Vocalization Structure of Oriental Magpie-robin (*Copsychus saularis* Linnaeus, 1758) along Urbanization Gradient in Kathmandu Valley, Nepal

Submitted by

Madhu Maharjan
T.U. Registration No.: 5-2-37-1312-2015
T.U. Examination Roll No.: 829
Batch: 2076 BS/2020 AD

A thesis submitted in partial fulfilment of the requirements for the award of the degree of Master of Science in Zoology with special paper Ecology and Environment

Submitted to

Central Department of Zoology
Institute of Science and Technology
Tribhuvan University
Kirtipur, Kathmandu
Nepal

May 2023

DECLARATION

I hereby declare that the work presented in this thesis "**Vocalization Structure of Oriental Magpie-robin (*Copsychus saularis* Linnaeus, 1758) along Urbanization Gradient in Kathmandu Valley, Nepal**" has been done by myself and has not been submitted elsewhere for the award of any degree. All sources of information have been acknowledged by reference to the authors or institutions.

Madhu

....

Madhu Maharjan

T.U. Registration no: 5-2-37-1312-2015

T.U. examination Roll. No:829

Batch: 2076 BS

Date: 2023/05/09

त्रिभुवन विश्वविद्यालय
TRIBHUVAN UNIVERSITY
प्राणी शास्त्र केन्द्रीय विभाग
CENTRAL DEPARTMENT OF ZOOLOGY
कीर्तिपुर, काठमाडौं, नेपाल ।
Kirtipur, Kathmandu, Nepal.

☎ ०१-४३३१८९६
01-4331896
Email: info@cdz.tu.edu.np
URL: www.cdztu.edu.np

पत्र संख्या :-
च.नं. Ref.No.:-

RECOMMENDATION

This is to recommend that the thesis entitled **"Vocalization Structure of Oriental Magpie-robin (*Copsychus saularis* Linnaeus, 1758) along Urbanization Gradient in Kathmandu Valley, Nepal"** has been carried out by **Madhu Maharjan** for the partial fulfillment of Master's Degree of Science in Zoology with special paper ecology and environment. This is his/her original work and has been carried out under my supervision. To the best of my knowledge, this thesis work has not been submitted for any other degree in any institutions.

....

Dr. Laxman Khanal
Associate Professor
Central Department of Zoology
Tribhuvan University
Kirtipur, Kathmandu, Nepal
Date: 2080.01.21

त्रिभुवन विश्वविद्यालय
TRIBHUVAN UNIVERSITY
प्राणी शास्त्र केन्द्रीय विभाग
CENTRAL DEPARTMENT OF ZOOLOGY
कीर्तिपुर, काठमाडौं, नेपाल ।
Kirtipur, Kathmandu, Nepal.

☎ ०१-४३३१८९६
01-4331896
Email: info@cdz.tu.edu.np
URL: www.cdztu.edu.np

पत्र संख्या :-
च.नं. Ref.No.:-

LETTER OF APPROVAL

On the recommendation of supervisor "Associate Professor Dr. Laxman Khanal" this thesis submitted by Madhu Maharjan entitled **"Vocalization Structure of Oriental Magpie-robin (*Copsychus saularis* Linnaeus, 1758) along Urbanization Gradient in Kathmandu Valley, Nepal"** is approved for the examination in partial fulfillment of the requirements for Master's Degree of Science in Zoology with special paper Ecology and Environment.

……………………………………

Prof. Dr. Kumar Sapkota
Head of Department
Central Department of Zoology
Tribhuvan University
Kirtipur, Kathmandu, Nepal
Date: 2080-02-07

त्रिभुवन विश्वविद्यालय
TRIBHUVAN UNIVERSITY
प्राणी शास्त्र केन्द्रीय विभाग
CENTRAL DEPARTMENT OF ZOOLOGY
कीर्तिपुर, काठमाडौं, नेपाल ।
Kirtipur, Kathmandu, Nepal.

☎ ०१-४३३१८९६
01-4331896
Email: info@cdz.tu.edu.np
URL: www.cdztu.edu.np

पत्र संख्या :-
च.नं. Ref.No.:-

CERTIFICATE OF ACCEPTANCE

This thesis work submitted by Madhu Maharjan entitled "**Vocalization Structure of Oriental Magpie-robin (*Copsychus saularis* Linnaeus, 1758) along Urbanization Gradient in Kathmandu Valley, Nepal**" has been approved as a partial fulfillment for the requirements of Master's Degree of Science in Zoology with special paper Ecology and Environment.

EVALUATION COMMITTEE

………………………………
Dr. Laxman Khanal
Associate Professor
Central Department of Zoology
Tribhuvan University
Kirtipur, Kathmandu, Nepal

………………………………
Prof. Dr. Kumar Sapkota
Head of Department
Central Department of Zoology
Tribhuvan University
Kirtipur, Kathmandu, Nepal

………………………
Internal Examiner
Dr. Hari Prasad Sharma

………………………
External Examiner
Dr. Hem Sagar Baral

Date of Examination: 2023/05/21

ACKNOWLEDGEMENTS

I would like to express my sincere gratitude to my research supervisor Dr. Laxman Khanal, Associate Professor of Central Department of Zoology for his invaluable supervision and support throughout the course of research study. I would also like to express my special appreciation to Dr. Anuj Ghimire, for his consistent guidance and advice for making this research possible.

I would like to express my gratefulness towards Prof. Dr. Kumar Sapkota, Head of Department and Prof. Dr. Tej Bahadur Thapa, former Head of Department for their support during the research. Similarly, thanks to all faculties and staff members of the Central Department of Zoology for their kind support whenever needed throughout my study.

I would also thank University Grant Commission (UGC), Nepal for supporting my work under Masters Research Support Program, project MRS-78-79-S&T-133, without which carrying out this research would not have been possible. I would like to express my gratitude towards Cornell Lab of Ornithology, Ithaca, NY, USA for providing me with Raven Pro 1.6 software.

I would like to thank my friends Mr. Ashish Maharjan and Mr. Amrit Nepali for helping me in the field work. I appreciate the helps from my seniors, Mr. Naresh Pandey and Mr. Sandeep Regmi for their valuable support in the analysis. Last but not least, I owe my utmost gratitude to my family members and all my friends for always encouraging and supporting for my research study.

Madhu Maharjan
Kirtipur, Kathmandu

TABLE OF CONTENT

LIST OF FIGURES

LIST OF TABLES

LIST OF PHOTOGRAPHS

LIST OF ACRONYMS

Abbreviated form	**Details of abbreviations**
GLMM	Generalized Linear Mixed Model
LMM	Linear Mixed Model
NDVI	Normalized Difference Vegetation Index
OMR	Oriental Magpie-robin
WAV	Waveform Audio File Format

ABSTRACT

Urbanization is an important factor for global land transformation and Nepal is one of the most rapidly urbanizing countries in the world. One of the negative impacts of urbanization and population growth is noise pollution causing various biological responses. Such anthropogenic noises cause ‘signal masking’ to the bird communities which use acoustic signals for communication. This creates obstacles for birds for communications, territory defense and mate attraction. So, this study was carried out to explore the vocal response; both calls and songs of Oriental Magpie-robin (OMR), along the urbanization gradient of Kathmandu Valley as it has lower vocal frequencies vulnerable for being masked. Thirty-one random sites were selected and differentiated into rural, suburban and urban based on the Normalized Difference Vegetation Index (NDVI) index. The vocal recordings of the OMR were made from 06:00 a.m. to 11:00 a.m. from September 2022–October 2022 for calls and February 2023–March 2023 for songs with Zoom H2n recorder and shotgun microphone. The data were extracted using Raven pro 1.6 software from spectrograms and analyzed in R Program. The minimum frequency of calls and number of elements were statistically different along the urbanization gradient. But for the songs, only the maximum frequency differed statistically. Similarly, the minimum frequency had a statistically significant positive correlation with anthropogenic noise level, whereas the number of elements of call had a negative correlation with the same. However, no significant relationship was observed with other song parameters and anthropogenic noise levels. Vegetation structure should be increased in urban areas of Kathmandu Valley to reduce the impacts of noise as vegetation acts as the sound absorbing materials.

1 INTRODUCTION

1.1 Background

Urbanization is an important factor for the global land transformation and more than 50% of the total population of the world live in the city area (Dearborn and Kark 2010; Ludbrook 2015). With such swift pace, Nepal is one of the most rapidly urbanizing countries in the world (Bakrania 2015). Due to this rapid unplanned urbanization, the environment in and around the city area changes from rural areas which results in varied environment conditions in which wild and urban individuals thrive (Mendes et al. 2011). Human activities create new type of habitat that has never existed before, which changes the shape of urban animal communities (Seress and Liker 2015). Different abiotic factors of the environment like temperature, humidity, air quality, light intensity, etc. are altered creating an impact on various biotic factors (Seress and Liker 2015). For instance, heat island effect (higher temperature of urban areas than surroundings) is seen in urban areas that results in earlier blooming dates of flowers affecting on insect life cycles and in turn on the food availability of bird species (Seress and Liker 2015). Even the behavior of birds such as orientation, migration, foraging, reproduction is changed due to urbanization (Seress and Liker 2015). For example, migrant birds use light cues for migration during night time and due to attraction of birds from artificial lightnings several birds are trapped or died due to collisions specially during foggy and cloudy nights (Seress and Liker 2015).

Urbanization causes various negative impacts on birds. Various anthropogenic infrastructures such as buildings, skyscrapers, fun parks, etc. in urban areas cause homogenization of avian communities (Slabbekoorn 2013) resulting in decreasing population densities and change in population composition (Blair 2004; Mendes et al. 2011). The species richness is negatively affected due urbanization but is not always monotonic, richness is increased if the disturbance is moderate due to landscape heterogeneity, novel communities and prevention of competitors as explained by intermediate disturbance hypothesis (Seress and Liker 2015). Another major consequence of urbanization is increased urban noise pollution (Walters et al. 2019). Anthropogenic noise has dramatically increased in recent years due to population growth and urbanization (Shannon et al. 2016). Noise can induce compound biological response (Shannon et al. 2016). Anthropogenic noise caused due to urbanization is one of the factors that influence these effects on species richness (Mendes et al. 2011). It strongly overlaps with low frequency vocalization of birds. This phenomenon is known as 'signal masking' (Walters et al. 2019). This masking negatively impacts on the species that use acoustic communication, creating obstacles for mate attraction and territorial defense (Brumm 2004; Mendes et al. 2011; Walters et al. 2019). For example, Brumm (2004) found that male common nightingale (*Luscinia megarhynchos)* at noisier locations sang with higher sound levels than that at less nosier places and they have to bear the increased cost of singing.

Since vocal communication is important in bird species, it has been the common subject of the study to test the impact of anthropogenic noise on birds (Walters et al. 2019). Birds, with the help of syrinx, communicate through vocalization and their songs help to maintain boundaries, bonding and courtship (Brumm and Slabbekoorn 2005; Brumm and Zollinger 2013), species recognition (Dowling et al. 2012) and predation avoidance (Brumm and Zollinger 2013). Some species have narrower and lower frequency bandwidth and are more vulnerable to the anthropogenic noise (Mendes et al. 2011). Urban birds use different strategies to deal with unfavorable noise conditions. If a bird spends less energy on low frequency notes or excludes them, then it may result in less signal efficacy and less territorial defense (Mockford and Marshall 2009). As a consequence, the bird is less attractive to the mates and has less reproductive success (Mockford and Marshall 2009). So, to overcome this problem, some bird species modify their vocalization in order to reduce being masked from noise (Mendes et al. 2011), as a part of their behavioral plasticity to overcome the negative impact of unfavorable noise (Brumm 2004; Mendes et al. 2011).

To overcome masking of background effect on vocalization, terrestrial animals change their frequency and amplitude of the vocals (Mendes et al. 2011; Warren et al. 2006). Raising frequency of song also helps in detectability (Walters et al. 2019). Although increase in amplitude is more effective in noisy environment, frequency change in real time has been found in birds. For example, in European blackbirds (*Turdus merula*) studied by Mendes et al. (2011), found that the minimum frequency of the song decreased from urban 2277.24±199.75 Hz., semi-urban 2031±100.49 Hz to rural 1917.97±123.97 Hz. In American robin (*Turdus migratorius*), maximum frequency and band width of the song increased with urbanization causing the entire song to shift upwards (Dowling et al. 2012). Brumm (2004) found out that in common nightingale, males in noisier places sang with higher song amplitude i.e., 91dB but sang with less amplitude i.e., 77dB in less noisier places. But some bird species also have shown no change in song frequency (Walters et al. 2019). For example, grey flycatcher (*Empidonax wrightii*) didn't change the vocal frequency with increased noise exposure (Francis et al. 2011a). Birds with high pitched songs tends to show less frequency shifting behavior than lower pitched species (Walters et al. 2019). Birds such as Eastern bluebirds narrowed their frequency range in urban areas (Kight and Swaddle 2015). Some song birds increased the length of the song with increase in anthropogenic noise. For example, vermilion flycatchers (*Pyrocephalus rubinus*) increased the length of song with increase in noise level (Ríos-Chelén et al. 2013). But some other birds like great gits (*Parus major*) (Mockford and Marshall 2009) and Tūī birds (*Prosthemadera novaeseelandiae*) (Ludbrook 2015) decreased the length of the song with increase in noise level.

Some research have been carried out on frequency change of birds to reduce masking effect but still lack experimental evidence on tendency on noise-dependent spectral adjustment (Slabbekoorn 2013). Although Nepal has over 875 species of birds with 43 species of birds under oscines family, study of songs is limited despite being popular in Europe, US and Japan (Karna et al. 2020). So, this study was performed with an aim to better understand whether there were change in frequencies and durations of calls/songs in Oriental Magpie-robin (OMR) in response to anthropogenic noises along the urbanization gradient of the Kathmandu Valley. Anthropogenic noise sources are often concentrated at lower frequencies (Warren et al. 2006) and given the low-pitched masking of low frequency song by anthropogenic noises. Since the OMR has low frequency songs, the it was chosen as the study subject to test the effects of anthropogenic noise on its songs. Bird vocalization is used to analyze various ecological aspects and the OMR has wide variety of interesting and elaborative vocalizations but hardly any studies on vocalization activities have been carried out (Wanniarachchi and Wijesundara 2016). The study of bird songs have been done by many researchers as they have duel functions; mate attraction and territory defense but that of calls are limited and called as 'neglected orphan' (Grace and Anderson 2015; Marler 2004). Thus, this study has been carried out for better understanding of calls and songs of OMR along the urbanization gradient of Kathmandu Valley.

1.2 Research objectives

The general objective of the study was to explore the vocalization structure of Oriental Magpie-robin along urbanization gradient inside Kathmandu Valley.

The specific objectives of the study are as follows:

i. To compare the frequencies and duration of the calls and songs of Oriental Magpie-robin in urban, suburban and rural areas.
ii. To determine the relation between frequency of the calls and songs with different levels of anthropogenic noises.

1.3 Research hypothesis

The research hypothesis is: The minimum frequency of the call and song in urban areas are higher to reduce the effect of masking by anthropogenic noises and are for longer duration to overcome noise disturbance that helps in better communication.

1.4 Statement of the problem

In Nepal, very few studies have observed at vocalization of birds. Some studies have focused on singing patterns of the OMR but the impact of anthropogenic noise on the vocal frequency is the topic yet to be studied. Since, vocalization is an important behavior in birds for communicating with other individuals, it is vital for understanding their vocalization and factors that affect them. All of the factors in turn are very crucial for their survival and reproduction. Hence research like this shall help us explore how anthropogenic sound changes have been affecting birds, which shall help to protect/conserve bird species by planning for better urbanization in future.

2 LITERATURE REVIEW

The vocalization of birds can be divided as the bird songs and calls. But there is no standard definition for calls and songs (Karna et al. 2020). Bird songs are the most beautiful, most complex sound produced in the nature. They tend to be long, complex vocalizations produced especially by males during breeding season for mate attraction and territorial defense (Ríos-Chelén et al. 2016). The songs are often spontaneous and synchronized with diurnal rhythm whereas, calls are short, simple and produced by both sexes throughout the year generally produced during flight, threat and alarm (Catchpole and Slater 2008; Ríos-Chelén et al. 2016).

Some bird species may have more than one version of the song and each version is called song type (Catchpole and Slater 2008). Each song consists of number of distinct sections with particular pattern which is called phrases. But sometimes the units in phrases can be all different. Each unit of phrase is called syllable (Catchpole and Slater 2008). The syllable can be very simple or quite complex in its structure. When its complex, several building blocks forms the syllable which is called the elements or notes (Catchpole and Slater 2008).

Both calls as well as songs are used by OMR for communication purposes (Danmek and Sitasuwan 2017). According to Mansor and Gawin (2020), there are six different types of calls in Oriental Magpie-robin namely, territorial calls, submissive calls, juvenile calls, threat calls, distress calls and begging calls. Mansor and Gawin (2020) described territorial call as whistling call that can be heard as "*swee…swee.*." call. It generally has two types of elements; type I element and type II element. Similarly, submissive call can be heard as "*cheo....chee...chee...chee...*", juvenile call as "*chree....chree...*",threat call as "*char...char....*", distress call as "*tserr....tserr....*" and begging call as "*che...chee...chee....*". The submissive calls were found to be uttered by most females during non-breeding seasons when the females were being chased by the males while intruding the male's territory. This call generally has two different elements in it; element A and B. Element A is uttered once followed by several elements of B. The minimum frequency and maximum frequency of submissive call was found to be 2.13 ± 0.05 and 5.62 ± 0.12 kHz respectively.

OMR has large complicated song repertoire in which each male could sing more than two different types of songs and some songs were different than the songs of other males (Danmek and Sitasuwan 2017). A repertoire of 20-82 types of songs were recorded in nine

OMR alone with an average of 42.59 ± 13.05 song types (Singh et al. 2019). Sometimes they merge two or more different song types or portion of the songs to form a new type of song (Singh et al. 2019). Hence, it is an open song learner by which the males song new songs throughout the year (Singh et al. 2019). But Zebra Finch have only one type of song and all sang the same song invariably (Brumm and Slater 2006b). The song frequency of OMR generally ranged from 2-5.97kHz (Danmek and Sitasuwan 2017). OMR along other birds such as shama, black drongo can also mimic the songs of other birds (Karna et al. 2020).

Song dialect is the regional variant of song that differs in structure that differs in structure, frequency or time parameter. Dunmak and Sitasuwan (2007) studied on song dialect of OMR of Northern Thailand and found the three main features to identify the song from other species. The first feature was that, the song frequency generally ranged from 2 to 6 kHz. Secondly, each complete song consisted 2 to 112 strophes. And lastly, the core elements occurred within the first second of the strophe. The last element of the core element is known as the marking element and this was used to distinguish the song between two populations.

2.1 Effect of urbanization in birds' calls

Very few researches have been carried out in the calls of birds in comparison to the songs. Not just the raising of minimum frequency of songs occurs in urban birds but also the minimum frequency of calls of parrots and passerines were increased with urban sites (Hu and Cardoso 2010). Similarly, peak frequency of songs and calls of ash-throated flycatcher were positively related to the noise amplitude (Francis et al. 2011a). Penguins (*Aptenodytes patagonicus*) tend to call more with more syllables in wind noise and tawny owls (*Strix aluco*) calls less in rain noise (Mendes et al., 2011). Similarly, a study on tree swallows (*Tachyconeta bicolor*) found that duration, amplitude and frequency range of begging calls increased with the noise levels in the field but only call amplitude increased in the laboratory with noise playback (Ríos-Chelén et al. 2016). Silvereys (*Zosterops lateralis*) call with higher pitch in urban areas with noisy environment than in rural areas (Ríos-Chelén et al. 2016).

2.2 Effects of urbanization in birds' songs

Various studies have found the divergence of song from quiet places and places with higher anthropogenic noises (Mockford and Marshall 2009). For example, in European blackbirds studied by Mendes et al. (2011), it was found that the minimum frequency of the song decreased from urban 2277.24±199.75 Hz., suburban 2031±100.49 Hz to rural 1917.97±123.97 Hz. Halfwerk and Slabbekoorn (2009) found that, when great tits (*Parus major*) were exposed to recorded city noise, inverse city noise and white noise, some birds stopped singing and flew away and some changed their song time. They sang high pitched song type relatively longer in response to low frequency noise and low song type for longer time in response to high frequency noise.

Another study on great tit (*Parus major*) performed in European cities tended to have higher low frequency with shorter and fast songs in urban areas in compared to rural areas (Mendes et al. 2011; Slabbekoorn and den Boer-Visser 2006). Similar results were observed in UK for the same species (Mockford and Marshall 2009). Great tits birds exposed to low frequency noise treatment switched to higher minimum frequency whereas seven of the nine birds exposed to high frequency noise treatment switched to lower minimum frequencies. Songs became of higher pitched in Northern mockingbird (*Mimus polyglottus*) as found by (Walters et al. 2019). This behavior is the temporal switching behavior in response to the noise exposure. Similarly, Dowling et al. (2012) found that species with lower frequency songs are more affected by noise and two of six species showed increase in minimum frequency when exposed to the noise. Hanafi et al. (2019) demonstrated that low frequency of the Magpie-robin increased from rural to semi-urban followed by birds of urban area. In chipping sparrows (*Spizella passerine*), it was found that males with lower minimum frequency and higher frequency range increased its minimum frequency and decreased range with increasing noise and urban structure (Job et al. 2016). Whereas, males with higher low frequency and lower frequency range decreased its lower frequency and increased the range in order to improve the transmission of sound. Ríos-Chelén et al. (2016) found that in red-winged blackbirds the minimum frequency increased with playback noise with by-eye practice method but with threshold method, there was no significant shift in minimum frequency. These rise of minimum frequency was generally shown by species with intermediate minimum frequency (about 1-1.5kHz) and species with high minimum frequency did not raise frequency as they were less affected by the ambient noise (Hu and Cardoso 2010).The minimum song frequency of Northern cardinals (*Cardinalis cardinalis*) increased at higher levels of environmental noise (Narango and Rodewald 2016; Seger-Fullam et al. 2011). Maximum song frequency positively correlated to ambient noise (Seger-Fullam et al. 2011).The minimum song frequency of American robins was positively correlated with noise (Seger-Fullam et al. 2011). Noise amplitude was positively correlated with minimum frequency in Great Tits but maximum frequency was not significantly correlated (Hamao et al. 2011). Background noise have positive effect on low frequency of Northern mockingbird songs no effect on high frequency (Walters et al. 2019). Rufous-collared sparrows in suburban had significantly higher minimum frequency than rural ones (Laiolo 2011). But minimum frequency of song in red-winged blackbird was independent of noise (Ríos-Chelén et al. 2015). Minimum frequency in OMR increased with increase in noise (Zhan et al. 2021).

Significant decrease in maximum frequency of common chiffchaff (*Phylloscopus collybita*) songs was observed in Manchester Airport with increase in noise level (Wolfenden et al. 2019). Male chaffinches of noisier territories sang with higher pitched song (Brumm and Slater 2006a). Maximum frequency of Oriental Magpie-robin increased with increase in noise (Zhan et al. 2021). Male forest Common birds used songs of frequency below 2kHz more often than the city birds (Nemeth et al. 2013).

The length of songs were longer and sung at faster rates by Northern Cardinals when exposed to environmental noise (Narango and Rodewald 2016). But no correlation was found by in Northern cardinals and American robin (Seger-Fullam et al. 2011).Song length and number of phrases of song significantly increased with increase of noise in great tits (Hamao et al. 2011). Chaffinches in the noisier place produced longer bouts of songs (*Fringilla coelebs*) (Brumm and Slater 2006a). Red-winged blackbirds (*Agelaius phoeniceus*) sang with less syllables of song in noisier places than in quieter areas (Ríos-Chelén et al. 2015). Brumm (2004) showed that male common nightingale (*Luscinia megarhynchos*) had higher song pressure in noisier territories than in less noisier territories in order to lower the effect of noise and to communicate with another conspecific. This mechanism was known as Lombard effect. This study was the first evidence of the effect in the natural environment. Male zebra finch (*Taeniopygia guttata*) increased the amplitude of the call in response to increase in white noise (Cynx et al. 1998).

In Nepal, very few studies have been performed on bird songs. On singing pattern of OMR in Biratnagar 1782 song samples were recorded from seven different individuals at various sites (Karna et al. 2020). Out of these, 328 song types were identified and all the individuals have different motif (patterns) from each other. Another study in seven countries of Asia including Nepal on OMR in urban and rural areas show that urban birds sang longer song and have longer syllable intervals for efficient information transformation (Hill et al. 2018).

3 MATERIALS AND METHODS

3.1 Study area

Thirty-one different sites of Kathmandu, Bhaktapur and Lalitpur districts inside the Kathmandu Valley were randomly selected as the study area. From each site, at least three individuals of OMR were observed. The valley lies in a temperate zone and has warm climate most of the year with moderate rainfall. It has generally five seasons; spring (March–April, 10–28°C), summer (May–June, 19–29°C), monsoon (June–August, 19–29°C), autumn (September–November, 10–27°C) and winter (November–February, 2–20°C) (Climate 2021). During monsoon season, there is an average rainfall of between 20–37cm (Climate 2021). Kathmandu Valley has an estimated population of 2.54 million and is one of the fastest growing metropolitan areas in South Asia with a growing rate of 6.5% per year (Timsina et al. 2020). Similarly, the noise levels in Kathmandu Valley exceeded 70dB surpassing the recommended levels of national as well as international noise standards (Singh et al. 2022).

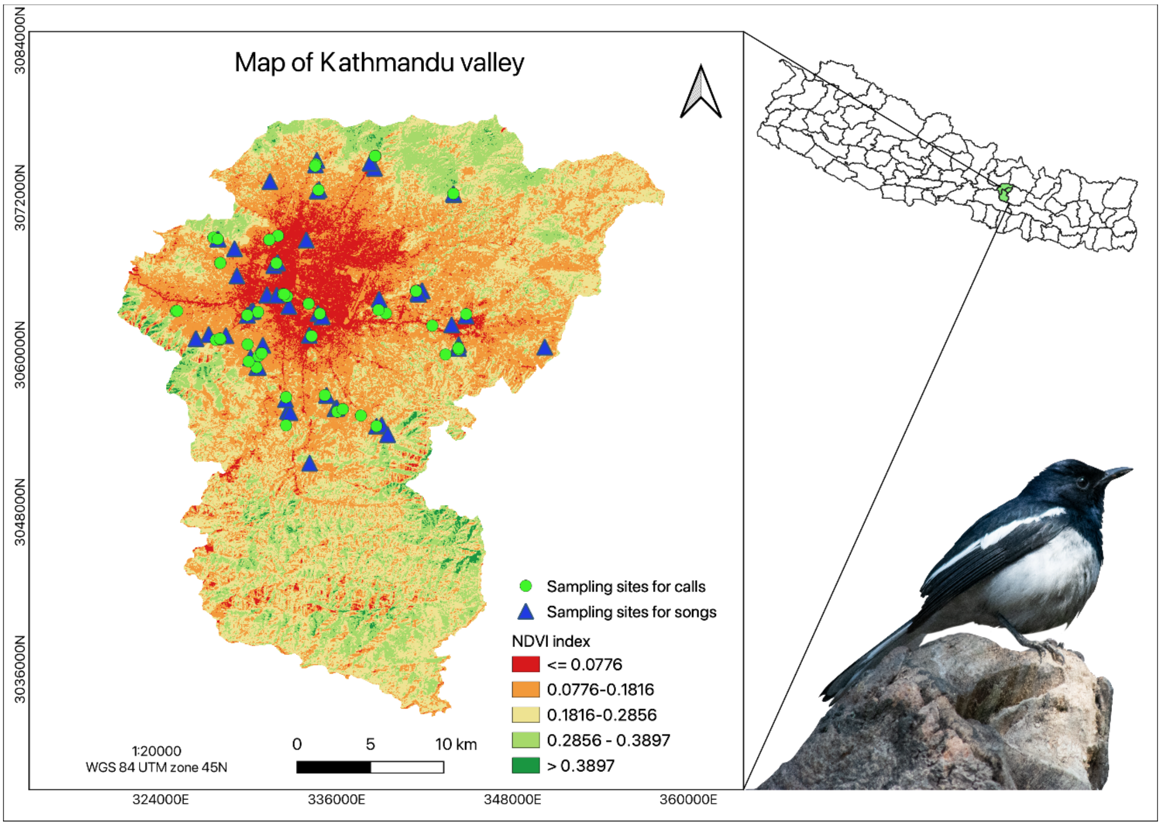


Figure 1. Map of the study area showing sampling sites for recording the calls and songs of the OMR in Kathmandu Valley.

3.2 Study species

OMR belongs to the Passeriformes order of Muscicapidae family (Danmek and Sitasuwan 2017). OMR is a resident breeder of South Asia preferring woodlands and areas around human settlements (Koli 2014). The territories are defended by monogamous pairs and the range of territory is generally 1 to 2 km^2 (Danmek and Sitasuwan 2017). They start to sing early in the morning from around 4:30–5:45 a.m. around their nests (Koli 2014). Males sing loudly from the top of the perch in exposed places such as trees during the breeding season (Danmek and Sitasuwan 2017). They start to change in position and sing more complex songs once they get responses from other conspecific birds (Koli 2014). The songs were heard from mid-February to the end of the breeding season (i.e, mid-August) (Singh et al. 2019).

3.3 Criteria for urban gradient

At first, the Landsat image of Kathmandu Valley during the month of February 2023 was downloaded from the website (https://earthexplorer.usgs.gov/) by keeping the cloud cover of less than 30%. Then after, NDVI (Normalized Difference Vegetation Index) of study sites of Kathmandu Valley was calculated from the Landsat 8 image using QGIS (version 3.28) software with the help of 'Zonal statistics' tool. For each location of data collection, a buffer of 400m radius was kept and average NDVI was calculated. The mean NDVI value ranged from 0.05–0.23. The range of NDVI value from 0.05–0.11 inside the Ringroad of Kathmandu Valley was considered as urban habitats. The NDVI value below 0.16 outside the Ringroad was considered as suburban and greater than 0.16 was considered as rural habitats.

3.4 Call and song recordings

All the spontaneous calls and songs of male OMR were recorded along the urbanization gradient of Kathmandu Valley. The recordings were made from 06:00 a.m. to 11:00 a.m. from September 2022–October 2022 (post-breeding season) for calls and February 2023–March 2023 (breeding season) for songs, as the breeding season of OMR is late–February to August (Singh et al. 2019). For recording, Zoom H2n recorder (sampling rate 96kHz, resolution 24 bit and WAV file format) with BOYA (BY-PVM1000L) shotgun microphone was used. Only calls and songs of perched birds were recorded by approaching them as close as possible without alarming them. Headphones were used to listen the vocals while recording. The study was carried out only during sunny days and in low wind speed. The location of bird, habitat (rural, suburban or urban), song post of the bird, recording time and date, WAV file number in the recorder and distance of recorder from the source of the bird were noted down.

To reduce the recording of the same bird twice, no songs were recorded within the 200m of the recorded bird but if another bird was observed singing while recording one individual then the second bird have been recorded closer than 200m (Wolfenden et al. 2019).

3.5 Measurement of anthropogenic noise

Sound Level Meter (Mengshen Digital Precision Instrument) was used to measure the anthropogenic noises in all the habitats. The noise was measured for two minutes immediately after bird song stopped (Brumm 2004). The meter was kept 1.2 meters above the ground to avoid the sound degraded by reflecting surface (Hanafi et al. 2019).

3.6 Acoustic analysis

Acoustic data were extracted by using Raven Pro 1.6 software (Cornell Lab of Ornithology, Ithaca, NY, USA) by making the spectrograms of the recorded sound [spectrogram settings: Hamming window Fast Faurier Transformation (FFT) size= 512]. The spectral parameters measured were maximum frequency, minimum frequency and frequency range whereas the temporal parameters were length and number of elements of calls and songs (Table 1). Ten consecutive calls/songs from recordings of each individual were selected (Zhan et al. 2021). Since, there were different kinds of calls of OMR, all these calls were identified from the article with the help of spectrogram (Mansor and Gawin 2020). Since, the number of submissive calls obtained were higher than other calls, these calls were analyzed.

Table 1. Definition of call and song parameters.

Call/song parameters	**Definition**
Minimum frequency	Lowest frequency of call/song
Maximum frequency	Highest frequency of call/song
Frequency range	Difference between minimum and maximum frequency
Length of call/strophe of song	Length of a call/ verse in a song
Time interval between calls/strophe of song	Time interval between call/ verse in a song
Number of elements in call/strophe of song	Number of elements in call/ verse of a song

3.7 Statistical analysis

Minimum frequencies, maximum frequencies, frequency range, length and interval between calls/songs and number of elements in calls/songs were analysis within urban, suburban and rural area was analyzed by using analysis of variance (ANOVA) if the data were normally distributed. If the data were not normally distributed, then Kruskal-Wallis test was done. Tukey HSD test and Dunn's test were performed as post-hoc test. Similarly, Pearson correlation coefficient was used to determine the relationship between the level of anthropogenic noise with song and call parameters.

Since the sample size of submissive calls during September and October 2022 was small, it was tested with the samples of submissive calls (n=6) obtained during February and March 2023 by independent sample t-test. But t-test for maximum frequency (t=-2.20, df=29, p= 0.018) and frequency range (t=-2.20, df=29, p=0.035) of calls were significantly different between two seasons. Therefore, data were not merged.

For linear mixed model (LMM) and generalized linear mixed model (GLMM) were further performed to test whether any environmental factors affected the song parameters of OMR. The normality of the data was confirmed by conducting residual analysis, plotting the residuals against the fitted values, normal quantile-quantile (qq)-plot of the residuals, the square-root of the absolute values of the standardized residuals versus the fitted, and the residuals against the leverages. ‘lme4’ package was used for the analysis. The function *dredge* in the package ‘MuMIn’ was used to obtain Akaike Information Criteria (AIC). And the model selection was done by information theory approach. Similarly, correlations between the predictor variables were checked. There was high correlation between temperature and humidity (r=0.73) so, humidity was removed from the model.

In each model, song parameters (minimum frequency, maximum frequency, frequency range, length, time interval between calls/songs and number of elements were used as dependent variables. Similarly, environmental variables such as anthropogenic noise level, temperature, habitat types (urban, suburban and rural), interaction between anthropogenic noise and temperature, between noise and urbanization level and between temperature and urbanization level were used as independent variables. Lastly, site from which the vocals of bird was recorded was used as the random effects. All the statistical analysis was carried out using R Program (R Core Team 2023).

3.8 Ethical, Legal and Social Implications (ELSI)

The necessary permission to conduct the research was taken from Department of Forests and Soil Conservation, Babarmahal, Kathmandu. No animals and their habitats were harmed during the study.

4 RESULTS

4.1 Calls of Oriental Magpie-robin

A total of 91 vocals of different individuals of Oriental Magpie-robin (OMR) were collected from different sites of the Kathmandu Valley. There were 25 submissive calls, 24 territorial calls, 22 juvenile calls, one begging call, two songs and some threat and alarm calls were obtained during the months of September and October 2022 which had better distinction of noise and vocal frequencies.

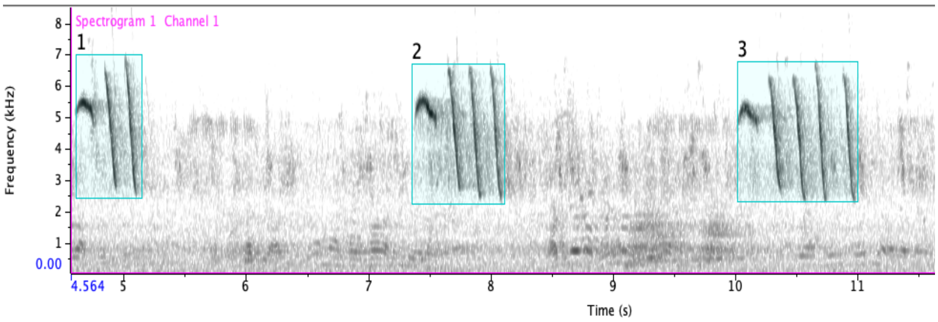


Figure 2. Submissive call of Oriental Magpie-robin with call selections of 3, 4 and 5 number of elements each.

4.1.1 Average noise for call recordings

The average noise of urban site (n=6) was 60.08±7.60 dB, suburban (n=8) was 53.10±2.9 dB and rural (n=11) was found to be 53.96±4.86 dB. The average anthropogenic noise differed along the urbanization gradient (F= 3.654, df=2, p= 0.043). The differences were statistically significant urban and suburban (p=0.051).

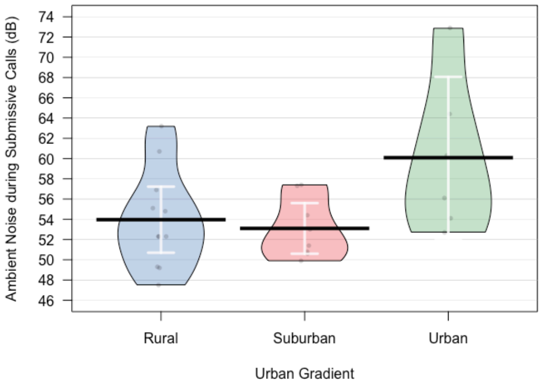


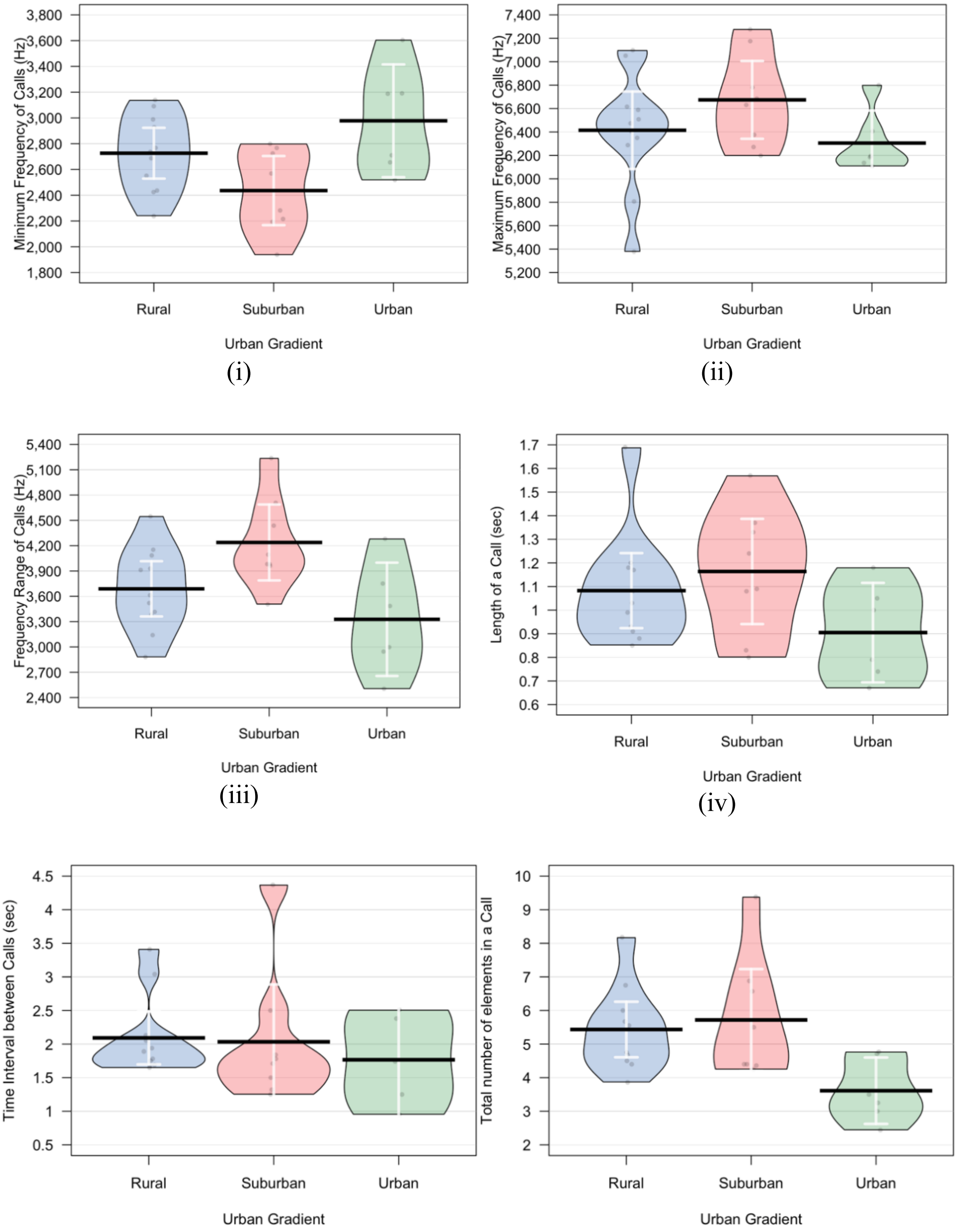
Figure 3. Average anthropogenic noise along the urbanization gradient for submissive call recordings.

4.1.2 Call parameters of OMR

Table 2. Test of submissive call parameters along urban gradient.

Call Parameters	Habitats	Mean	S.D.	ANOVA/ Kruskal Wallis	p-value
Maximum Frequency of call (Hz)	Rural	2726.21	293.47	4.608	**0.021**
	Suburban	2436.00	320.95		
	Urban	2977.76	416.96		
Minimum Frequency of call (Hz)	Rural	6414.86	492.04	3.896	0.143
	Suburban	6674.34	397.58		
	Urban	6305.112	264.13		
Frequency Range of call (Hz)	Rural	3688.66	487.21	5.117	**0.015**
	Suburban	4139.62	579.90		
	Urban	3327.62	639.94		
Length of call (sec)	Rural	1.08	0.24	2.055	0.152
	Suburban	1.12	0.27		
	Urban	0.91	0.20		
Interval between calls (sec)	Rural	2.09	0.59	1.116	0.572
	Suburban	2.11	1.02		
	Urban	1.77	0.68		
No. of elements of call	Rural	5.43	1.23	0.655	**0.038**
	Suburban	5.63	1.74		
	Urban	3.61	0.96		

Further post-hoc analysis showed that there was significant difference between minimum frequency of urban and suburban sites (p=0.017), frequency range of urban and suburban sites (p=0.013) and number of elements of calls of urban and rural sites (p= 0.022).



(i) (ii)

(iii) (iv)

(v) (vi)

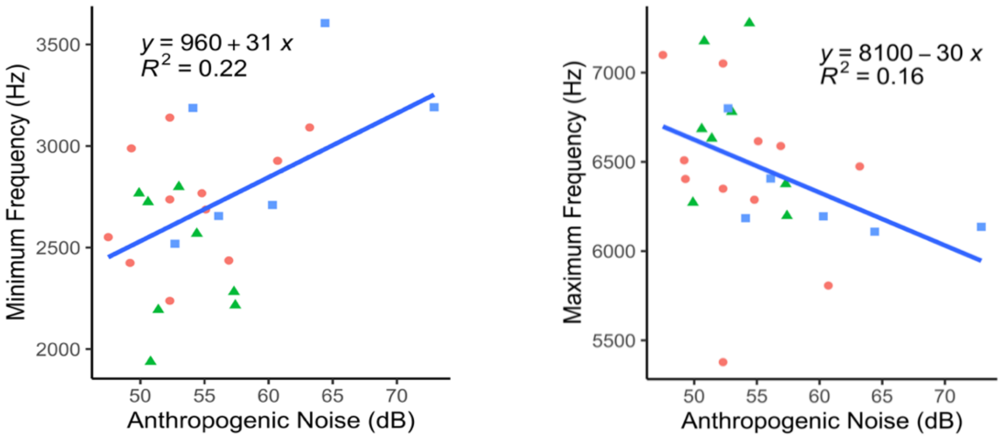
Figure 4. (i) Average minimum frequency (ii) Average maximum frequency (iii) Average frequency range (iv) Average length of call (v) Average time interval between calls (vi) Average number of elements of call along the urbanization gradient.

4.1.3 Test of parameters with anthropogenic noise

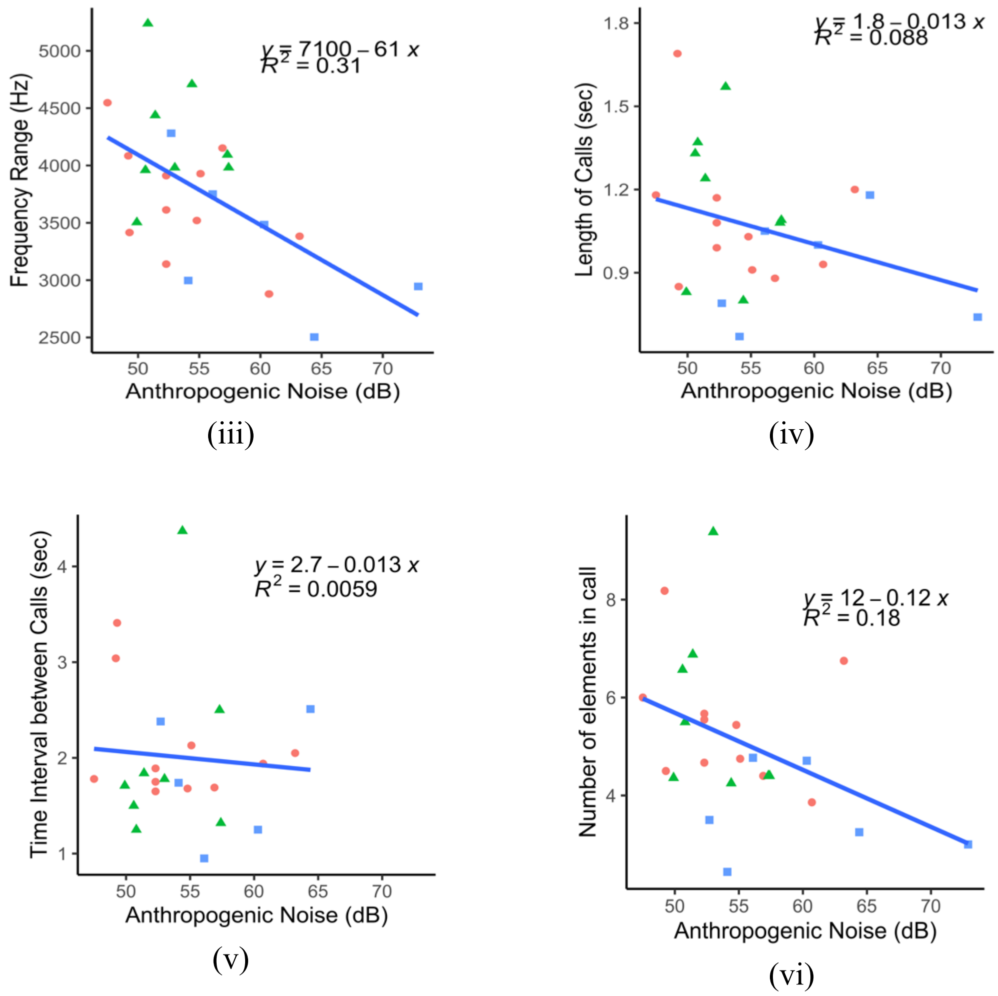
In OMR, minimum frequency of submissive call significantly increased with noise but number of elements significantly decreased with noise. Although maximum frequency and frequency range decreased with increase in noise, they were not statistically significant. Other parameters did not show any correlation with anthropogenic noise (Table 3, Figure 5).

Table 3. Pearson coefficient of correlation between submissive call parameters of the OMR and anthropogenic noise.

Call parameters	**Pearson coefficient (r)**	**p-value**
Minimum frequency	**0.47**	**0.017**
Maximum frequency	-0.4	0.508
Frequency range	-0.56	0.556
Length of call	-0.30	0.149
Time interval between calls	0.07	0.721
Number of elements in calls	**-0.42**	**0.030**



(i) (ii)



(iii) (iv)

(v) (vi)

Figure 5. Association between (i) Minimum frequency (ii) Maximum frequency (iii) Frequency range (iv) Length of call (v)Time interval between the calls and (vi) Number of elements in a call with anthropogenic noise (Here, red dot represents rural, green triangle represents suburban and blue square represents urban sites).

4.2 Songs of Oriental Magpie-robin

A total of 123 vocalizations of different individuals of Oriental Magpie-robin were recorded along the urbanization gradient in Kathmandu Valley during the month of February and March 2023. Out of them, 102 were songs, 6 were submissive calls and 12 were territorial calls, two were juvenile calls and one alert call. Out of the recorded songs of different individuals, only 62 songs that had better distinction of noise and vocal frequency in spectrogram were used.

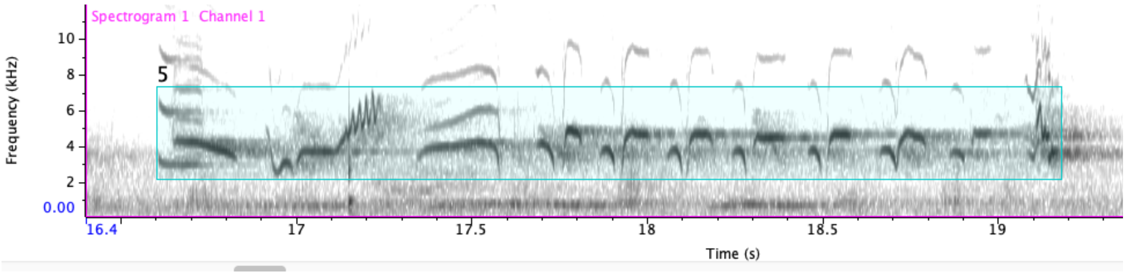


Figure 6. Song of Oriental Magpie-robin with 11 elements.

Across the overall sites, the mean minimum frequency was 2149.59±311.47 Hz, maximum frequency was 6034.86±745.31, frequency range was 3885.27±724.91 Hz, mean length of the phrase of song was 2.07±1.15 secs, interval between the phrase of the songs was 3.30±2.10 secs and the mean elements present in the phrase of the song was 7.78±2.64.

4.2.1 Average noise for song recordings

The average anthropogenic noise of urban site (n=20) was 57.02±4.97 dB, suburban (n=18) was 54.85±6.30 dB and rural (n=24) was found to be 51.33±4.66 dB (Figure 7). The noise differed along the urbanization gradient with statistical difference (F=6.532, df=2, p=0.002). The differences were statistically significant between rural and urban only (p=0.002) but not between suburban and rural (p=0.091) and between urban and suburban (p=0.420).

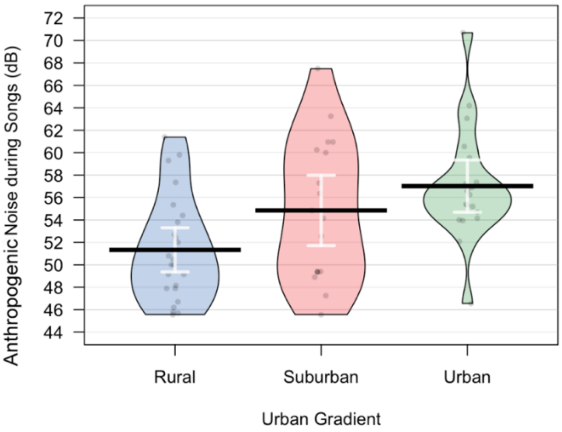


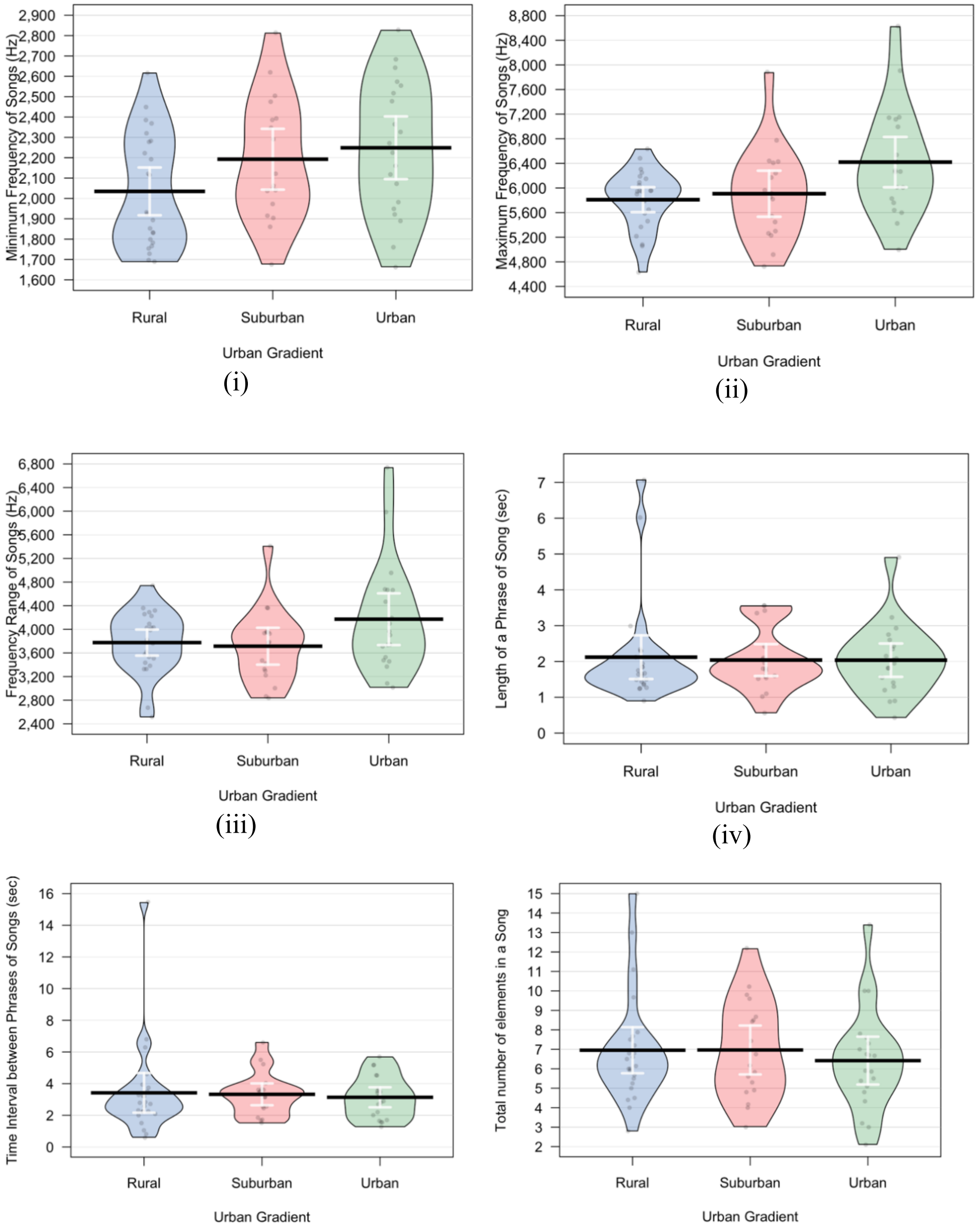
Figure 7. Average anthropogenic noise along the urbanization gradient for song recordings.

4.2.2 Song parameters of OMR

Table 4. Test of song parameters along urban gradient.

Song Parameters	Habitats	Mean	S.D.	ANOVA/ Kruskal Wallis	p-value
Maximum frequency of song phrase (Hz)	Rural	2034.63	277.92	5.819	0.0545
	Suburban	2192.57	300.36		
	Urban	2248.85	329.29		
Minimum frequency of song phrase (Hz)	Rural	5809.80	480.57	4.497	**0.0152**
	Suburban	5906.73	752.48		
	Urban	6420.26	872.55		
Frequency range of song phrase (Hz)	Rural	3775.17	522.73	2.838	0.242
	Suburban	3714.15	627.77		
	Urban	4171.41	935.14		
Length of song phrase (sec)	Rural	3.4	2.96	0.555	0.758
	Suburban	2.04	0.90		
	Urban	2.04	0.99		
Interval between song phrases (sec)	Rural	3.42	2.96	0.648	0.723
	Suburban	3.33	1.39		
	Urban	3.14	1.35		
No. of elements in phrase of song	Rural	6.95	2.80	0.835	0.825
	Suburban	6.67	2.53		
	Urban	6.42	2.63		

Further post-hoc test showed that maximum frequency differed in urban and rural sites (p=0.016). But there was increase in trend for minimum frequency of songs, decrease in trend for interval between the song phrases and number of elements in song phrases from rural to urban sites.



(i) (ii) (iii) (iv) (v) (vi)

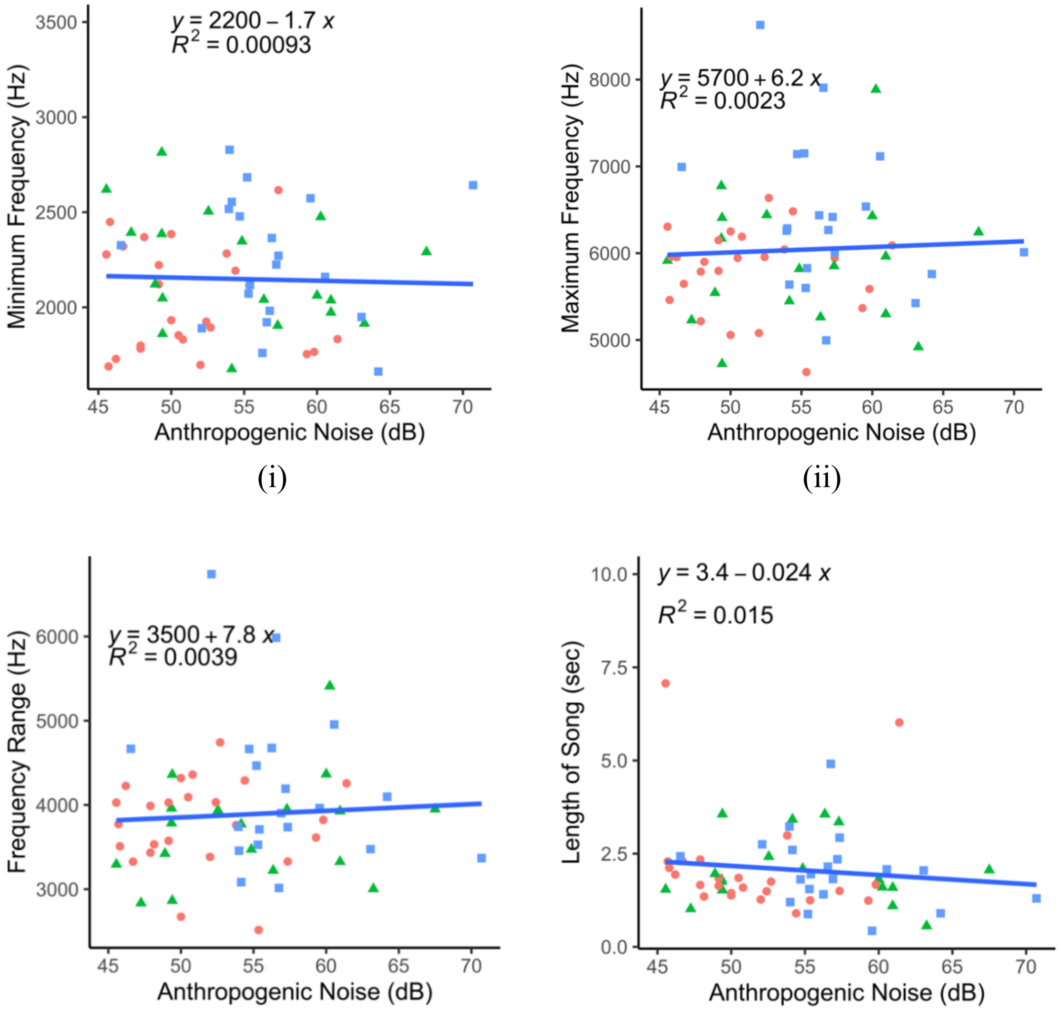
Figure 8. Average (i) Minimum frequency (ii) Maximum frequency (iii) Frequency range (iv) Length of song (v) Time interval between song (vi) Number of elements of song along the urbanization gradient.

4.2.3 Test of song parameters with anthropogenic noise

In OMR, the song parameters did not show any significant correlation with anthropogenic noise level (Table 5, Figure 9).

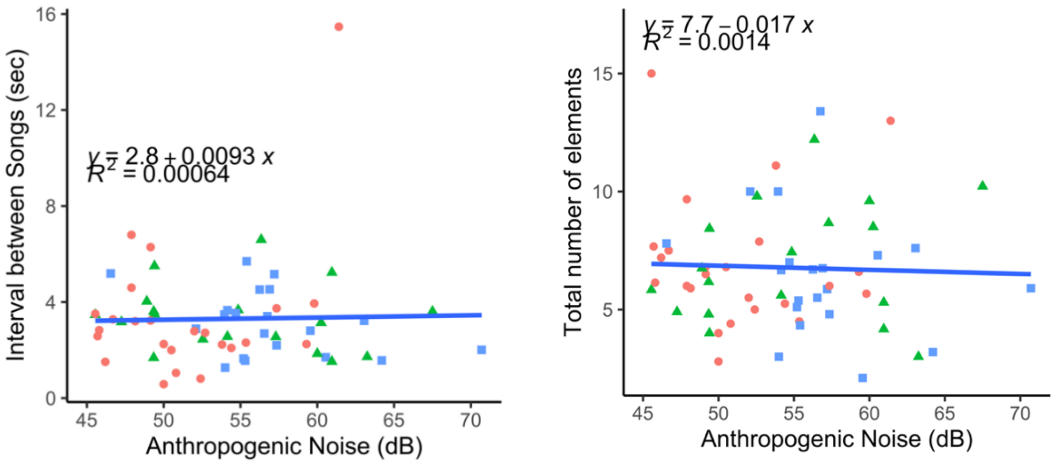
Table 5. Pearson coefficient of correlation between song parameters of the OMR and noise

Song parameters	**Pearson coefficient (r)**	**p-value**
Minimum frequency	-0.03	0.814
Maximum frequency	0.048	0.713
Frequency range	0.222	0.082
Length of songs	-0.122	0.345
Time interval between songs	0.025	0.846
Number of elements	-0.038	0.769



(i) (ii)

(iii) (iv)



(v) (vi)

Figure 9. Association between (i) Minimum frequency of song (ii) Maximum frequency of song (iii) Frequency range of song(iv) Length of song (v)Time interval between the songs and (vi) Number of elements in a song with anthropogenic noise (Here, red dot represents rural, green triangle represents suburban and blue square represents urban sites).

4.3 Effects of environmental factors on song parameters

LMM and GLMM analysis showed that there were single and interaction effects of environmental factors on the song parameters of OMR. The minimum frequency of song was affected by temperature (E=-159.86, t=-2.026 and p=0.048), urban gradient (Urban) (E=272.92, t=2.748 and p=0.009) and interaction of temperature and noise (E=-183, t=-2.827 and p=0.006). The minimum frequency decreased with increase in temperature and with interaction of temperature and noise but increased in urban areas. And the best fit of the model was described by anthropogenic noise and urban gradient (Table 6). Similarly, the maximum frequency of song significantly decreased with interaction effect of temperature and noise (E=-378.74, t=-2.454 and p=0.017) and increased in urban areas (E=802.58, t=3.448 and p=0.001). And the best model was described by urban gradient for the maximum noise (Table 6). Frequency range significantly increased in urban areas (E=533.76, t=2.05 and p=0.031).

There was no significant interaction of variables in the length of song. The song interval was significantly increased when anthropogenic noise increased (E=1.380, t=2.71 and p=0.008) but decreased with noise in urban areas (E=-2.039, t=-2.762 and p=0.007). The GLMM analysis indicated that the number of elements of song significantly increased with the anthropogenic noise (E=0.441, z=3.067 and p=0.002) but significantly decreased with noise in suburban area (E=-0.452, z=-2.164 and p=0.030) and with noise in urban areas (E=-0.694, z=-3.027 and p=0.002). And the best model for the frequency range, length of song, interval between the songs and number of elements of song was best fitted by the null model with no any variables (Table 6).

Table 6. Linear mixed models and generalized linear mixed model (only for number of elements in song) based on AICc for determining Oriental Magpie-robin's songs at urban, suburban and rural areas. All models were generated based on three variables (i.e, AN, T and UG) and their interactions. Best model with delta less than 2.0 are presented. AN= Anthropogenic Noise, T= Temperature and UG= Urbanization Gradient.

Model	Intercept	df	logLik	AICc	Δ AICc	Weight
Minimum frequency						
AN+UG	2017	6	-411.89	837.4	0	0.16
Null	2163	3	-415.52	837.5	0.05	0.157
AN+T+UG+AN*T	2005	8	-409.29	837.5	0.1	0.153
UG	2050	5	-413.20	837.5	0.12	0.151
Maximum frequency						
UG	5835	5	-462.74	936.6	0	0.365
AN+UG	5786	6	-462.24	938.1	1.48	0.174
Null	6052	3	-466.42	939.3	2.65	0.097
Frequency range						
Null	3894	3	-465.28	937	0	0.296
UG	3789	5	-463.19	937.5	0.54	0.226
Length of song						
Null	1.569	3	-95.11	196.7	0	0.484
AN	1.568	4	-94.89	198.5	1.87	0.19
Interval between songs						
Null	2.776	3	-126.04	258.5	0	0.389
T	2.776	4	-125.44	259.6	1.12	0.222
Number of elements in song						
Null	1.002	2	-114.33	232.9	0	0.23
T	0.996	3	-113.35	233.1	0.27	0.201
AN+T+UG+AN*UG	1.191	8	-107.64	234.2	1.35	0.117
AN+UG+AN*UG	1.208	7	-109.23	234.7	1.83	0.092

5 DISCUSSION

The minimum frequency, frequency range and number of elements of the submissive calls of Oriental Magpie-robin (OMR) differed along the urbanization gradient of Kathmandu Valley. The minimum frequency of submissive calls increased whereas the number of elements decreased along the increase in anthropogenic noise. Similarly, there was increase in maximum frequency along the urbanization gradient from rural to urban habitats. However, no distinct association was observed between the song parameters and anthropogenic noise.

5.1 Variation in calls of OMR along urbanization gradient

The minimum frequency of calls of OMR increased significantly with increase in noise in our study similar to the research done in silvereyes (Potvin et al. 2011), red-winged blackbird (*Agelaius phoeniceus*) (Hanna et al. 2011) to improve the signal-to-noise ratio (Potvin and Mulder 2013). Higher frequencies of vocals attenuate the masking effect more rapidly than the lower ones that enhances signal transmission (Hanna et al. 2011). Increasing frequency also decreased the bandwidth that concentrates the energy in frequency domain and helps receiver to discriminate from background noise (Hanna et al. 2011; Lohr et al. 2003). It also increases the communication distance; with 205 Hz increase of frequency in great tit the communication distance increased by 20% keeping constant amplitude (Grace and Anderson 2015; Nemeth and Brumm 2010). Contrary to our findings, no impact of traffic noise was observed in minimum frequency of calls of Carolina chickadee (*Poecile carolinensis*) as there was no more room for plasticity of calls (innate ones) than songs (learned vocalization). Calls are generally innate and higher frequency calls are due to possibility of some genetic adaptations or higher call plasticity in urban birds (Potvin et al. 2011). Although the minimum frequency of call was higher than 2kHz in our study there was significant difference along the urban structures which was contrary to the study done by Lowry et al. (2019). In this study, minimum frequency for the calls between urban and rural noisy miners (*Manorina melanocephala*) higher than 2kHz was not significantly different but there was significant difference for the calls lower than 2kHz like chur alarm calls, cue territorial calls and post-feed-calls.

The maximum frequency of the calls decreased with increase in noise in our study. Contrary to our study, there was no any shifts in maximum frequency calls of silvereyes

(Potvin and Mulder 2013), calls of Carolina chickadee when exposed to the noise. Only minimum frequency increased and not maximum frequency because songs differed only at those aspects masked by prevailing noise (Wood and Yezerinac 2006).

The frequency range of call decreased with increase in noise but was not significant whereas the change along the urban structure was significant. Similar results were found in the begging calls of nestling tree sparrows (*Tachycineta bicolor*) while they were exposed to playbacks of white noise (Leonard and Horn 2008). This decrease in frequency range narrows the frequency bandwidths that helps to be more detectable against the background noise (Leonard and Horn 2008; Warren et al. 2006). Similarly, narrow frequency range concentrates more signal energy in adjusted band that reduces the effect of signal to noise ratio in the band (Leonard and Horn 2008; Lohr et al. 2003).

The increase in noise decreased the length of call in our study but was not significant. The decrease in length of song was similar (Francis et al. 2011b) in plumbeous vireos (*Vireo plumbeus*) (Francis et al. 2011b). But no impact of traffic noise was observed in duration of calls of Carolina chickadee, trill of red-winged blackbirds as the energetic trill outweighs the potential benefits (Hanna et al., 2011). In contrary to this, the length of call increased with noise in silvereyes (Potvin and Mulder 2013).

Similar to our study, the length of call did not statistically differ between rural and urban noisy miner birds which may be due to lack of vocal plasticity or due to ‘pre-adapted’ vocal traits like having dominant frequency above the noise levels (Lowry et al. 2019).

The increase in noise significantly decreased the number of elements in calls of the OMR as in the study of songs of red-winged blackbirds (Ríos-Chelén et al. 2015). This may be due to fact that longer signals are easy to detect and discriminate in the noisy environments (Ríos-Chelén et al. 2015). Contrary to our findings, no impact of traffic noise was observed in number of notes of calls of Carolina chickadee (Grace and Anderson 2015).

5.2 Variation in songs of OMR along urbanization gradient

Contrary to our study, the minimum frequency increased with increase in noise level in song of blackbirds (Nemeth and Brumm 2009), songs of song sparrow (*Melospiza melodia*) (Wood and Yezerinac 2006), great tits (Mockford and Marshall 2009), house finches (*Carpodacus mexicanus*) (Bermúdez-Cuamatzin et al. 2011), Tūī birds (Ludbrook 2015), chiffchaffs (Verzijden et al. 2010) with similar anthropogenic habitat (Kight and Swaddle 2015). Regardless of the source of noise (i.e, anthropogenic or natural) the emberizid species also increased the minimum frequency of song, reduced the bandwidth and longer songs to overcome the masking effect of the noise (Davidson et al. 2017). This increase in minimum frequency in urban sites in other birds maybe to increase salience of song in noisy environment (Bermúdez-Cuamatzin et al. 2011) and increase diversity of song (Bermúdez-Cuamatzin et al. 2011; Ripmeester et al. 2010). Another reason may be due to behavioral plasticity in which birds modify their songs according to the background noise (Ludbrook 2015; Wood and Yezerinac 2006). Another hypothesis is that process of ontogenetic change the song of the birds matches the noise level of their territory (Ludbrook 2015; Wood and Yezerinac 2006). But increasing the frequency is not always sufficient to overcome the masking effect of the noise (Lowry et al. 2019).

Although there was no increase in minimum frequency with increase in noise level in our study, there was some trend of increase in minimum frequency from rural to urban areas. ‘‘Human-modified and noisy may not always be synonymous, and may not always provoke the same behavioral adjustments in wildlife’’ (Kight and Swaddle 2015). The increase in minimum frequency of song in urban areas were observed in dark-eyed juncos (*Junco hyemalis*), silvereyes (Potvin et al. 2011), European blackbirds (*Turdus merula*) (Mendes et al. 2011), great tits (Mockford and Marshall 2009). Chipping sparrow that had higher maximum frequency increased the minimum frequency and narrowed bandwidth with increase in noise and vegetation structure (Job et al. 2016). But it was found that relationship between noise and minimum frequency was lesser than vegetation structure and minimum frequency suggesting structure have greater influence on the song trait (Job et al. 2016). But the research is limited on this (Job et al. 2016). This increase in minimum frequency along urban gradient but not with increase in noise level is explained by trade-off adjustment of song frequency to noise or reverberation (Dowling et al. 2012). Birds sing at low frequency in forests to optimize their song in more frequency absorbing environment (Nemeth and Brumm 2009). High frequency has better signal transmission in urban areas than forested ones (Boncoraglio and Saino 2007; Slabbekoorn et al. 2012). Vermilion flycatchers do not alter their song pitch (or song minimum, maximum, or peak frequencies) in response to background noise, even when taking into account long-term adaptations through natural or sexual selection (Brumm and Slabbekoorn 2005; Ríos-Chelén et al. 2013). Another reason for not significantly increasing minimum frequency along noise level may be due to the reason than 'vocal adaptation' may still be in the early stages of evolution (Lowry et al. 2019). Similarly, species with song minimum frequency having more than 1800 Hz have no correlation between noise and increase in minimum frequency (Dowling et al. 2012; Grace and Anderson 2015). For example, vermilion flycatcher has minimum frequency of 2.9kHz and maximum frequency of 6.1kHz, which is unmasked by the noise (Ríos-Chelén et al. 2013). Since, OMR has greater than 1800 Hz minimum frequency, there may be no impact of increase in noise in minimum frequency of the song.

Similar to our findings, in urban areas, the maximum frequency increased than in rural like in blackbird (higher than in forests) (Nemeth and Brumm 2009) and European blackbirds (*Turdus merula*) (Mendes et al. 2011). This may be due to the higher levels of song frequencies in urban sites were due to increased level of anthropogenic low-frequency noise as suggested for great tits (Slabbekoorn and Peet 2003) but that was not in our case as there was no correlation between maximum frequency and noise. The reasons for higher maximum frequency in our study may be due to higher level of arousal in urban areas caused due to higher bird density (Mendes et al. 2011; Nemeth and Brumm 2009, 2010; Slabbekoorn 2013) such as in great tits (Hamao et al. 2011). Also, the maximum frequency did not increase with increase in noise. As contrary to our study, Wolfenden et al. (2019) found the increase of maximum frequency of songs with noise levels in wild chiffchaffs of Manchester Airport, UK. This may be because birds modify their songs only in the bandwidth that have been masked by anthropogenic noise (Mendes et al. 2011; Slabbekoorn and den Boer-Visser 2006) and mean maximum frequency of OMR was above 5kHz which was higher than traffic noises.

The frequency range of OMR in our study was not correlated with noise and urban sites. Similar results was obtained in Tūī birds where the bandwidth did not increase with noise (Ludbrook 2015). Contrary to our findings, the frequency range in urban areas were narrower and in rural areas were wider in songs on Eastern bluebirds (Kight and Swaddle 2015).

There was no any relation between noise level and urban structure with the length of the song similar with the study in OMR (Zhan et al. 2021), European blackbirds (*Turdus merula*) (Mendes et al. 2011) and in silvereyes (Potvin et al. 2011), with urban sites in dark-eyed juncos (*Junco hyemalis*) (Slabbekoorn et al. 2006), house finches (Bermúdez-

Cuamatzin et al. 2011) and in blackbirds (Nemeth and Brumm 2009). In contrary to our findings, the length of the song increased with increase in noise level in vermilion flycatchers (*Pyrocephalus rubinus*) by increasing more number of elements in their songs (Ríos-Chelén et al. 2013). In opposite with our findings, OMR songs in urban sites were longer than rural ones (Hill et al. 2018). Urbanization alone may not be the factor for the increase in song length rather other factors such as density may contribute in song variation (Hill et al. 2018). For example, Northern cardinals (*Cardinalis cardinalis*) sing longer and faster songs in presence of larger conspecific densities (Narango and Rodewald 2016).

As suggested by Nemeth and Brumm (2009) in blackbirds, the song interval decreased in nonsignificant trend from rural to urban areas due to higher level of arousal in urban areas. Also, no correlation was obtained between noise level and urban habitat with interval between the notes in European blackbirds (Mendes et al. 2011). In contrary, the song interval of OMR raised from rural to urban to maximize the efficiency of sound transmission and reduce sound degradation caused by sound reflective buildings, that subsequently give rise to longer songs in urban areas (Hill et al. 2018). And this increase in length makes the bird easily heard by conspecifics (Hill et al. 2018).

There was no correlation between anthropogenic noise and number of elements in songs of the OMR as suggested by Wood and Yezerinac (2006) in song sparrows, (Bermúdez-Cuamatzin et al. 2011) in house finches. But increase in noise significantly decreased the number of elements of songs of red-winged blackbirds (Ríos-Chelén et al. 2015). The urban areas are more open than the forested ones so the great tits used the shorter songs with smaller elements at faster rate for better long-distance transmission (Slabbekoorn and den Boer-Visser 2006).

5.3 Shift in minimum frequency of calls with increase in noise level but not in songs

Our results were similar to the study done by LaZerte et al. (2017) where mountain chickadees increased the minimum frequency of *chick-a-dee* calls when exposed to experimental noise but not the frequency of songs. This maybe because calls are more vulnerable to masking and degraded by anthropogenic noise than the songs (LaZerte et al. 2017) so, to overcome this effect, calls are of higher frequency than songs. Another reason could be the cost for the vocal adjustment (LaZerte et al. 2017) as costs for changing frequency may be higher than that of calls since songs are more complex than calls.

Similarly, calls are of innate whereas songs are learned so songs may need long-term adaptation for shifting its frequency.

5.4 Effects of environmental factors on song parameters

Analysis of LMMs and GLMM showed that various single as well as interactions between the predictor variables (anthropogenic noise level, temperature and habitat type) had effects on the song parameters of the OMR. The minimum frequency of the song decreased with increase in temperature and increase in interaction of temperature and anthropogenic noise. Maximum frequency decreased with increase in temperature and increase in interaction of temperature and anthropogenic noise. Similar results were obtained in OMR in which the increase in humidity along with interaction of noise and temperature decreased the maximum frequency of the song (Hanafi et al. 2019). But there was no any significant relationship between variables with the length of the song. But contrary to it, the length of the song reduced with higher temperature and noise (Hanafi et al. 2019). The song interval and number of elements increased with the noise level. This was similar to the study done by Hanafi et al. (2019) but contrast to the findings of Hill et al. (2018). This indicated that the OMR can adapt their song in different environmental factors by altering the frequency of their songs (Hanafi et al. 2019).

6 CONCLUSION AND RECOMMENDATION

6.1 Conclusion

The minimum frequency of submissive calls of OMR was positively correlated with noise level along the urbanization gradient of Kathmandu Valley. Similarly, there was negative correlation between noise level and number of elements in the submissive call. Likewise, the minimum frequency increased from rural to urban and number of elements decreased from rural to urban significantly. However, in case of songs, only maximum frequency had significant difference along urban habitat and minimum frequency showed the increase in trend along the urban gradient and no any relationship was observed with song parameters and noise level. This may be due more vulnerability of calls to be masked by noise than for songs, costs of vocal adjustment and long-term adaptation for songs.

6.2 Recommendation

Better urbanization policies and strategies should be carried out in Kathmandu Valley as it exceeds the recommended noise levels. Further, vegetation structure should be increased in urban areas to reduce the impacts of noise as vegetation acts as the sound absorbing materials.

7 REFERENCES

Bakrania, S. 2015. Urbanisation and urban growth in Nepal. GSDRC University of Birmingham, Birmingham, UK.

Bermúdez-Cuamatzin, E., Ríos-Chelén, A. A., Gil, D. and Garcia, C. M. 2011. Experimental evidence for real-time song frequency shift in response to urban noise in a passerine bird. Biology Letters **7**(1):36–38. https://doi.org/10.1098/rsbl.2010.0437

Blair, R. 2004. The effects of urban sprawl on birds at multiple levels of biological organization. Ecology and Society **9**(5):2. http://www.ecologyandsociety.org/vol9/iss5/art2/

Boncoraglio, G. and Saino, N. 2007. Habitat structure and the evolution of bird song: a meta-analysis of the evidence for the acoustic adaptation hypothesis. Functional Ecology **21**(1):134–142. https://doi.org/10.1111/j.1365-2435.2006.01207.x

Brumm, H. 2004. The impact of environmental noise on song amplitude in a territorial bird. Journal of Animal Ecology **73**(3):434–440. https://doi.org/10.1111/j.0021-8790.2004.00814.x

Brumm, H. and Slabbekoorn, H. 2005. Acoustic communication in noise. In Advances in the Study of Behavior, pp. 151–209. Elsevier. https://doi.org/10.1016/S0065-3454(05)35004-2

Brumm, H. and Slater, P. J. B. 2006a. Ambient noise, motor fatigue, and serial redundancy in chaffinch song. Behavioral Ecology and Sociobiology **60**(4):475–481. https://doi.org/10.1007/s00265-006-0188-y

Brumm, H. and Slater, P. J. B. 2006b. Animals can vary signal amplitude with receiver distance: evidence from zebra finch song. Animal Behaviour **72**(3):699–705. https://doi.org/10.1016/j.anbehav.2006.01.020

Brumm, H. and Zollinger, S. A. 2013. Avian vocal production in noise. In H. Brumm (Ed.), Animal Communication and Noise, Vol. 2, pp. 187–227. Springer Berlin Heidelberg. https://doi.org/10.1007/978-3-642-41494-7_7

Catchpole, C. K. and Slater, P. J. B. 2008. Bird song biological themes and variations. (second edition). Cambridge University Press.

Climate. 2021. Kathmandu weather and climate. https://www.tripreport.com/cities/kathmandu/climate. Accessed on 4 May 2023.

Cynx, J., Lewis, R., Tavel, B. and Tse, H. 1998. Amplitude regulation of vocalizations in noise by a songbird, *Taeniopygia guttata*. Animal Behaviour **56**(1):107–113. https://doi.org/10.1006/anbe.1998.0746

Danmek, A. and Sitasuwan, N. 2017. Persistence and alteration of the song structure of the Oriental Magpie Robin (*Copsychus saularis*) in some areas of Northern Thailand. Chiang Mai Journal of Science **44**(2):478–486.

Davidson, B. M., Antonova, G., Dlott, H., Barber, J. R. and Francis, C. D. 2017. Natural and anthropogenic sounds reduce song performance: insights from two emberizid species. Behavioral Ecology **28**(4):974–982. https://doi.org/10.1093/beheco/arx036

Dearborn, D. C. and Kark, S. 2010. Motivations for conserving urban biodiversity. Conservation Biology **24**(2):432–440. https://doi.org/10.1111/j.1523-1739.2009.01328.x

Dowling, J. L., Luther, D. A. and Marra, P. P. 2012. Comparative effects of urban development and anthropogenic noise on bird songs. Behavioral Ecology **23**(1): 201–209. https://doi.org/10.1093/beheco/arr176

Dunmak, A. and Sitasuwan, N. 2007. Song dialect of Oriental Magpie-robin (*Copsychus saularis*) in Northern Thailand. The Natural History Journal of Chulalongkorn University **7**(2):145–153.

Francis, C. D., Ortega, C. P. and Cruz, A. 2011a. Vocal frequency change reflects different responses to anthropogenic noise in two suboscine tyrant flycatchers. Proceedings of the Royal Society B: Biological Sciences **278**(1714):2025–2031. https://doi.org/10.1098/rspb.2010.1847

Francis, C. D., Ortega, C. P. and Cruz, A. 2011b. Different behavioural responses to anthropogenic noise by two closely related passerine birds. Biology Letters **7**(6):850–852. https://doi.org/10.1098/rsbl.2011.0359

Grace, M. K. and Anderson, R. C. 2015. No frequency shift in the “D” notes of Carolina chickadee calls in response to traffic noise. Behavioral Ecology and Sociobiology **69**(2):253–263. https://doi.org/10.1007/s00265-014-1838-0

Halfwerk, W. and Slabbekoorn, H. 2009. A behavioural mechanism explaining noise-dependent frequency use in urban birdsong. Animal Behaviour **78**(6):1301–1307. https://doi.org/10.1016/j.anbehav.2009.09.015

Hamao, S., Watanabe, M. and Mori, Y. 2011. Urban noise and male density affect songs in the great tit *Parus major*. Ethology Ecology & Evolution **23**(2):111–119. https://doi.org/10.1080/03949370.2011.554881

Hanafi, S., Chong, L. P., Maruthaveeran, S. and Yeong, K. L. 2019. Vocal response of Oriental Magpie Robin (*Copsychus saularis*) to urban environmental factors in Peninsular Malaysia. Sains Malaysiana **48**(10):2061–2069. https://doi.org/10.17576/jsm-2019-4810-01

Hanna, D., Blouin-Demers, G., Wilson, D. R. and Mennill, D. J. 2011. Anthropogenic noise affects song structure in red-winged blackbirds (*Agelaius phoeniceus*). Journal of Experimental Biology **214**(21): 3549–3556. https://doi.org/10.1242/jeb.060194

Hill, S. D., Aryal, A., Pawley, M. D. M. and Ji, W. 2018. So much for the city: Urban-rural song variation in a widespread Asiatic songbird. Integrative Zoology **13**(2):194–205. https://doi.org/10.1111/1749-4877.12284

Hu, Y. and Cardoso, G. C. 2010. Which birds adjust the frequency of vocalizations in urban noise? Animal Behaviour **79**(4):863–867. https://doi.org/10.1016/j.anbehav.2009.12.036

Job, J. R., Kohler, S. L. and Gill, S. A. 2016. Song adjustments by an open habitat bird to anthropogenic noise, urban structure, and vegetation. Behavioral Ecology **27**(6):1734–1744. https://doi.org/10.1093/beheco/arw105

Karna, J., Subba, B. R., Bhattacharya, H. and Chhetry, D. T. 2020. Singing patterns of the Oriental Magpie Robin *Copsychus saularis* Linnaeus Our Nature **18**(1):16–27. https://doi.org/10.3126/on.v18i1.34238

Kight, C. R. and Swaddle, J. P. 2015. Eastern bluebirds alter their song in response to anthropogenic changes in the acoustic environment. Integrative and Comparative Biology **55**:418–431. https://doi.org/10.1093/icb/icv070

Koli, V. K. 2014. Morning territorial calls of male oriental magpie robin (*Copsychus saularis*). TAPROBANICA: The Journal of Asian Biodiversity **6**(1):60–62. https://doi.org/10.4038/tapro.v6i1.7092

Laiolo, P. 2011. The rufous-collared sparrow *Zonotrichia capensis* utters higher frequency songs in urban habitats. Revista Catalana d'Ornitologia **27**:25–30.

LaZerte, S. E., Otter, K. A. and Slabbekoorn, H. 2017. Mountain chickadees adjust songs, calls and chorus composition with increasing ambient and experimental anthropogenic noise. Urban Ecosystems **20**(5):989–1000. https://doi.org/10.1007/s11252-017-0652-7

Leonard, M. L. and Horn, A. G. 2008. Does ambient noise affect growth and begging call structure in nestling birds? Behavioral Ecology **19**(3):502–507. https://doi.org/10.1093/beheco/arm161

Lohr, B., Wright, T. F. and Dooling, R. J. 2003. Detection and discrimination of natural calls in masking noise by birds: estimating the active space of a signal. Animal Behaviour **65**(4):763–777. https://doi.org/10.1006/anbe.2003.2093

Lowry, H., Lill, A. and Wong, B. 2019. Do the calls of a bird, the noisy miner (*Manorina melanocephala*), need adjustment for efficient communication in urban anthropogenic noise? Animals **9**(3):118. https://doi.org/10.3390/ani9030118

Ludbrook, M. R. 2015. Effects of urban noise on vocalisations of Tūī (*Prosthemadera novaeseelandiae*). Master's Thesis. Massey University.

Mansor, Z. and Gawin, D. F. A. 2020. Call types of the Oriental Magpie Robin (*Copsychus saularis*) in suburban areas in Kota Samarahan, Sarawak. Borneo Journal of Resource Science and Technology **10**(1):37–44. https://doi.org/10.33736/bjrst.257.2011

Marler, P. 2004. Bird calls: their potential for behavioral neurobiology. Annals of the New York Academy of Sciences **1016**(1):31–44. https://doi.org/10.1196/annals.1298.034

Mendes, S., Colino-Rabanal, V. J. and Peris, S. J. 2011. Bird song variations along an urban gradient: the case of the European blackbird (*Turdus merula*). Landscape and Urban Planning **99**(1):51–57. https://doi.org/10.1016/j.landurbplan.2010.08.013

Mockford, E. J. and Marshall, R. C. 2009. Effects of urban noise on song and response behaviour in great tits. Proceedings of the Royal Society B: Biological Sciences **276**(1669):2979–2985. https://doi.org/10.1098/rspb.2009.0586

Narango, D. L. and Rodewald, A. D. 2016. Urban-associated drivers of song variation along a rural–urban gradient. Behavioral Ecology **27**(2):608–616. https://doi.org/10.1093/beheco/arv197

Nemeth, E. and Brumm, H. 2009. Blackbirds sing higher-pitched songs in cities: adaptation to habitat acoustics or side-effect of urbanization? Animal Behaviour **78**(3):637–641. https://doi.org/10.1016/j.anbehav.2009.06.016

Nemeth, E. and Brumm, H. 2010. Birds and anthropogenic noise: are urban songs adaptive? The American Naturalist **176**(4):465–475. https://doi.org/10.1086/656275

Nemeth, E., Pieretti, N., Zollinger, S. A., Geberzahn, N., Partecke, J. and Brumm, H. 2013. Bird song and anthropogenic noise: vocal constraints may explain why birds sing higher-frequency songs in cities. Proceedings of the Royal Society B: Biological Sciences **280**(1754):20122798. https://doi.org/10.1098/rspb.2012.2798

Potvin, D. A. and Mulder, R. A. 2013. Immediate, independent adjustment of call pitch and amplitude in response to varying background noise by silvereyes (*Zosterops lateralis*). Behavioral Ecology **24**(6):1363–1368. https://doi.org/10.1093/beheco/art075

Potvin, D. A., Parris, K. M. and Mulder, R. A. 2011. Geographically pervasive effects of urban noise on frequency and syllable rate of songs and calls in silvereyes (*Zosterops lateralis*). Proceedings of the Royal Society B: Biological Sciences **278**(1717): 2464–2469. https://doi.org/10.1098/rspb.2010.2296

Ríos-Chelén, A. A., Lee, G. C. and Patricelli, G. L. 2015. Anthropogenic noise is associated with changes in acoustic but not visual signals in red-winged blackbirds. Behavioral Ecology and Sociobiology **69**(7):1139–1151. https://doi.org/10.1007/s00265-015-1928-7

Ríos-Chelén, A. A., Lee, G. C. and Patricelli, G. L. 2016. A comparison between two ways to measure minimum frequency and an experimental test of vocal plasticity in red-winged blackbirds in response to noise. Behaviour **153**(12):1445–1472. https://doi.org/10.1163/1568539X-00003390

Ríos-Chelén, A. A., Quirós-Guerrero, E., Gil, D. and Macías Garcia, C. 2013. Dealing with urban noise: Vermilion flycatchers sing longer songs in noisier territories. Behavioral Ecology and Sociobiology **67**(1):145–152. https://doi.org/10.1007/s00265-012-1434-0

Ripmeester, E. A. P., Kok, J. S., van Rijssel, J. C. and Slabbekoorn, H. 2010. Habitat-related birdsong divergence: a multi-level study on the influence of territory density and ambient noise in European blackbirds. Behavioral Ecology and Sociobiology **64**(3):409–418. https://doi.org/10.1007/s00265-009-0857-8

Seger-Fullam, K. D., Rodewald, A. D. and Soha, J. A. 2011. Urban noise predicts song frequency in Northern Cardinals and American Robins. Bioacoustics **20**(3):267–276. https://doi.org/10.1080/09524622.2011.9753650

Seress, G. and Liker, A. 2015. Habitat urbanization and its effects on birds. Acta Zoologica Academiae Scientiarum Hungaricae **61**(4):373–408. https://doi.org/10.17109/AZH.61.4.373.2015

Shannon, G., McKenna, M. F., Angeloni, L. M., Crooks, K. R., Fristrup, K. M. and Wittemyer, G. 2016. A synthesis of two decades of research documenting the effects of noise on wildlife: Effects of anthropogenic noise on wildlife. Biological Reviews **91**(4):982–1005. https://doi.org/10.1111/brv.12207

Singh, A., Bhatt, D. and Sethi, V. K. 2019. Singing behaviour of the oriental magpie robin (*Copsychus saularis*). Journal of Ornithology **160:**185–193. https://doi.org/10.1007/s10336-018-1595-3

Singh, R., Pant, D. R., and Baniya, R. 2022. Traffic noise pollution assessment along the Ring Road of Kathmandu Valley, Nepal. Current Science **123**(5):677–686. https://doi.org/10.18520/cs/v123/i5/677-686

Slabbekoorn, H. 2013. Songs of the city: noise-dependent spectral plasticity in the acoustic phenotype of urban birds. Animal Behaviour **85**(5):1089–1099. https://doi.org/10.1016/j.anbehav.2013.01.021

Slabbekoorn, H. and den Boer-Visser, A. 2006. Cities change the songs of birds. Current Biology **16**(23):2326–2331. https://doi.org/10.1016/j.cub.2006.10.008

Slabbekoorn, H. and Peet, M. 2003. Birds sing at a higher pitch in urban noise. Nature **424**(6946): 267–267. https://doi.org/10.1038/424267a

Slabbekoorn, H., Yang, X.-J. and Halfwerk, W. 2012. Birds and anthropogenic noise: singing higher may matter: (a comment on Nemeth and Brumm, “Birds and anthropogenic noise: are urban songs adaptive?”). The American Naturalist **180**(1):142–145. https://doi.org/10.1086/665991

Slabbekoorn, H., Yeh, P. and Hunt, K. 2006. Sound transmission and song divergence: a comparison of urban and forest acoustics. The Condor **109:**67–78. https://doi.org/10.1093/condor/109.1.67

Timsina, N. P., Shrestha, A., Poudel, D. P., and Upadhyaya, R. 2020. Trend of urban growth in Nepal with a focus in Kathmandu Valley: A review of processes and drivers of change. University of Edinburgh. https://era.ed.ac.uk/handle/1842/37436

Verzijden, M. N., Ripmeester, E. A. P., Ohms, V. R., Snelderwaard, P. and Slabbekoorn, H. 2010. Immediate spectral flexibility in singing chiffchaffs during experimental exposure to highway noise. Journal of Experimental Biology **213**(15):2575–2581. https://doi.org/10.1242/jeb.038299

Walters, M. J., Guralnick, R. P., Kleist, N. J. and Robinson, S. K. 2019. Urban background noise affects breeding song frequency and syllable-type composition in the Northern Mockingbird. The Condor **121**(2):1–13. https://doi.org/10.1093/condor/duz002

Wanniarachchi, S. and Wijesundara, C. S. 2016. The repertoire and structure of vocalizations of the southern Magpie Robin (*Copsychus saularis ceylonensis*) in the Kandy region, Sri Lanka. Ceylon Journal of Science **45**(3):47–54. https://doi.org/10.4038/cjs.v45i3.7400

Warren, P. S., Katti, M., Ermann, M. and Brazel, A. 2006. Urban bioacoustics: it's not just noise. Animal Behaviour **71**(3):491–502. https://doi.org/10.1016/j.anbehav.2005.07.014

Wolfenden, A. D., Slabbekoorn, H., Kluk, K. and Kort, S. R. 2019. Aircraft sound exposure leads to song frequency decline and elevated aggression in wild chiffchaffs. Journal of Animal Ecology **88**(11):1720–1731. https://doi.org/10.1111/1365-2656.13059

Wood, W. E. and Yezerinac, S. M. 2006. Song sparrow (*Melospiza melodia*) song varies with urban noise. The Auk **123**(3):650–659. https://doi.org/10.1093/auk/123.3.650

Zhan, X., Liang, D., Lin, X., Li, L., Wei, C. and Liu, Y. 2021. Background noise but not urbanization level impacted song frequencies in an urban songbird in the Pearl River Delta, Southern China. Global Ecology and Conservation **28**:e01695. https://doi.org/10.1016/j.gecco.2021.e01695

8 PHOTOGRAPHS

Photograph 1. Female OMR (left) and male OMR (right) photographed during field of post-breeding season

Photograph 2. Recording the calls of OMR using shotgun microphone and recorder

Photograph 3. Male OMR photographed during field visits of breeding season

Photograph 4. Measuring distance between recorder and OMR through range finder