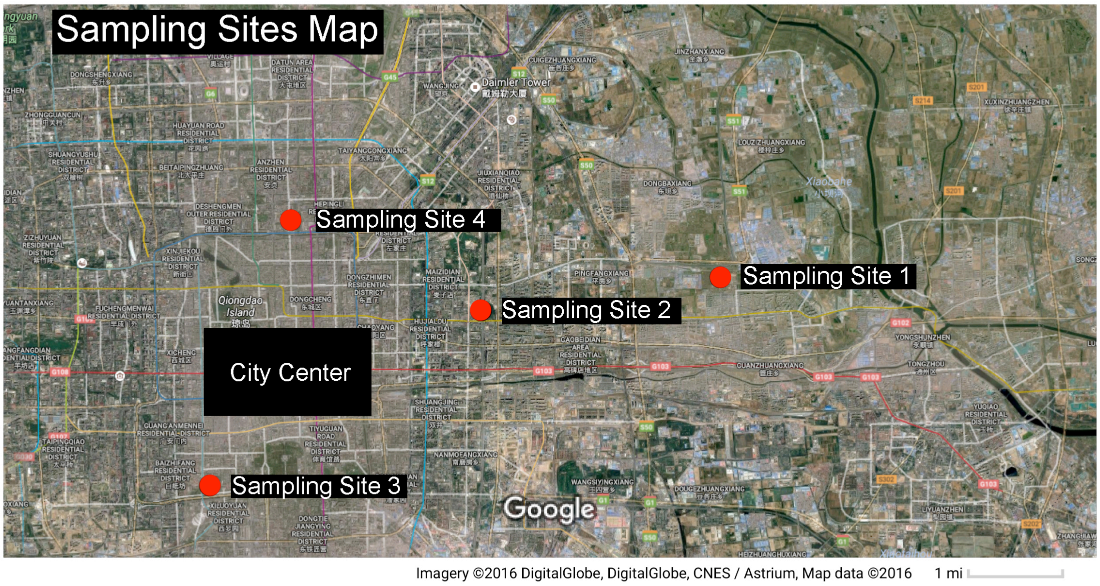

Figure 1. Sampling Sites Map (From Google Map)

2.3 Data Collection

2.3.1 Recording

All samples of bird calls were recorded in August 2016. The recording time was set at 6:30 to 8:30 in the morning when the birds were active and traffic noise during the morning rush hours could be accounted. A Takstar SGC-568 Interview Microphone was connected to a laptop to record the sounds via Avisoft SASLab Lite. The recordings were taken at the sampling frequency of 22.05kHz and sampling rate of 16bits and then converted to WAV files for acoustic analysis. When the bird calls were heard, the microphone was fixed at a position 1.2 meters above the ground to record the sound with "hypercardioid" mode until the individual stopped calling or flew away (Figure 2). To accurately determine the instantaneous noise data when the birds were calling, we extract background noise data from the recording samples instead of measuring noise with a separate instrument. In each sampling site the calls of nine individuals was recorded with the same protocol to ensure that the standards of measurement was consistent throughout the experiment.

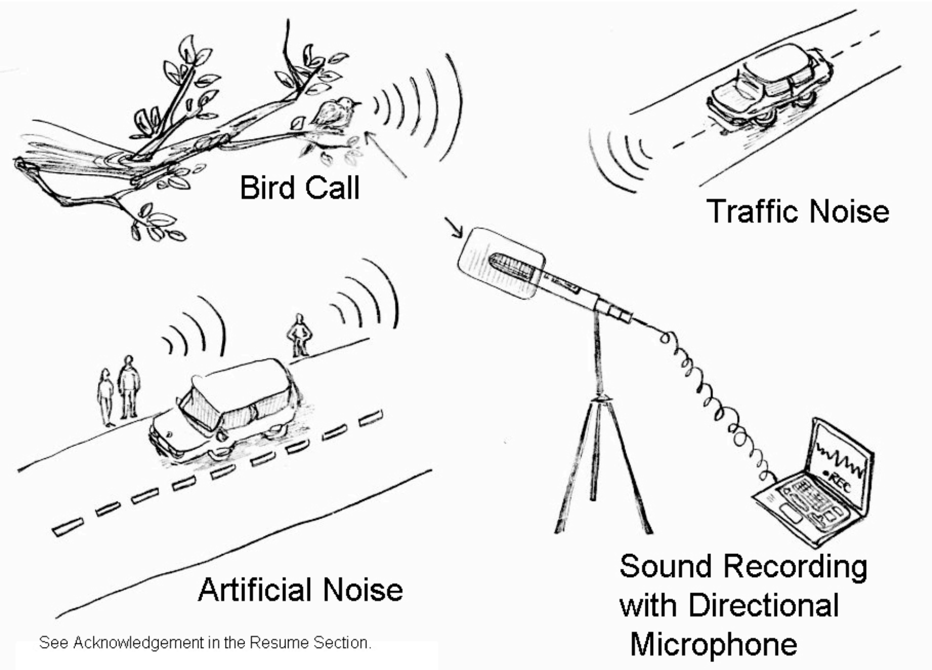

Figure 2. Experiment Design Diagram

2.3.2 Bird Sound Analysis

Computer software Raven Pro 1.4 (Cornell Lab of Ornithology) were used to conduct sonogram analysis with the Discrete Fourier Transform (DFT) algorithm embedded in the program. The purpose of this process was to convert the time-domain sound signal into frequency-domain spectrogram that humans can interpret. DFT size was set at 400 samples to create the sharpest spectrogram, and the display brightness and contrast values were adjusted until the sonogram of bird call signals became visible on screen. The sonogram is a three dimensional diagram in which the horizontal axis represents the time length, the vertical axis shows the frequency, and the darkness of the gray scale pixels indicate the sound intensity. Typical sonograms of Magpie and Azure-winged magpie can been seen in Figure 3 and 4.

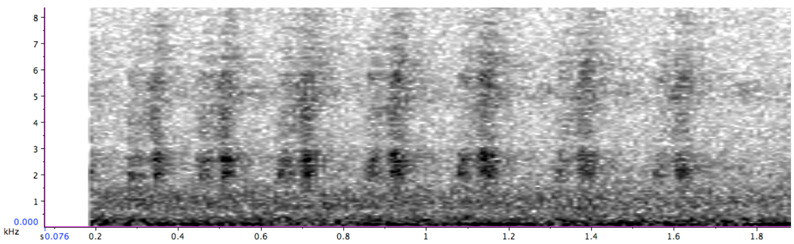

Figure 3. A Sonogram of Magpie's Calls

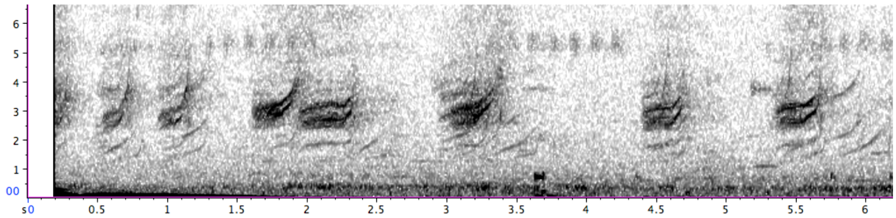

Figure 4. A Sonogram of Azure-winged Magpie's Calls

Six recording samples of Magpie and Azure-winged Magpie with discernible sonogram are selected for qualitative analysis. In each of these 12 samples, five call syllables were randomly selected to measure their minimum frequency, maximum frequency, peak frequency (the frequency at the highest intensity of the sound), and syllable sound length (See Figure 5). The results are saved in an Excel spreadsheet.

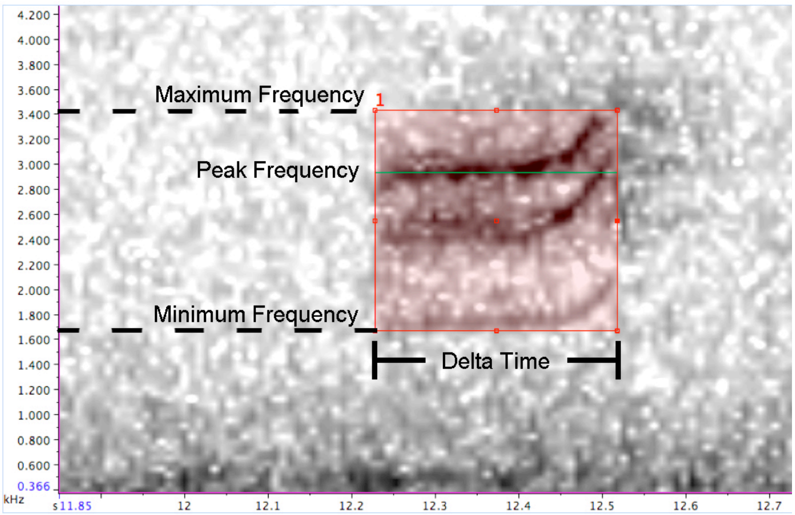

Figure 5. Definitions of Bioacoustics Indices Used in the Experiment

2.3.3 Noise Analysis

In each recording file, three sound fragments of 0.2 seconds were chosen to calculate the energy of background noise. The following algorithm[1]

$$\left| \sum_{i=i_1}^{i_2} (W_i \cdot 10^{S_i/10}) \right| \Delta f$$

was programmed in the "spectrum" window of Raven Pro. The intensities of low-frequency noise (0-4000Hz), high-frequency noise (4000-9000Hz), and total noise (0-11025Hz) were recorded separately in decibel scale.

3 Statistical Processing

3.1 The Composition of Urban Noise

SPSS 22.0 was used to calculate the mean values of the intensities of background noise between each frequency range. The results showed that the noise measured in this experiment agreed with previous literature, with average total noise,

[1] From Comprehensive Raven Pro 1.4 User's Manual

low-frequency noise, and high frequency noise at 65.2±5.8dB, 64.5±6.7dB, and 52.5±5.8dB, respectively. The values suggest that low-frequency noise is the major constituent of urban noise. To examine the validity of this assumption, a bivariate correlation test between the intensity of low-frequency noise and the total noise was conducted. The results from the correlation test (r=0.978， p=0.000) indicate that there is a very high correlation between the intensity of low frequency noise and the total intensity of the noise, suggesting that low frequency noise value is an effective representation the urban noise. As the low frequency noise generally coincides with the pitch range of Magpie and Azure-winged magpie, it is also the type of noise that is supposed to have the greatest impact on birds' calls. Therefore, we identified the intensity of low frequency noise as a potential the independent variable that might impact the call structure of birds and used it in subsequent bioacoustics analysis.

3.2 Differences of Noise Intensities Across Four Sampling Sites

As mentioned before, the four sampling sites were selected in attempt to reflect variations in noise intensities at different locations within the city. To confirm that the sampling covered locations with a diverse range of noise levels, we implemented a One-Way ANOVA test to compare the mean values of low-frequency noise intensities at four sampling sites. The test results (Table 1) indicate the difference of low-frequency noise levels across the sampling sites is significant.

Table 1. One-Way ANOVA of Mean Low-frequency Noise Intensity at Different Sampling Sites

	df	F	Sig.
Between Groups	3	50.63	0
Within Groups	32		
Total	35		

We furthered compared the differences of low frequency noise levels between each two sampling sites using Duncan post hoc comparison method. As shown in Table 2, the noise levels of Sampling Site 3,4 are classified together into subset 1, while Site 1 and Site 2 are classified into subset 2 and subset 3 respectively. This result generally corresponds with empirical estimation. Location 2 has the highest low-frequency noise level mainly because it is significantly affected by traffic noise form the highway. Location 2 and Location 3 are affected by artificial music emitted from visitors' loudspeakers. However, since birds generally avoid regions frequented by humans, these artificial noises were not reflected in the data. Location 1, though less affected by artificial noise pollution, shows medium-level noise due to the interference of loud cicada calls in the summer. Overall, the data reflects diverse types and intensity levels of urban noises.

Table 2. Multiple Comparison with Duncan Method

	Location	N	Subset for alpha = 0.05		
			1	2	3
Duncan	4	6	56.7667		
	3	9	58.4		
	1	12		67.4417	
	2	9			72.0556

3.3 The correlation between low-frequency noise levels and the structures of bird calls

Previous investigations (see the background introduction in Abstract) suggest birds tend to increase the minimum frequency, peak frequency, and time length of their songs in city noise. To study whether this phenomenon also exists in bird calls, we ran bivariate correlation tests between the low-frequency noise intensities and these bioacoustics indices. The results are summarized in the Table 3 and 4.

Table 3 . Correlation Between Low-frequency Noise Intensity and Major Bioacoustics Indices of Magpie Calls

	Low-Frequency Noise Intensity		
	Sample Size (N)	Pearson Correlation Index (r)	Two-Tailed Significance (p)
Minimum Frequency (Hz)	6	0.433	0.391
Peak Frequency (Hz)	6	-0.462	0.357
Time Length (s)	6	-0.675	0.141

The results suggest none of the magpie's minimum frequency, peak frequency, and time length is significantly correlated with low-frequency noise intensity.

Table 4 . Correlation Between Low-frequency Noise Intensity and Major Bioacoustics Indices of Azure-winged Magpie Calls

	Low-Frequency Noise Intensity		
	Sample Size (N)	Pearson Correlation Index (r)	Two-Tailed Significance (p)
Minimum Frequency (Hz)	6	-0.64	0.171
Peak Frequency (Hz)	6	-0.735	0.096
Time Length (s)	6	0.167	0.752

The results suggest none of the azure-winged magpie's minimum frequency, peak frequency, and time length is significantly correlated with low-frequency noise intensity.

4 Discussion

As mentioned, low frequency noise intensity and variations in birds' call structures do not show significant relevance. The data suggests bird calls do not display adaptations to urban noise similar to that of bird songs (higher minimum frequency and lengthened song time etc.). We made a few possible assumptions to explain the observation described above.

1. Bird call has a relatively simple structure and is usually composed of short and discrete syllables. The shortness in time and rigidness in structure does not allow bird calls to be modified in large extent as bird song, and therefore bird call does not undergo remarkable variation in noisy environment.

2.Unlike song structure of some songbirds, data analysis shows that *Pica pica* and *Cyanopica cyanus* have a wider span of call frequency, thus calls may easily penetrate through noisy environment and are not serious affected by environmental disturbance.

3. While bird song is related to mating behavior, the biological functions of bird call are more complicated. Therefore, the structural variations of bird calls are affected by other more complex biological and ecological covariates that could not be explained only with the interference of environmental noises.

4.Unlike the reductionist approach made in other researches that treats urban and rural areas as a dichotomy of noisiness and quietness, our investigation shows there are significant differences in the intensity of noise in different location within the city. The difference does not follow a linear pattern but rather a mosaic-like distribution. According to the Noise Monitor data of 2000-2015 by the City's Environmental Protection Bureau[2], noise intensity level near road or highways is remarkably higher than average (paired t-test, $p<0.001$), while intensities of noise in the urban districts have no remarkable difference compared to that in the remote suburban areas (paired t-test, $p=0.24$). Our research also points out that locations far from traffic shows relatively insignificant level of noise whereas intensity level of noise is significantly higher near roads and traffic. Since traffic, which serves as the main source of noise in urban environment, generally produce low frequency sounds, the adaptation of birds to urban noises should be a dynamic process in which birds will modify their vocalization behavior according to the level of noise in their immediate surroundings.

According the analysis of the samples taken in the experiment, the call behavior of *Pica pica* and *Cyanopica cyanus* have no positive correlation with the intensity of low frequency noises in the bird's surrounding environment. Noise intensity level in urban area is unevenly distributed whereas roads, highways and traffic serve as a major source of low-frequency noise.

5 Evaluation and Reflection

Analysis of experimental data shows that, unlike preexisting hypothesis, noise in urban environment distributes unequally in a mosaic manner. Sampling location as well as statistic analysis of samples shows that transportation is one of the major sources of urban noise pollution. Therefore to maintain the sustainability of urban ecosystem, we would recommend cities to add noise proofing green belts between major road networks, providing living space for bird species.

Our experiment has certain limitations that may limit the accountability of the final result. Errors in the experiment mainly result from low-sensitivity of the

[2] Data Accessed From http://www.bjepb.gov.cn/bjepb/413526/413663/413717/413731/index.html

recording equipment, low sampling frequency, lack of comparison group, and small sample size. Therefore, when collecting data in the subsequent experiments, we will use higher quality recording equipment, and increase sampling frequency as well as sample size in order to obtain more accurate and representative data.

This experiment primarily investigated the relationship between low frequency source of urban noise and the vocalization of *Pica pica* and *Cyanopica cyanus*; we hope to further explore this topic with more appropriate sampling and statistical techniques.

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Group Members Resume

ZHENG Wanzheng, current AP senior at Beijing National Day School, mainly conducts field works in this experiment. Zheng shows great interest in biology, specifically bio-engineering, and had attended summer internship in bio medical laboratory in Tianjin University. Though it is the first time Zheng is exposed to the field of ecology, he finished his assignment of field work, and later translation of the paper, with efficiency. Corresponding to his interest in bio-engineering, Zheng is expecting to study general engineering, and switch to bio-engineering in his up-coming college years. He has already participated in numerous design competitions and projects like International Space Settlement Design Competition. In this specific project, Zheng showed excellent notion of time of which he acquired from his experiences in design competitions and helped the team to keep organized and on time.

FANG Jianing, current IB senior at Beijing National Day School, is responsible for the project design and data analysis. Fang is a passionate student of biology and has participated in multiple independent research projects. His research articles have been published on the Bulletin of Biology and received multiple school awards. Fang is concern about environmental issues in China and has conducted regular bird observations in Beijing for the last seven years. He leads a student research team investigating the wild life smuggling crimes in China during the last decade. Fang is also a leader of the school Natural History Society and volunteered at National Zoological Museum of China to promote the environmental awareness of the public.

YAN Yunan, current IB senior at Beijing National Day School, is responsible for the essay editing process of this project. He is a student actively engaging in the study of curriculum and various extracurricular researches. He shows persistence and enthusiasm in schoolwork. Usually he can participate class discussion and provide thoughtful insights in subjects including chemistry, music, and economics. Although sometimes he is confronted with problems that he could not deal with, he is able to work with his classmates and come up with solutions. He has special interests in chemistry and economics. He has conducted experiments on the synthesis of piezofluorochromic molecules which can be used in construction materials. He has also done several independent researches on China's contemporary economy and its relation with politics. As a passionate observer, he always records things going around him in the society and looks for patterns.
Project Advisor

Group Advisor

Dr. DOU Xiangmei graduated from Institute of Zoology, Chinese Academy of Sciences. An expert in molecular biology and biochemistry, Dr. Dou devoted her time to explore scientific innovation and to improve current experimental techniques. She published multiple articles on core biology journals including Bulletin of Biology and Biology Teaching. Many of her students won national prizes in academic competitions such as "China Adolescents Science & Technology Innovation Contest" and "The Award Program for Future Scientists."

Special Acknowledge to Yan Wan who drew the Experiment Design Diagram