NESTING AND BREEDING BEHAVIOUR OF BLACK DRONGO (*Dicrurus macrocercus*) AND INDIAN ROBIN (*Saxicoloides fulicata*) IN RURAL AREAS OF LUDHIANA DISTRICT

Thesis

Submitted to the Punjab Agricultural University
in partial fulfillment of the requirements
for the degree of

MASTER OF SCIENCE

in

ZOOLOGY
(Minor Subject: Biochemistry)

By

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(L-2016-BS-309-M)

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CERTIFICATE - I

This is to certify that the thesis entitled "**NESTING AND BREEDING BEHAVIOUR OF BLACK DRONGO (*Dicrurus macrocercus*) AND INDIAN ROBIN (*Saxicoloides fulicata*) IN RURAL AREAS OF LUDHIANA DISTRICT"** submitted for the degree of **Master of Science** in the subject of **Zoology** (Minor subject: **Biochemistry**) of the Punjab Agricultural University, Ludhiana, is a bonafide research work carried out by **Ms. Gursimran Kaur** (**L-2016-BS-309-M**) under my supervision and that no part of this thesis has been submitted for any other degree.

The assistance and help received during the course of investigation have been fully acknowledged.

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CERTIFICATE – II

This is to certify that the thesis entitled, **"NESTING AND BREEDING BEHAVIOUR OF BLACK DRONGO (*Dicrurus macrocercus*) AND INDIAN ROBIN (*Saxicoloides fulicata*) IN RURAL AREAS OF LUDHIANA DISTRICT"** submitted by **Ms. Gursimran Kaur** (Admn. No. **L-2016-BS-309-M**) to the Punjab Agricultural University, Ludhiana, in partial fulfillment of the requirements for the degree of **M.Sc.,** in the subject of **Zoology** (Minor subject: **Biochemistry**) has been approved by the Student's Advisory Committee after an oral examination on the same.

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Date: **(Gursimran Kaur)**

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ABSTRACT

The present study was designed to study the nesting and breeding behaviour of Black Drongo (*Dicrurus macrocercus*) and Indian Robin (*Saxicoloides fulicata*) in rural areas of Ludhiana district. The study was carried out for twelve months from January to December 2017 in the campus of Punjab Agricultural University (PAU), Ludhiana i.e. location A, village Baranhara (district Ludhiana) i.e. location B and village Ladiankhurd (district Ludhiana) i.e. location C. Common Babbler (5.65%) was the most abundant species in the bird community followed by the Common Myna (4.87%), Black Drongo (4.73%), Indian Peafowl (4.47%) and Blue Rock Pigeon (4.04%) at location A. House Crow was the most abundant species at location B. Blue Rock Pigeon (6.44%) was the most abundant species at location C. Nine nesting sites were observed in PAU campus (transects IA,IIA,IIIA,IVA and VA) out of which two were located on Indian Mahogany, two on Sukh Chain, one on Neem and four on Dhek. Five nesting sites were observed in the village Baranhara (transect IB and IIB) out of which two were located on Neem and three on Dhek tree. A total of four nesting sites were observed at village Ladiankhurd (transect IC and IIC) out of which two were located on Poplar and two on Dhek. Clutch size (3-4 eggs), incubation period (13±0.34 days), hatching and fledging success of Black Drongo were noted. It was observed that albumen, yolk and shell weights of Black Drongo ranged from 1.27 gm to 2.81 gm, 2.58 gm to 2.95 gm and 0.28 gm to 0.52 gm, respectively. The CaCO3 weight and proportion of eggs of Black Drongo ranged from 0.16 gm to 0.38 gm and 51.35% to 89.29% respectively. Six nesting sites of Indian Robin were observed in PAU campus out of which four ground nests were located in the undergrowth of hedges near roadside (transect IA, IIA and IIIA) and two ground nests were found in wild bushes (transect IVA). Five nesting sites were observed in the village Baranhara (transect IB and IIB) on the terrace of the underconstructed buildings. A total of six nesting sites were observed at village Ladiankhurd (transect IB and IIB) in the crevices of underconstructed buildings. The average incubation period of eggs of Indian Robin was 11.5±0.22 days. Albumen, yolk and egg shell weights of Indian Robin ranged from 1.35 gm to 1.60 gm, 3.27 gm to 3.79 gm and 0.39 gm to 0.51 gm respectively. The shell thickness ranged from 0.19 mm to 0.34 mm. The $CaCO_3$ weight and proportion were ranged from 0.27 gm to 0.41 gm and 61.70% to 81.40% respectively.

Keywords: Black Drongo, Indian Robin, incubation period, clutch size, egg shell

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Signature of Major Advisor **Signature of the student**

ਖੋਜ ਦਾ ਸਿਰਲੇਖ	:	ਲੁਧਿਆਣੇ ਜ਼ਿਲ੍ਹੇ ਦੇ ਦਿਹਾਤੀ ਖੇਤਰਾਂ ਵਿੱਚ ਕਾਲ ਕੜਛੀ (*ਡਾਇਕਰੁਰਸ ਸੈਕਰੋਕ੍ਰੱਕੱਸ*) ਅਤੇ ਇੰਡੀਅਨ ਰੌਬਿਨ (*ਸੈਕਸਿਕੋਲਾਈਡ ਫੁਲੀਕੇਟਾ*) ਦੇ ਨਿਘਾਰ ਅਤੇ ਪ੍ਰਜਨਨ ਵਿਵਹਾਰ
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ਸਾਰ-ਅੰਸ਼

ਵਰਤਮਾਨ ਅਧਿਐਨ ਨੂੰ ਲੁਧਿਆਣਾ ਜ਼ਿਲ੍ਹੇ ਦੇ ਪੇਂਡੂ ਖੇਤਰਾਂ ਵਿੱਚ ਕਾਲ ਕੜਛੀ (*ਡਾਇਕਰੁਰਸ ਸੈਕਰੋਕ੍ਰੱਕੱਸ*) ਅਤੇ ਇੰਡੀਅਨ ਰੌਬਿਨ (*ਸੈਕਸਿਕੋਲਾਈਡ ਫੁਲੀਕੇਟਾ*) ਦੇ ਆਲ੍ਹਣੇ ਅਤੇ ਪ੍ਰਜਨਨ ਦੇ ਵਿਵਹਾਰ ਦਾ ਅਧਿਐਨ ਕਰਨ ਲਈ ਤਿਆਰ ਕੀਤਾ ਗਿਆ ਸੀ। ਇਹ ਅਧਿਐਨ ਜਨਵਰੀ ਤੋਂ ਦਸੰਬਰ 2017 ਤੱਕ ਪੰਜਾਬ ਖੇਤੀਬਾੜੀ ਯੂਨੀਵਰਸਿਟੀ (ਲੁਧਿਆਣਾ) ਦੇ ਕੈਂਪਸ, ਲੁਧਿਆਣਾ ਦੇ ਸਥਾਨ ਏ, ਪਿੰਡ ਬਾਰਨਹਾੜਾ (ਜ਼ਿਲ੍ਹਾ ਲੁਧਿਆਣਾ) ਜਿਵੇਂ ਕਿ ਸਥਾਨ ਬੀ ਅਤੇ ਪਿੰਡ ਲਾਦੀਆਂ ਖੁਰਦ (ਜ਼ਿਲ੍ਹਾ ਲੁਧਿਆਣਾ) ਅਰਥਾਤ ਸਥਾਨ ਸੀ। ਆਮ ਬੈਬਲਰ (5.65%) ਪੰਛੀ ਭਾਈਚਾਰੇ ਦੀ ਸਭ ਤੋਂ ਭਰਪੂਰ ਪ੍ਰਜਾਤੀ ਸੀ ਜਿਸ ਦੇ ਬਾਅਦ ਕਾਮਨ ਮਾਈਨਾ (4.87%), ਕਾਲ ਕੜਛੀ (4.73%), ਇੰਡੀਅਨ ਪੀਓਫੋਨ (4.47%) ਅਤੇ ਬਲੂ ਰੌਕ ਪੀਜਨ (4.04%) ਸਥਾਨ ਏ। ਹਾਊਸ ਸਥਾਨ 'ਤੇ ਸਭ ਤੋਂ ਵੱਧ ਪ੍ਰਚੱਲਤ ਪ੍ਰਜਾਤੀ ਬੂਰਾਈ ਸੀ। ਬਲੂ ਰੌਕ ਪੋਜੋਨ (6.44%) ਸਥਾਨ ਤੇ ਸਭ ਤੋਂ ਵੱਧ ਪ੍ਰਮੁੱਖ ਜਾਤੀਆਂ ਸਨ। ਪਈ.ਏ.ਯੂ. ਕੈਂਪਸ (ਟ੍ਰਾਂਜ਼ੈਟ 1-ਏ, 2-ਏ, 3-ਏ, 4-ਏ ਅਤੇ 5-ਏ) ਜਿਨ੍ਹਾਂ ਵਿੱਚੋਂ ਦੋ ਇੰਡੀਅਨ ਮਹੈਗਨੀ ਤੇ ਦੋ ਸੁਖਚੈਨ ਇੱਕ ਨੀਮ ਅਤੇ ਚਾਰ ਡੇਕ ਤੇ ਸਥਿਤ ਸਨ। ਬਾਰਨਹਾੜਾ ਪਿੰਡ (ਟ੍ਰਾਂਜ਼ੈਟ -1ਬੀ ਅਤੇ 2-ਬੀ) ਵਿੱਚ ਪੰਜ ਘੇੜ ਪਾਉਣ ਵਾਲੀਆਂ ਥਾਵਾਂ ਦਾ ਨਿਰਖੀਣ ਕੀਤਾ ਗਿਆ, ਜਿਨ੍ਹਾਂ ਵਿੱਚੋਂ ਦੋ ਨੀਮ 'ਤੇ ਅਤੇ ਤਿੰਨ ਤਖ਼ਤ ਤੇ ਸਥਿਤ ਸਨ। ਪਿੰਡ ਲਾਦੀਆਂ ਖੁਰਦ (ਟ੍ਰਾਂਜ਼ੈਟ 1-ਸੀ ਅਤੇ 2-ਸੀ) ਵਿੱਚ ਆਲ੍ਹਣੇ ਦੀਆਂ ਸਾਰੀਆਂ ਥਾਵਾਂ ਦਿਖਾਈਆਂ ਗਈਆਂ ਸਨ ਜਿਨ੍ਹਾਂ ਵਿੱਚੋਂ ਦੋ ਪੋਪਲਰ ਅਤੇ ਦੋ ਡੇਕ ਤੇ ਸਥਿਤ ਸਨ। ਕੱਚ ਦਾ ਆਕਾਰ (3-4 ਅੰਡੇ), ਪ੍ਰਫੁੱਲਤ (13±0.34 ਦਿਨ), ਹੈਚਿੰਗ ਅਤੇ ਕਾਲ ਕੜਛੀ ਦਾ ਸਫਲਤਾਪੂਰਵਕ ਸਫਲਤਾ ਹੈ। ਇਹ ਦੇਖਿਆ ਗਿਆ ਸੀ ਕਿ ਕਾਲ ਕੜਛੀ ਸ਼ਬਦਾਵਲੀ, ਯੋਕ ਅਤੇ ਸ਼ੈੱਲ ਭਾਰ ਕ੍ਰਮਵਾਰ 1.27 ਗ੍ਰਾਮ ਤੋਂ 2.81 ਗ੍ਰਾਮ, 2.58 ਗ੍ਰਾਮ ਤੋਂ 2.95 ਗ੍ਰਾਮ ਅਤੇ 0.28 ਗ੍ਰਾਮ ਤੋਂ 0.52 ਗ੍ਰਾਮ ਸਨ। ਕੈਕਵੋ 3 ਵਜ਼ਨ ਅਤੇ ਕਾਲ ਕੜਛੀ ਦੇ ਅੰਡਿਆਂ ਦਾ ਅਨੁਪਾਤ ਕ੍ਰਮਵਾਰ 0.16 ਗ੍ਰਾਮ ਤੋਂ 0.38 ਗ੍ਰਾਮ ਅਤੇ 51.35% ਤੋਂ 89.29% ਸੀ। ਪੀ.ਏ.ਯੂ. ਦੇ ਕੈਂਪਸ ਵਿੱਚ ਛੇ ਘੇਰਾਬੰਦੀ ਸਥਾਨਾਂ ਨੂੰ ਦੇਖਿਆ ਗਿਆ, ਜਿਨ੍ਹਾਂ ਵਿੱਚੋਂ ਚਾਰ ਜ਼ਮੀਨ ਦੇ ਆਲੇ ਸੜਕ ਦੇ ਨੇੜੇ (ਟ੍ਰਾਂਜ਼ੈਟ 1-ਏ, 2-ਏ ਅਤੇ 3-ਏ) ਦੇ ਨੇੜੇ ਹੈਜਿਸਾਂ ਵਿੱਚ ਸਥਿਤਨ ਸਨ ਅਤੇ ਦੋ ਜ਼ਮੀਨੀ ਆਲ੍ਹਣੇ ਜੰਗਲੀ ਬੂਟੀਆਂ (ਟ੍ਰਾਂਜ਼ੈਟ 4-ਏ) ਵਿੱਚ ਪਾਏ ਗਏ ਸਨ। ਪਿੰਡ ਬਾਰਨਹਾੜਾ (ਟ੍ਰਾਂਜ਼ੈਟ 1-ਬੀ ਅਤੇ 2-ਬੀ) ਵਿੱਚ ਪੰਜ ਘੇੜ ਪੁਆਇੰਟਾਂ ਨੂੰ ਅੰਡਰਰਾਸ਼ਟ ਕੀਤੀਆਂ ਇਮਾਰਤਾਂ ਦੀ ਛੱਤਰੀ 'ਤੇ ਦੇਖਿਆ ਗਿਆ। ਅੰਡਰਕੰਕ੍ਰਿਤ ਇਮਾਰਤਾਂ ਦੀਆਂ ਘਾਟੀਆਂ ਵਿੱਚ ਪਿੰਡ ਲਾਂਦੀਆਂ ਖੁਰਦ (ਟ੍ਰਾਂਜ਼ੈਟ 1-ਬੀ ਅਤੇ 2-ਬੀ) ਵਿਖੇ ਕੁੱਲ ਛੇ ਆਲ੍ਹਣੇ ਦੀਆਂ ਥਾਵਾਂ ਨੂੰ ਦੇਖਿਆ ਗਿਆ। ਇੰਡੀਅਨ ਰੌਬਿਨ ਦੇ ਅੰਡਿਆਂ ਦਾ ਔਸਤਨ ਪ੍ਰਭਾਵੀ ਸਮਾਂ 11.5±0.22 ਦਿਨ ਸੀ। ਇੰਡੀਅਨ ਰੌਬਿਨ ਦੀ ਐਲਬਮਿਨ, ਯੋਕ ਅਤੇ ਅੰਡੇ ਦੀ ਬੇਸ਼ਕੀਮਤੀ ਵਜ਼ਨ 1.35 ਗ੍ਰਾਮ ਤੋਂ 1.60 ਗ੍ਰਾਮ, 3.27 ਗ੍ਰਾਮ ਤੋਂ 3.79 ਗ੍ਰਾਮ ਅਤੇ 0.39 ਗ੍ਰਾਮ ਤੋਂ 0.51 ਗ੍ਰਾਮ ਹੈ। ਸ਼ੈੱਲ ਮੋਟਾਈ 0.19 ਮਿਲੀਮੀਟਰ ਤੋਂ ਲੈ ਕੇ 0.34 ਮਿਲੀਮੀਟਰ ਤੱਕ ਹੁੰਦੀ ਹੈ। $CaCO_3$ ਦਾ ਭਾਰ ਅਤੇ ਅਨੁਪਾਤ ਕ੍ਰਮਵਾਰ 0.27 ਗ੍ਰਾਮ ਤੋਂ 0.41 ਗ੍ਰਾਮ ਅਤੇ 61.70% ਤੋਂ 81.40% ਤੱਕ ਸੀ ।

ਮੁੱਖ ਸ਼ਬਦ: ਕਾਲ ਕੜਛੀ, ਇੰਡੀਅਨ ਰੌਬਿਨ, ਪ੍ਰਫੁੱਲਤ ਸਮਾਂ, ਕਲੱਚ ਦਾ ਆਕਾਰ, ਅੰਡਾ ਸ਼ੈੱਲ ।

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ਮੁੱਖ ਸਲਾਹਕਾਰ ਦੇ ਹਸਤਾਖਰ **ਵਿੱਦਿਆਰਥੀ ਦੇ ਹਸਤਾਖਰ**

CONTENTS

CHAPTER – I

INTRODUCTION

The abundance of insectivorous birds is closely associated to the vegetation structure and agroecosystem. Conversion of the agroecosystem into another landuse will make these sites unfit for avian insectivores. Intensification of agriculture has resulted to the development of agroecosystem as substantial and highly managed terrestrial ecosystem (Stratford and Robinson 2005). The positive and negative role of the birds as key species in the agroecosystem is well illustrated. Different workers have found that insectivorous birds at higher trophic level are less abundant than that at lower trophic positions which supported that lower density species higher up in the food chain are more vulnerable to environmental changes (Duffy 2003 and Henle *et al* 2004). Mariappan *et al* (2013) had stated that majority of the birds hunt their food from the agricultural field areas. They are good bio-indicators in the agro-ecosystem and a majority of them are insectivorous that check the buildup of insect pest species (Rajashekara and Venkatesha 2014). Avian insectivores are most sensitive to agricultural field disturbances, making them useful as sentinels of agriculture ecosystem change. Maximum threat to birds is due to changes in agricultural patterns, habitat loss and infectious diseases and climate change out of which climate change and habitat loss are the major threats to the present day biodiversity (Powell *et al* 2015).

The insectivorous birds feed on the pest species which keeps a control on its population (Gokhale 1992). The insectivorous birds significantly reduce the number of insects on the plants and eventually increase the fitness of the plants on which they forage (Holmes *et al* 1979 and Lyon *et al* 1983). Birds act as depredators of insects and stand supreme among vertebrates (Patel *et al* 1987). The most important component of agro-ecosystems is constituted by birds and the role of birds in agro-ecosystems is gaining more and more attention (Dhindsa and Saini 1994). The most threatened species of birds include birds of agricultural system which has witnessed a sharp decline in population in the recent decades. Agricultural practices and habitat intensification has been proposed as a major cause for this decline. The reported decrease in the faunal quality of agricultural habitat is mainly due to intensification of agricultural practices such as crop specialization, use of pesticides and elimination of natural and semi-natural habitats. Due to increasing pressure on natural habitat as a result of urbanization and industrialization; farmers have adapted to large-scale monoculture practices. It forces the animals to adapt themselves to the changed habitat or to leave it. Biodiversity has decreased in many areas of the world due to intensive agriculture. Many species of animals, especially birds have started depending directly or indirectly on agricultural fields due to their adaptation to these altered conditions (Ranjit Daniels 1994). The agro-ecosystem is not completely modernised in many developing countries like India.

Birds become important bio-control agents, suppressing the insect pests in situations where the use of pesticides is avoided for low revenue crops like millet, maize (Parasharya *et al* 1994). Granivores, frugivores, insectivores, carnivores, nectarivores and omnivore bird species constitute birds of agricultural areas. The role of birds in the control of insect pests of agricultural areas is of top priority to India (Dhindsa and Saini 1994). Insectivorous birds act as important predators so they need to be encouraged in the agro-ecosystem by use of appropriate management practices (Sivakumaran and Thiyagesan 2003).

Vegetation structure, plant species composition, prey abundance and distribution significantly affected the foraging height selection of insectivorous bird species (Robinson and Holmes 1984). Insectivorous birds constitute a major component of tropical ecosystem (Gomes *et al* 2008). The Black Drongo *Dicrurus macrocercus* is a small passerine insectivorous bird which belongs to the family Dicruridae. It has an entirely black plumage with a distinctive forked tail (Ali *et al* 2010). It uses different modes of feeding to obtain its food (Somasundaram and Vijayan 2008). It is common throughout the Indian subcontinent and a resident breeder of South Asia. They are good bio-indicators in the agro-ecosystem and a majority of them check the buildup of insect pest species (Rajashekara and Venkatesha 2014). Black Drongo being fairly terrestrial perches close to the ground in grasslands and cultivation (Okosodo *et al* 2016).

Foraging ecology of birds helps to determine the community structure and co-existence in a particular habitat. It is useful in knowing the food habits of the species (Mac Nally 1994). McMaster *et al* (1999) mentioned that several aspects of avian biology have been poorly studied for most of the passerine species. Insectivorous birds are generally height generalists that forage on various perch sites at different heights. The nesting period of Black Drongo is from April to August. It builds a flimsy bottomed cup of fine twigs and fibres. It lays 3-5 white eggs with brownish red spots (Ali 2002). Diet is mainly insectivorous and feeds mainly on beetles, grasshopper, bees, bugs and dragonflies (Ali *et al* 2010). Foraging ecology of a species helps in the determination of the economic status of the species and its ecological adaptation to the environment (Anthal and Sahi 2013). The habitat selection of Black Drongo depend upon the availability of perching sites and their heights (Narayana *et al* 2014). Black Drongo is an aggressive bird that plays a significant role in controlling agricultural insect pests (Okosodo *et al* 2016).

Indian Robin is found abundantly in South Asia and inhabits open stony, grassy and scrub forest which are closely associated to human habitation (Ali and Ripley 1998). They exhibit distinct sexual dimorphism with males being black and females mainly brown (Grimmett *et al* 1998). The throat of juvenile birds is mottled but they are much like females. The Indian Robin is another insectivorous, terrestrial bird species and belongs to the Muscicapidae family (Vinaya *et al* 2010). It is generally found in open savannas and

countries. It is found from sea level to 1900 metres of elevation. Nesting season mainly extends from May to July. The nest is well concealed on the ground, made up of a cup of moss, dry grass lined with fur and hair. It lays four eggs that are incubated by female (Ali 2002).

The detailed and reliable information on the breeding activities of Black Drongo and Indian Robin in relation to its habitat is lacking from the rural areas of Punjab. There is need to generate information about their breeding biology so as to find the reasons behind their population abundance. Therefore, keeping in view the above studies and the lack of detailed and systematic information on composition and breeding behaviour of Black Drongo and Indian Robin, it was proposed to carry out detailed analysis of breeding profile with the following objectives.

i. To study the bird abundance in selected villages of Ludhiana and PAU campus.
ii. To study the habitat and breeding biology of Black Drongo and Indian Robin.
iii. To carry out morphometric analysis of the eggs of Black Drongo and Indian Robin

CHAPTER – II

REVIEW OF LITERATURE

The Indian subcontinent constitutes a portion of the vast Oriental biogeographic regions and supports wide biodiversity. The Indian subcontinent contains about 1,300 species out of the more than 9,000 birds found all over world which constitutes about 13% of the world's birds. The Indian subcontinent being rich in avifauna, also boasts of 48 bird families out of the total 75 families found all over the world. Two families occur in the Oriental region namely the Asiatic barbets *Megalaimidae* and Leafbirds *Irenidae*. The remaining families of the birds are found in other biogeographical regions of the world. Many bird groups such as the drongos, laughingthrushes, pitas, pheasants, leafbirds, parrotbills and flower-peckers are also found in the Oriental region which acts as a centre of radiation for their existence (Grimmett *et al* 1998). Colonization of virtual wilderness and the building of sprawling metropolises is a result of rapidly increasing social species of mankind. The Native flora and fauna is under the influence of complex direct and indirect effects of urbanisation. The various ecosystem processes, habitat type, food, competitors, predators and disease gets affected and undergoes a change with the settlement of a bird species. The population biology of bird species in urban areas undergoes significant changes including prominent effects on the structure and composition of bird communities (Marzluff 2001). In developing countries, agricultural land use pattern constitutes an essential driver of biodiversity loss. The future threat to near threatened and globally threatened bird species was found to be the current farming technique (Green *et al* 2005). Habitat destruction and degradation has become one of the greatest threats to the biodiversity (Hamer *et al* 2015).

Maintenance of rich biodiversity in the agro-ecosystems has become an important measure to maintain high abundances of well adapted beneficial species. It is a major step towards ecological sustainability (Duelli 1997). Birds are important and effective organism controlling insect pest in agricultural lands and are closely integrated with farmer's day to day activities. But bird population has been tremendously affected by the extensive application of synthetic fertilizers and chemicals which has resulted in the non availability of its regular prey. Bird richness in an agricultural area is dependent upon the availability of food, nesting and breeding places. Any disturbance in any of these factors led to changes in their number. Different bird species are accommodated by different agricultural habitats. Highest species diversity is found in fallow land (62) followed by wetland (53), cropland (37) and lowest in plantations (31) (Mariappan *et al* 2013).

Oriental Magpie-Robin is a small passerine bird whose breeding behavior has been studied. It usually feeds on insects and invertebrates. It is a tropical song bird that uses naturally occurring tree cavities for making nests (Ali and Ripley 2001). Bhatt *et al* (2014)

stated that the breeding season of Oriental Magpie-Robin ranged from March to August and the clutch size averaged four to five eggs. The young one is fed by both the sexes. The fights for nesting sites were common which suggested the scarcity of the nesting sites due to habitat degradation. Birds provide vital ecosystem services such as pest control, seed dispersal and pollination (Perfecto *et al* 2004, Sekercioglu 2006 and Van Bael *et al* 2008). The species richness of large insectivorous birds often decline in the agroforests (Greenberg *et al* 2000) and this raises an urgent need for understanding the avian functional diversity in agroecosystems (Komar 2006). About one-third of the total birds use agricultural areas as habitats for rendering the ecosystem services (Sekercioglu *et al* 2007).

Nijman and Sozer (1995) and Frey *et al* (2000) mentioned that Drongos belong to a largely (sub) tropical family of insectivorous birds and are well known for their aggressive behaviour to frequently mob raptors. The mobbing willingness of the Drongo is more during the breeding season than the non breeding season. This is mainly due to their more aggressive behaviour during the breeding season. The breeding of Drongo has been observed during all the months but maximum nests are found during April-June. Dowling (2003) mentioned about the breeding season of Red-capped Robin which bred for five months each year. The nests were built in forks with two or three supporting branches, with an average diameter of nest cup being 22.4 mm. The clutch size of the Red-capped Robin ranges from one to three eggs. Gokula and Vijayan *et al* (2007) mentioned that the birds White-breasted Kingfisher, Indian Roller and Black Drongo took insect prey in various foraging substrates, trees and stumpy vegetation. Black Drongo has a broad diet, consisting mainly on insect pests. Black Drongo fed on both insects and plant resources available to them but mainly consumed insects in larger proportions. Black Drongo hence proves to be useful species for farmers as they keep a check on various harmful insects in agricultural fields (Okosodo *et al* 2016).

Indian Robin is a passerine bird whose breeding season depends on the region and is marked by the beginning of first rain (Betts 1951). The populations of Indian Robin are resident and non migratory (Ali and Ripley 1998). Pied Bushchat is a tropical avian specie whose breeding activities begin advent of spring till July. The males were highly territorial during the breeding season and delivered a dawn chorus that played a vital role in maintaining social relationship among the neighbouring males. The nest was built by the female, though the selection of the nest site is done by both the sexes. Maximum numbers of clutches (35%) were observed in the month of May. Sethi *et al* (2012) mentioned that nest formation in the human settlements depicted the scarcity of natural habitat mainly due to the process of urbanization. Study of breeding biology of avian insectivores will help in the application of meaningful conservation and management actions (Powell *et al* 2015).

2.1 Habitat

Bird species actively select their habitat on the basis of various factors i.e. landscape

features, substrate, terrain, vegetative structure and arrangement (Wiens 1969). A preferred habitat is the one in which the bird species is found proportionally and more frequently, out of all other remaining habitats present in the surroundings (Petrides 1975). Differential habitat selection acts as a principal relationship, which allows the various bird species to co-exist (Rosenzweig 1981). Bird species prefer some habitats to others as the resources in the environment are not uniformly distributed (Osborn 2005).

Black Drongo is a common resident breeder in most of the tropical southern Asia (India and Srilanka and Indonesia). They are mostly found in the terrestrial habitats. Black Drongo is mainly found in the open areas and inhabits a variety of habitats ranging from forests to savanna including farmland and garden. It is mainly found from sea level to 1900 meters of elevation (Elgood 1973). It is mainly seen in pairs and only rarely in larger groups (Chari *et al* 1982). Black Drongo is often found about cultivation and on the outskirts of habitations. Black Drongo inhabits edge habitat as it had open cultivated land on one side that provided vast quantities of insect pests. It did not show any preference for logged habitat due to lack of tall trees. It mostly preferred upper branches of the trees for easy prey detection. Black Drongo utilized three different habitats namely secondary forest, farmland and developed area. It was observed to utilize forest area more than the other remaining compartments namely farmland and developed areas. The nesting sites of Black Drongo were found close to wetland, forest and farms, both during the breeding and the non-breeding season (Okosodo *et al* 2016). Mariappan *et al* (2013) stated that Black Drongo inhabits four types of habitats namely plantation (coconut, mango), crop lands (cereals and vegetables), wetlands (farm pond, paddy field and adjoining area of river) and fallow land. Black Drongo was noted to perched on the electric power lines in the developed areas and on trees, branches and shrubs in secondary forest and farmland.

The Indian Robin is a small sized, endemic passerine bird species that is distributed throughout the Indian subcontinent except northeast, higher Himalaya and Thar Desert. Indian Robin is a sexually dimorphic bird species which is found in grassy, open stony and scrub forest habitats. It prefers dry and stony areas with sparse scrub, low rocky hills outcrops, deserted buildings, arid stony ridges, edges of cultivation and, and groves and gardens (Whistler 1949, Grimmett *et al* 1998).They are mostly found in close association to human habitation and frequently perch on rooftops. All the population of Indian Robin are resident, non-migratory and are mainly seen in dry habitats. They are mostly absent from the thicker forest regions and high rainfall areas. The populations of Indian Robin are present from sea level upto an altitude of 1.600 m (Ali and Ripley 1998).

2.2 Foraging and Feeding

Birds diets exhibit a great variation and often include nectar, plants, fruit, carrion, seeds and different small animals, including other birds. Birds are generally generalists as

they employ different strategies to obtain food or feed on food items (Gill 1995). The foraging guilds in a bird community determine the way in which the bird species obtain food, the types of food taken, the foraging substrates exploited, and the heights at which they usually forage (MacNally 1994). It helps in the comparison of the communities within and between habitats (Recher and Davis 1998, Gokula and Vijayan 2000). The feeding strategies of the birds vary from species to species. Many bird species glean for invertebrates, insects, fruit and seeds. The bird species that hunt pest insects are considered as beneficial 'biological control agents' and their populations are encouraged in biological pest control programs (Reid 2006). Searching and exploiting food resources is termed as foraging. It plays a vital role in an animal's ability to survive and reproduce Foraging ecology of birds highlight the community structure, resource use and competition or co-existence in a particular habitat (Danchin *et al* 2008).

Black Drongo has a broad diet consisting largely of insects. It also gleaned on various plant species for feeding purposes. It derived 65% of its food resources from forest, 23% from farmland and 12% from developed area (Okosodo *et al* 2016). Various workers noted that the feeding habit of Black Drongo is insectivorous in nature (Ali *et al* 2011). Narayana *et al* (2014) stated that Black Drongo used plants (herbs, shrubs and trees) as foraging substrates to detect and hunt the insect prey. Aerial feeding, ground feeding and gleaning are the various foraging methods adopted by Black Drongo for feeding purposes. The foraging technique is determined partly by morphology of birds (Gokula and Vijayan 2000). It changes according to the habitat and abundance of prey (Recher and Davis 1998). Indian Robin is a common bird of urban gardens and forests. It mainly forage along the ground and perch on low rock and shrubs. The feeding habit of Indian Robin is mainly insectivorous (Ali *et al* 2011). They feed mostly on insects and other small invertebrates but are known to take frogs and lizards especially when feeding young at the nest. It may forage late in the evening to detect and hunt the prey insects. They are especially fond of migrating termites and will keep hunting them even at twilight. Individuals of Indian Robin hop on the ground in search of the insects (Bhatt *et al* 2014).

2.3 Breeding Biology

The breeding season is the most vital and fascinating phase in the socio-biology of bird species as a number of interesting events take place during this period (Faaborg and Chaplin 1984). A variety of strategies are used by birds for successful execution of their breeding activities (Catchpole and Slater 1995). Bird species invest a lot of their energy to find a suitable mate, safe nesting site and to maintain pair-bond throughout nesting period. After pairing with their mate, the individuals of bird species select suitable site for nesting and further breeding activities (Cody 1985, Robertson 1995). Nest protection, successful incubation, parental care and feeding to young ones, even after successful dispersal of

fledglings are the important components of breeding activity (Kumar 2003). In most passerines, the song is mainly used by bird species for territory establishment and pair formation (Kumar 2004, Kumar 2011).

2.3.1 Breeding Season

Breeding of Black Drongo is directly related to abundance insects as the nestling's need much quantity of proteins in their diet. The breeding period of Black Drongo is from April to August. It builds a bottomed cup shaped nest of fine twigs and fibres in a horizontal fork of branch tip of a tree. It lays 3-5 white eggs with brownish red spots (Ali 2002). Authors mentioned that the clutch size of bird species is dependent upon the diet and territory quality (Hustler and Howells 1989). Both the parents share the domestic duties and protect the nest. The eggs of Black Drongo are incubated by both the parents (Awais and Bibi 2014). The incubation period lasts from 13- 16 days. The newly hatched chicklings are naked and fleshy coloured. The nestlings are fed by both the parents. They left their nests on the 20^{th} or 22^{nd} day post hatch (Ali *et al* 2010).

The breeding period of Indian Robin extends from May to July. The nest of Indian Robin is a shallow cup made up of thin twigs with fine inner linings. It may also be lined with fur and hair. The eggs of Indian Robin are incubated by female (Ali 2002). Both sexes participated in nest formation after searching for a suitable nesting place. It lays 2- 4 eggs which are pale greenish in background with specks and small brownish, reddish blotches. The average incubation period is 8 days. The eggs are incubated by the female. The male guards and protects the nest (Kumar 2011).

2.3.2 Courtship Behaviour

Courtship includes all the activities of the male and female, beginning from the time of formation of pairs through the process of copulation (Morris 1956, Henwood and Fabrick 1979). The phenomenon of natural selection has placed the burden on each bird to leave descendants therefore birds use different methods to meet the challenge of providing the next generation. Courtship and mating activities are among the most varied and fascinating rituals of all bird behaviours. It varies widely among the various bird species. It begins with territorial defense and song followed by mate-attraction displays, courtship feeding, and selection of a nest site (Anonymous 2007). The main purpose of courtship is to attract a receptive mate. The prominent bird sounds are used to attract mates and help the birds to choose compatible mates. The courtship behaviours also serve to reduce territorial aggression between bird species and allow them to relax together to form a pair bond (Melissa 2009). According to acoustic transmission hypothesis, in many species the birds sing their songs most intensively at dawn as it is the time of the day when songs suffer least from environmentally induced degradation and propagate over the longest distances (Dabelsteen and Mathevan 2002, Marler and Slabbekoorn 2004).

Black Drongo sings in the morning, during the breeding season. Courtship behaviour includes aerobatic chases in which they lock their wings and beaks together with the pair and often fall to the ground. Displays by Black Drongo are usually made on the ground. Pair bonds formed during the courtship behaviour are retained for a whole breeding season (Awais and Bibi 2014). Indian Robin exhibits courtship behaviour during the last days of nesting or just after nest formation. During courtship display, male Indian Robin approaches female quickly with extremely up tail, forwarded, lowered head and complex song. Workers stated that most avian species use either visual or vocal or both types of displays for mating purposes (Faaborg and Chaplin 1984). For the acquisition of a suitable mate, mostly the male birds use various postures, display of brilliant plumage and colour badges. They also use undulating flights and to attract a suitable mate (Welty and Baptista 1988, Kumar 2010).

The males of Indian Robin sing during the breeding season and display by lowering and spreading their tail feathers and strutting around the female. The males display their sides and fluff their under tail coverts. The songs of the males are found to be more melodious than females. Individuals were observed singing from exposed branches of trees, electric wires, rocks, walls and on the ground. The songs of males have variants for inviting mates for courtship and mating and for deterring other males. Males drive away other males and protect and defend their territory by flying with slow wing-beats from one perch to another perch. It exhibits an aggressive display which involves holding the bill high and fluffing up the feathers (Kumar 2012). The male individuals of Indian Robin use discrete songs for mate attraction and male-male competition for territory. Kumar stated that the songs were discrete type with occasional monosyllabic whistles and composed of usually stereotyped phrases i.e. structural units, preceded and followed by mainly temporal intervals. Two categories of songs have been reported in Indian Robin; first category songs were simple, stereotyped, spontaneous and commonly used for territory advertisement, while second category songs were rare, female oriented and more complex than the first category songs (Kumar 2011).

2.3.3 Nesting Ecology

A bird nest is the place in which a bird lays its eggs and incubates it to raise its young ones. All bird species do not build nests, some species lay their eggs directly on the ground. Brood parasites lay their eggs in the nests of other bird species. Nests are usually used for breeding purposes but they may also be reused in the non-breeding season for roosting purposes (Skutch 1960). Bird species build their nest on the roofs of houses, holes of walls, trees, railway station and wells. They also readily accept artificial nesting sites i.e. nest boxes for laying their eggs (Sengupta 1982, Ali and Ripley 1983). The nesting trees of Black Drongo were found to be very close to agricultural lands as these areas provided abundant insect prey for feeding young ones (Shukkur and Joseph 1978). The nest of Black Drongo is constructed by both the sexes. The materials used for nest building were grass, twigs and dry

fibres. Workers stated that Black Drongo constructed nests on Rain tree (*Enterolobium saman*), Babool (*Acacia nilotica*), Neem (*Azadirachta indica*) and Tamarind tree (*Tamarindus indicus*). The trees used by Black Drongo for nesting had potential habitats such as agricultural lands and perching sites (Ali *et al* 2010). Indian Robin builds nests at different places such as in wall-hole, on open wall under the leaves of creeper plants, under iron waste dump near railway, in mud-hole in a graveyard. The nest of Indian Robin was a shallow cup shaped, made up of thin twigs with fine inner linings. The average nestling period was of 12-15 days (Kumar 2011).

2.3.4 Parental Care and Fledging

The parental care varies widely amongst different orders of the bird species. The chicks on emerging from the hatched eggs, range in development from helpless to independent species. Helpless chicks are born small, blind, immobile and naked which develop into chicks that are mobile and feathered through the phenomenon of thermo regulation (Elliott 1994). Both the sexes of Black Drongo took equal part in the nestling period. The hatched chicks were fed by both the parents throughout the day from morning till late evening. The parents transferred the whole insect food directly into the mouth of the nestlings (Ali *et al* 2010). Both the parents of Indian Robin participated in parental duties after egg hatching. Workers noted that the average nestling period was 13.25±0.27 days (Kumar 2011).

CHAPTER – III

MATERIALS AND METHODS

The present study on the nesting and breeding activities of Black Drongo (*Dicrurus macrocercus*) and Indian Robin (*Saxicoloides fulicata*) was carried out from January 2017 to December 2017 in the campus of Punjab Agricultural University (PAU), Ludhiana i.e. location A, village Baranhara (district Ludhiana) i.e. location B and village Ladian Khurd (district Ludhiana) i.e. location C, which were further divided into transects. Each transect had a distinct diversity of tree species, crop plantation and food availability. The PAU campus (30^0 54' 3.4740" N, 75^0 51' 26.1972" E) is located in the west of the Ludhiana city comprising of large stretch of agriculture fields (Plate I). A total of five transects i.e. transect IA, transect IIA, transect IIIA, transect IVA and transect VA) were selected at PAU campus site (Plate III). The village Baranhara (30^0 54' 3.4740" N, 75^0 51' 26.1972" E) is situated to the west of Ludhiana district and lies to the left side of the Hambran road. Two transects were selected in the village Baranhara namely transect IB and transect IIB. Transect IB was selected in residential area starting from main road to village interior. Transect IIB was selected from village interior up to seasonal water stream (Buddha Nala) that drains into Sutlej river. The village Ladian Khurd (30^0 54' 3.4740" N, 75^0 51' 26.1972" E) is located in the west tehsil of Ludhiana district. Two transects were selected in the village Ladian Khurd namely transect IC and transect IIC. Transect IC was selected in residential area of the village interior. Transect IIC was selected in the agricultural area of the village outskirts around the village pond (Plate II and Plate IV).

Point transect method was used to identify the different birds on the basis of visual observations using Bushnell binocular of magnification 8X and objective lens of 42 mm, without disturbing them (Verner 1985). Photography of the birds was done using Nikon coolpix B500 camera (16.0 Mega pixels and 40x Optical zoom). Ravi altimeter was used to measure the tree height and nest height from ground level. The common names and scientific names of birds observed at studied locations were written according to list prepared by Manakadan and Pittie (2001). Observations were made to note various breeding activities such as nesting, clutch size, incubation period and number of hatchlings. The morphometric characteristics of the eggs of Black Drongo and Indian Robin were also studied to determine the egg constituents, egg shell thickness and calcium concentration.

3.1 Study Areas

3.1.1 Location A: Punjab Agricultural University (PAU), Ludhiana - The categorization of transects was as described below.

1. Transect IA- Mohinder Singh Randhawa library road adjacent to ground

This area has been referred as PAU Transect IA. A complete record of the existing

components including tree diversity was maintained (Table 1). This transect had no agricultural field around it.

Table 1: Tree diversity in transect IA of PAU

Sr. No.	Common Name	Scientific Name
1	Indian mahogany	*Chukrasia tabularis*
2	Ashoka	*Polyalthia longifolia*
3	Silver Oak	*Grevillea robusta*
4	Peepal	*Ficus religiosa*

2. Transect IIA - Botanical garden

This area has been referred as PAU Transect IIA. A complete record of the existing components including tree diversity was maintained (Table 2). This transect had agricultural field around it.

Table 2: Tree diversity in transect IIA of PAU

Sr. No.	Common Name	Scientific Name
1	Neem	*Azadirachta indica*
2	Amaltas	*Cassia fistula*
3	Jamun	*Syzygium cumini*
4	Lassora	*Cordia myxa*
5	Silver Oak	*Grevillea robusta*
6	Kadipatta	*Murraya koenigii*
7	Tahli	*Dalbergia sissoo*
8	Toon	*Toona ciliate*
9	Dhek	*Melia azedarach*
10	Sukh Chain	*Pongamia pinnata*

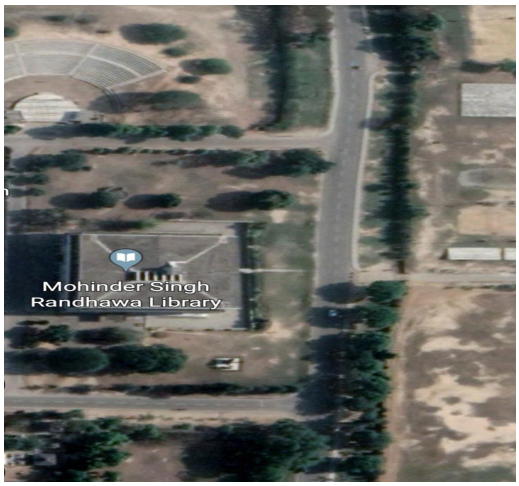
3. Transect IIIA- Biotechnology road

This area has been referred as PAU Transect IIIA. A complete record of the existing components including tree diversity was maintained (Table 3). This transect had agricultural field around it.

Table 3: Tree diversity in transect IIIA of PAU

Sr. No.	Common Name	Scientific Name
1	Silver Oak	*Grevillea robusta*
2	Bottlebrush	*Callistemon*
3	Tun	*Toona ciliate*
4	Dhek	*Melia azedarach*
5	Simbal	*Bombax ceiba*
6	Neem	*Azadirachta indica*
7	Ficus	*Ficus benjamina*
8	Ashoka	*Polyalthia longifolia*

PLATE I



Transect IA

Transect IIA

Transect IIIA

Transect IVA

Transect VA

4. Transect IVA - Backside of PAU clock tower

This area has been referred as PAU Transect IVA. A complete record of the existing components including tree diversity was maintained (Table 4). This transect had agricultural field around it.

Table 4: Tree diversity in transect IVA of PAU

Sr. No.	Common Name	Scientific Name
1	Date Palm	*Phoenix dactylifera*
2	Ashoka	*Polyalthia longifolia*
3	Silver oak	*Grevillea robusta*
4	Banyan	*Ficus benghalensis*
5	Peepal	*Ficus religiosa*
6	Dhek	*Melia azedarach*
7	Bottle palm	*Hyophorbe lagenicaulis*
8	Jamun	*Syzygium cumini*

5. Transect VA- Road to College of Fisheries

This area has been referred as PAU Transect VA. A complete record of the existing components including tree diversity was maintained (Table 5).This transect had agricultural field around it.

Table 5: Tree diversity in transect VA of PAU

Sr. No.	Common Name	Scientific Name
1	Peepal	*Ficus religiosa*
2	Dhek	*Melia azedarach*
3	Bottlebrush	*Callistemon*
4	Neem	*Azadirachta indica*
5	Mulberry	*Morus alba*
6	Jamun	*Syzygium cumini*
7	Mango	*Mangifera indica*

3.1.2 Location B: Village Baranhara, Ludhiana - The categorization of transects was as described below.

1. Transect IB

This area has been referred as village Baranhara transect IB. A complete record of tree diversity was maintained (Table 6). This transect had agricultural field around it.

Table 6: Tree diversity in transect IB of Village Baranhara

Sr. No.	Common Name	Scientific Name
1	Guava	*Psidium guajava*
2	Date palm	*Phoenix dactylifera*
3	Banana	*Musa acuminate*
4	Neem	*Azadirachta indica*
5	Peepal	*Ficus religiosa*
6	Ashoka	*Polyalthia longifolia*
7	Kadipatta	*Murraya koenigii*

3. Transect IIB

This area has been referred as village Baranhara transect IIB. A complete record of the existing components including tree diversity was maintained (Table 7). This transect had no agricultural field around it. Transect IIB was selected in uncultivated area having thirty uncemented houses of labourers and three cattle sheds. Dense growth of wild bushes and shrubs was mainly present. The large part of said transect was utilized for drying cattle dung for fuel purposes. Heaps of domestic waste (kitchen waste) and cattle shed waste were also present. The farmers had constructed huge conical mounds for storing straw and chaff.

Table 7: Tree diversity in transect IIB of Village Baranhara

Sr. No.	Common Name	Scientific Name
1	Peepal	*Ficus religiosa*
2	Neem	*Azadirachta indica*
3	Dhek	*Melia azedarach*
4	Kadipatta	*Murraya koenigii*

3.1.3 Location C: Village Ladian Khurd, Ludhiana - The categorization of transects was as described below.

1. Transect IC

This area has been referred as village Ladian Khurd transect IC. A complete record of the existing components including tree diversity was maintained (Table 8). This transect had no agricultural field around it.

Table 8: Tree diversity in transect IC of Village Ladian Khurd

Sr. No.	Common Name	Scientific Name
1	Peepal	*Ficus religiosa*
2	Neem	*Azadirachta indica*
3	Dhek	*Melia azedarach*
5	Poplar	*Populus deltoids*
6	Eucalyptus	*Eucalyptus oblique*
7	Date Palm	*Phoenix dactylifera*

PLATE II

Transect IB and Transect IIB

Transect IC and Transect IIC

PLATE III

Transect IA

Transect IIA

Transect IIIA

Transect IVA

Transect VA

PLATE IV

Transect I of location B

Transect II of location B

Transect I of location C

Transect II of location C

2. Transect IIC

This area has been referred as village Ladian Khurd transect IIC. A complete record of the existing components including tree diversity was maintained (Table 9). This transect had no agricultural field around it.

Table 9: Tree diversity in transect IIC of Village Ladian Khurd

Sr. No.	Common Name	Scientific Name
1	Peepal	*Ficus religiosa*
2	Neem	*Azadirachta indica*
3	Dhek	*Melia azedarach*
4	Sheesham	*Dalbergia sissoo*
5	Date Palm	*Phoenix dactylifera*
6	Eucalyptus	*Eucalyptus oblique*

3.2 Community structure

Bird species were observed to determine the relative abundance, species richness, species diversity and species evenness at all the studied locations.

3.2.1 Community characteristics

(A) Species Richness- Total number of bird species observed at studied locations.

(B) Relative Abundance- Relative abundance was calculated as:

$$ni/N \times 100$$

Where ni is the number of birds of ith species and N is the total number of birds recorded.

(C) Species Diversity- Species diversity was calculated by Shannon- Weiner Index:

$$H = -\Sigma Pi \log Pi$$

Where Pi is the proportion of the ith species of birds. H is referred as Shannon's Index.

(D) Species Eveness- It was calculated using the formula:

$$J = H/H'max.$$

Where H represented the observed species diversity and H'max represented the log of total number of species i.e. species richness (Krebs *et al* 1985). Species evenness is denoted as E and is also known as Equitability.

3.2.2 Statistical Analysis

Mann-Whitney U test was used to compare the number of individuals at all the studied locations. Student's t-test was carried out to determine any significant difference between the numbers of individuals.

3.3 Egg laying Pattern and Morphometry of eggs

3.3.1 Egg Laying, Clutch Size

The nests of Black Drongo and Indian Robin were observed periodically at all study

areas for the presence of eggs. The egg laying, clutch size, incubation period, hatching of Black Drongo and Indian Robin eggs were studied. The numbers of eggs in each nest were counted to note the clutch size. The morphological parameters of the eggs of Black Drongo and Indian Robin were also recorded.

3.3.2 Morphometery of eggs

Active nests of Black Drongo and Indian Robin were located on various trees and bushes/crevices of underconstructed buildings respectively. The variation in the number of eggs, weight and dimensions were also noted. Precaution was taken to place the egg of Black Drongo and Indian Robin in the same position after the measurements were taken, so as not to interfere with the development of the eggs.

3.3.2.1 Egg length and width

The Egg length and width of Black Drongo and Indian Robin eggs were measured by using digital vernier calliper. The length of the eggs were measured across the line where the distance was maximum and similarly the width was measured between the widest points.

3.3.2.2 Egg weight

Weight of the eggs was measured using a portable digital weighing balance. One egg was taken at a single time and was replaced in the nest after the measurements were taken.

3.3.2.3 Egg volume

Egg volume was estimated from length (L) and breadth (B). Data were calculated using an empirical formula calibrated to Northern Lapwing eggs by Galbraith (1988):

Egg volume = $(0.457).(L).(B^2.).10^{-3}$ml

3.3.2.4 Egg shell thickness

Three little egg shell pieces were randomly taken from the egg shells of Black Drongo and Indian Robin for the measurement. The egg shell pieces were air-dried. The parts that were covered with vaterite or adhering with membrane were avoided for the measurements as it causes great variation in thickness. Three measurements were taken on all three pieces of the eggshell using a Travelling microscope. Average of all the three measurements (cm) were o taken to get a mean value for the egg shell thickness as outlined in the procedure by Dirksen and Boudewijn (2001).

3.3.2.5 Eggshell composition

The entire egg shell was taken and the inner membrane was removed. After crushing the entire contents in a pestle and mortar the powder was put in 250 ml beaker. 50 ml of 3 M HCl was added to it and stirred. When the bubbling stopped and foam disappeared after waiting for some time, the mixture was filtered and dried overnight. The leftover substance was not calcium carbonate but eggshell. The mass and percent composition of calcium carbonate was calculated as outlined by Butcher and Miles (2000).

Full Equation of Reaction:

$CaCO_3$ (s) + 2HCl (aq) $CaCl_2$ (aq) + CO_2 (g) + H_2O (l)

Calculations:

1. Mass of unreacted eggshell = mass of filter paper and unreacted eggshell – mass of filter paper.
2. Mass of $CaCO_3$ in eggshell = mass of eggshell – mass of unreacted eggshell
3. $CaCO_3$ in eggshell = mass of $CaCO_3$ / mass of eggshell

% $CaCO_3$ in eggshell = mass of $CaCO_3$ X 100 / mass of eggshell

3.3.2.6 Egg components (shell, albumen and yolk) weight

The shell was cracked and the yolk was separated from albumen materials (after cooling the egg, the egg was broken and yolk and albumen was separated using funnel. The albumen drained below while the yolk remained in the funnel). Weights of the egg shell, yolk and albumen materials were determined using an electronic weight balance.

3.3.2.7 Egg components (shell, albumen and yolk) percentage:

Percentages of egg components (shell, yolk and albumen materials) as a ratio to total egg weight were determined by using the equation below (Stadelman and Cotterill 1995):

$$\text{Egg components percentages} = \frac{\text{Component weight (gm)}}{\text{Egg weight (gm)}}$$

3.3.2.8 Specific gravity

Egg specific gravity was determined according to Stadelman and Cotterill (1995) using the equation given as under:

$$\text{Egg specific gravity (gm/cm}^3\text{)} = \frac{\text{Egg weight (gm)}}{\text{Egg volume (cm}^3\text{)}}$$

3.3.2.9 Egg shape index

Egg shape index determined using the micrometer according to (Stadelman and Cotterill 1995) using the following equation:

$$\text{Egg shape index} = \frac{\text{Egg breadth (mm) x 100}}{\text{Egg length (mm)}}$$

3.3.2.10 Statistical analysis

Data collected in morphometry and egg parameters of the eggs of Black Drongo and Indian Robin was analysed using ANOVA (SPSS 20 Software).

3.3.3 Hatching Success and Fledging Success

The hatching success and fledging success of Black Drongo and Indian Robin was determined according to Murray (1999).

$$\text{Hatching success (\%)} = \frac{\text{Number of eggs hatched}}{\text{Total number of eggs laid}} \times 100$$

$$\text{Fledging success (\%)} = \frac{\text{Number of nestlings fledged}}{\text{Total number of eggs hatched}} \times 100$$

CHAPTER – IV

RESULTS AND DISCUSSION

The present study was conducted for the period of one year from January to December 2017. Three locations namely PAU campus, village Baranhara and village Ladian Khurd were surveyed at weekly intervals. Observations on the abundance of different bird species were taken within the selected areas. The detailed observations were taken on the breeding biology of Black Drongo (*Dicrurus macrocercus*) and Indian Robin (*Saxicoloides fulicata*) including courtship behaviour, nest site selection, egg laying, clutch size, incubation period, hatching success and nesting success. Morphometric analysis of eggs have also been discussed. Height of nesting tree and height of nest were also noted down. Results have been discussed according to the description of the studied locations described in Chapter III.

4.1 Location A

4.1.1 Bird Composition

A total of 39 bird species were noted at location A during study period from January to December 2017. Common Babbler (5.65%) was the most abundant species in the bird community followed by the Common Myna (4.87%), Black Drongo (4.73%), Indian Peafowl (4.47%) and Blue Rock Pigeon (4.04%) (Plate V). The other species recorded in appreciable numbers were Purple Sunbird (4.00%), Red-vented Bulbul (3.80%) and House Crow (3.25%). Asian Koel (2.94%), Rose-ringed Parakeet (2.85 %) and Brown Rock Chat (2.85%) were found to be most equally abundant species. Pied Myna (1.60 %), Oriental Magpie-Robin (1.29%) and Cattle Egret (1.10 %) were less than 2%. Four bird species namely Brown-headed Barbet, House Sparrow, White-breasted Kingfisher and Spotted Owlet constituted less than 1% of total birds as observed throughout the year (Table 10).

Thirty nine species were recorded in the month of January. Common Myna (6.17%) and Common Babbler (6.17%) were the most abundant species followed by Indian Peafowl (4.94%) and Black Drongo (4.63%). In the month of February, there were recorded 38 bird species. Indian Peafowl (5.80%) was the most abundant species. Common Myna (4.93%) and Common Babbler (4.93%) were the second and equally abundant bird species (Plate VI). Cattle Egret (4.35 %) was the third most abundant bird species. In the month of March, Blue Rock Pigeon and Common Babbler were recorded as the most abundant species (6.60%). Black Drongo (5.28%) was the second most abundant species followed by Common Myna (4.42%). Purple Sunbird (5.13%) was the first most abundant species in the month of April; it was followed by Common Myna (4.87%), Common Babbler (4.87%), Indian Peafowl (4.87%) and Red-vented Bulbul (4.62%) (Plate VII). In the month of May, Common Myna (4.81 %) and Common Babbler (4.81%) were recorded as the most abundant species followed by Red-vented Bulbul (4.33%).

Table 10: Bird composition and community characteristics from January 2017 to December 2017 at location A

Month / Bird Species	Jan 17	Feb 17	Mar 17	April 17	May 17	June 17	July 17	Aug 17	Sept 17	Oct 17	Nov 17	Dec 17	Relative Abundance (%) of birds
Pied Bushchat	2.47	3.19	2.37	0.77	2.88	2.82	3.08	2.45	2.02	1.79	1.33	1.87	2.27
Spotted Munia	1.85	2.90	2.90	1.28	2.16	2.60	2.42	2.23	1.35	1.79	1.33	1.07	2.00
Oriental Magpie-Robin	0.62	0.29	0.79	0.26	1.44	1.52	1.98	2.23	2.47	1.28	0.80	1.07	1.29
Brown-headed Barbet	0.62	1.16	1.06	1.03	0.72	1.08	0.88	1.11	0.67	1.02	1.07	0.80	0.94
House Sparrow	0.62	1.16	1.32	1.54	0.96	0.65	0.88	0.45	0.90	0.77	0.53	0.80	0.87
Large Pied Wagtail	1.23	2.32	2.90	3.85	0.96	2.60	2.20	2.90	2.92	3.57	2.13	1.60	2.46
Red-wattled Lapwing	2.47	1.74	1.85	2.31	2.88	3.25	2.86	3.12	2.25	2.81	2.40	1.87	2.52
Cattle Egret	2.16	4.35	2.64	1.54	2.88	2.39	2.86	3.12	2.70	3.83	2.67	4.28	1.10
Pied Myna	2.78	2.32	1.58	2.56	1.92	1.52	1.32	0.67	0.90	1.28	1.07	1.87	1.60
White-breasted Kingfisher	0.62	0.87	0.26	1.03	0.72	0.43	0.22	0.67	0.22	1.02	1.33	0.27	0.62
Indian Pond-Heron	0.93	1.16	1.85	1.54	2.16	3.25	3.52	3.79	3.60	3.06	1.07	1.60	2.39
Common Myna	6.17	4.93	4.22	4.87	4.81	5.21	4.63	4.23	4.04	5.10	4.53	6.15	4.87
Bank Myna	0.93	1.16	1.58	2.05	1.44	0.87	1.98	2.23	3.15	3.06	3.20	2.41	2.02
House Crow	3.70	4.06	2.64	3.08	3.37	2.17	2.64	3.34	3.60	2.81	2.67	3.48	3.25
Rose-ringed Parakeet	2.16	2.61	2.90	3.59	2.88	1.95	2.20	2.67	2.47	3.57	3.47	4.01	2.85
Yellow-legged Green-Pigeon	1.85	2.03	2.64	2.31	2.40	1.95	2.64	2.45	2.92	2.04	1.87	1.07	2.21
Eurasian Collared-Dove	2.16	2.32	2.37	2.56	2.16	2.60	2.42	2.90	3.15	2.55	2.13	1.87	2.46
Blue Rock Pigeon	3.70	2.90	6.60	3.33	3.61	4.34	3.74	4.01	4.94	3.57	4.80	2.67	4.04
Little Green Bee-eater	2.78	2.03	1.32	2.31	2.40	2.39	1.76	1.56	2.47	2.55	2.40	3.21	2.25

Red-vented Bulbul	2.47	2.90	2.11	4.62	4.33	4.12	3.30	3.56	3.15	4.59	4.27	3.48	3.80
Spotted Owlet	0.62	-	0.26	0.26	0.48	1.08	0.66	0.45	1.35	0.51	0.80	0.53	0.60
Indian Robin	2.47	2.61	1.32	1.54	2.40	2.60	2.42	2.67	2.47	1.79	2.40	2.14	2.25
Purple Sunbird	2.47	3.48	3.69	5.13	3.85	3.69	5.51	3.56	4.94	2.81	5.33	2.94	4.00
Black Drongo	4.63	3.48	5.28	2.31	4.09	3.90	3.52	4.23	3.15	2.55	4.00	3.74	4.73
Black Redstart	2.78	2.90	1.85	1.28	2.16	1.30	0.88	1.78	2.70	2.81	2.67	2.41	2.08
Brown Rock Chat	2.78	2.90	2.90	3.08	3.37	3.25	2.64	3.12	2.70	2.81	2.40	2.14	2.85
Common Swallow	2.78	2.32	1.85	2.31	1.20	2.39	2.64	1.56	0.90	2.04	2.67	2.94	2.10
House Swift	2.78	2.03	2.64	3.08	3.37	2.60	2.86	2.23	2.02	2.81	2.67	2.94	2.66
Common Golden-backed Woodpecker	2.78	3.48	2.90	3.59	2.88	2.82	2.42	2.67	3.15	2.55	2.40	1.87	2.79
Asian Koel	3.70	4.06	3.17	3.33	3.61	3.04	2.20	2.45	2.70	2.30	2.13	2.94	2.94
Greater Coucal	3.09	2.61	3.17	2.82	2.16	1.74	1.54	2.23	2.47	2.30	2.13	2.67	2.37
Common Babbler	6.17	4.93	6.60	4.87	4.81	5.42	5.07	4.68	5.62	4.85	5.33	6.68	5.65
Common Hoopoe	2.78	2.90	2.90	3.08	3.13	1.95	2.64	2.23	1.80	3.83	3.73	3.21	2.81
Indian Roller	2.78	2.32	3.17	2.56	2.64	2.60	3.08	2.67	2.02	1.79	2.67	2.94	2.60
Baya Weaver	1.85	2.03	2.11	2.31	2.40	3.25	3.08	2.90	2.25	2.30	1.87	2.14	2.41
Black Kite	2.78	1.45	2.11	1.79	2.16	1.95	2.20	2.45	1.80	1.79	3.20	2.67	2.19
Wire- tailed Swallow	2.78	2.32	1.85	2.56	2.88	2.82	3.08	2.67	2.47	2.55	2.40	2.41	2.58
Indian Treepie	2.78	2.03	2.64	2.82	2.88	1.74	1.98	1.34	1.57	2.04	1.87	1.87	2.10
Indian Peafowl	4.94	5.80	3.69	4.87	2.40	4.12	3.96	4.45	4.04	3.57	4.27	5.35	4.47
Species Richness	39	38	39	39	39	39	39	39	39	39	39	39	
Species Diversity	3.53	3.54	3.53	3.54	3.57	3.56	3.56	3.57	3.55	3.58	3.55	3.52	
Species Evenness	0.96	0.97	0.96	0.97	0.97	0.97	0.97	0.97	0.97	0.98	0.97	0.96	

In the month of June, Common Babbler (5.42%) was noted as the most abundant bird species followed by Common Myna (5.21%), Blue Rock Pigeon (4.34%), Red-vented Bulbul (4.12%) and Indian Peafowl (4.12 %). In the month of July, Purple Sunbird (5.51%) was the most abundant species. Second most abundant species was Common Babbler (5.07%), Common Myna (4.63%) and Indian Peafowl (3.96%). In the month of August, Common Babbler (4.68%) was the most abundant species. The second most abundant species was Indian Peafowl (4.45%), followed by Common Myna (4.23%) and Black Drongo (4.23%). In the month of September, Common Babbler (5.62%) was noted to be the most abundant bird species followed by Blue Rock Pigeon (4.94%), Purple Sunbird (4.94%), Common Myna (4.04%), and Indian Peafowl (4.04%). In the month of October, Common Myna (5.10%) was the most abundant species. Common Babbler (4.85%) and Red-vented Bulbul (4.59%) was the second and third most abundant species. Common Babbler and Purple Sunbird with relative abundance of 5.33% were the most abundant species in the month of November (Table 1). Blue Rock Pigeon (4.80%) and Common Myna (4.53%) was recorded as second and third most abundant species respectively. There were three bird species namely Oriental Magpie-Robin, House Sparrow and Spotted Owlet with relative abundance of less than 1%. House sparrow was recorded as the least abundant species with relative abundance of 0.53% only. In the month of December, a total of 39 bird species were noted. Common Babbler was the most abundant species followed by Common Myna (6.15%) and Indian Peafowl (5.35%) as the second and third most abundant species. Four bird species namely Brown-headed Barbet, House Sparrow, White-breasted Kingfisher and Spotted Owlet constituted less than 1% of total birds.

4.1.2 Bird Community Characteristics

The Species richness peaked 39 in all the months of the one year study period, except in the month of February where it was 38. Highest (3.58) and lowest (3.52) species diversity was noted in the month of October and December respectively. It was noted that species evenness was highest (0.98) in the month of October. Lowest species eveness (0.96) was noted in the months of January, March and December.

4.2 Location B

4.2.1 Bird Composition

A total of 38 bird species were recorded at village Baranhara i.e. location B during the observation from January 2017 to December 2017. House Crow was the most abundant species. Rose-ringed Parakeet (5.22%), Cattle Egret (5.19%) was second and third most abundant species followed by Common Babbler (5.16%) and Common Myna (5.10%). Four species namely Spotted Owlet, House Swift, Common Golden-backed Woodpecker and Indian Treepie constituted less than 1% of total birds as observed throughout the year

PLATE V

Black Drongo

PLATE VI

Male Indian Robin

PLATE VII

Female Indian Robin

(Table 11).

In the month of January, Blue Rock Pigeon (6.09%) was the most abundant species. Common Babbler was the second most abundant species with relative abundance of 5.65%. House Crow and Cattle Egret were the third most abundant species with equal relative abundance of 5.22%. In the month of February, Rose-ringed Parakeet (6.20%) was the most abundant species. Blue Rock Pigeon, House Crow, Cattle Egret and Red-vented Bulbul were the second most abundant species with equal relative abundance of 5.47% (Table 2). Purple Sunbird and Eurasian Collared-Dove were the third most abundant species with the equal relative abundance of 4.38%. There were three bird species namely White-breasted Kingfisher, House Swift and Black Kite observed with the relative abundance of less than 1%. In the month of March, Red-vented Bulbul (6.69%) was the most abundant species. Rose-ringed Parakeet (6.30%), Common Myna (5.91%) was the second and third most abundant species followed by Blue Rock Pigeon, Eurasian Collared-Dove, Purple Sunbird and House Crow with same relative abundance of 5.51%. In the month of April, the relative abundance of most abundant species namely House Crow was recorded 7.28%. Other species recorded in the appreciable numbers were Purple Sunbird (5.75 %), Red-wattled Lapwing (5.36%), Cattle Egret (5.36%), Common Myna (5.36%) and Rose-ringed Parakeet (5.36%). In the month of May, House Crow (6.00%) was the most abundant species with Common Myna, Rose-ringed Parakeet and Blue Rock Pigeon as second most abundant species with equal relative abundance of 5.33%. Cattle Egret and Eurasian Collared-Dove were the third most abundant species with relative abundance of 5.00%.

In the month of June, Common Myna was the most abundant species. Red-vented Bulbul (5.19%) was the second most abundant species followed by Indian Peafowl, Red-wattled Lapwing, Cattle Egret and Rose-ringed Parakeet with equal relative abundance of 4.87%. In the month of July, Cattle Egret (6.62%) was the most abundant species. Common Myna (4.97%) was second most abundant species. Common Babbler and Indian Peafowl were the third most abundant species with equal relative abundance of 4.64%. In the month of August, Cattle Egret (5.57%) was the most abundant species. Blue Rock Pigeon and Eurasian Collared-Dove (5.23%) were second most abundant species followed by House Crow, Rose-ringed Parakeet and Red-vented Bulbul with equal relative abundance of 4.88%. In the month of September, Common Babbler was the most abundant species with relative abundance of 6.32%. House Crow and Rose-ringed Parakeet were the second most abundant species with equal relative abundance of 5.26%. Common Myna, Eurasian Collared-Dove and Cattle Egret were the third most abundant species with equal relative abundance of 4.91%.In the month of October, Common Babbler (6.33%) was the most abundant species. Common Myna was the second most abundant species with relative abundance of 5.67%. House Crow (5.33%) was the third most abundant species. In the month of November, Common Babbler was (7.91%)

Table 11: Bird composition and community characteristics from January 2017 to December 2017 at location B

Month / Bird Species	Jan 17	Feb 17	Mar 17	April 17	May 17	June 17	July 17	Aug 17	Sept 17	Oct 17	Nov 17	Dec 17	Relative Abundance (%) of birds
Pied Bushchat	1.30	1.82	1.57	1.53	1.67	1.62	1.32	1.74	2.11	1.33	1.58	1.36	1.59
Spotted Munia	3.48	2.55	1.57	3.07	2.67	2.27	1.99	1.74	2.46	2.00	1.58	1.81	2.26
Oriental Magpie-Robin	1.30	1.46	1.97	2.30	2.33	2.60	2.98	3.14	2.46	2.67	1.58	2.26	2.29
Brown-headed Barbet	-	-	-	-	-	-	-	-	-	-	-	-	-
House Sparrow	3.91	2.55	3.94	4.21	4.00	2.60	0.99	2.09	1.40	1.67	1.58	2.71	2.60
Large Pied Wagtail	1.74	2.55	3.15	1.92	2.00	2.60	1.32	2.44	2.81	1.67	1.58	3.17	2.23
Red-wattled Lapwing	3.48	3.28	3.94	5.36	4.67	4.87	3.97	3.48	3.86	4.33	4.35	4.52	4.18
Cattle Egret	5.22	5.47	4.72	5.36	5.00	4.87	6.62	5.57	4.91	4.00	5.53	4.98	5.19
Pied Myna	3.48	2.55	1.97	3.45	1.33	0.65	1.66	2.79	1.40	2.00	3.16	3.17	2.23
White-breasted Kingfisher	3.04	0.73	1.57	1.92	1.33	1.95	1.66	1.39	1.75	2.33	0.79	2.26	1.71
Indian Pond-Heron	1.74	1.82	1.57	1.92	1.33	2.27	2.65	2.09	1.75	1.33	1.98	1.81	1.86
Common Myna	3.91	3.65	5.91	5.36	5.33	5.52	4.97	3.48	4.91	5.67	6.32	6.33	5.10
Bank Myna	3.48	1.46	3.54	2.68	2.67	3.25	3.64	3.48	3.16	2.33	2.37	3.17	2.93
House Crow	5.22	5.47	5.51	7.28	6.00	3.90	4.30	4.88	5.26	5.33	5.53	4.52	5.25
Rose-ringed Parakeet	4.35	6.20	6.30	5.36	5.33	4.87	3.97	4.88	5.26	5.00	5.93	5.43	5.22
Yellow-legged Green Pigeon	3.91	2.55	1.57	1.92	1.33	1.62	0.99	2.79	1.40	0.67	2.37	1.81	1.86
Eurasian Collared-Dove	4.35	4.38	5.51	3.45	5.00	4.55	3.97	5.23	4.91	4.33	4.35	4.52	4.55
Blue Rock Pigeon	6.09	5.47	5.51	4.60	5.33	4.55	3.31	5.23	4.56	3.67	5.93	4.98	4.89
Little Green Bee-eater	3.48	2.55	2.36	0.77	1.33	1.62	0.99	2.09	2.81	3.00	1.58	1.81	2.02
Red-vented Bulbul	3.91	5.47	6.69	4.60	4.67	5.19	4.30	4.88	3.86	3.33	3.16	4.07	4.52

Spotted Owlet	0.43	-	0.79	0.77	0.33	-	0.66	1.05	0.35	0.33	0.79	0.45	0.49
Indian Robin	3.48	2.55	1.97	2.68	3.33	3.90	3.31	1.39	1.75	2.67	1.58	2.26	2.60
Purple Sunbird	3.91	4.38	5.51	5.75	4.00	3.57	2.98	1.39	2.81	3.00	3.95	4.98	3.79
Black Drongo	-	4.01	1.97	3.07	4.67	3.57	4.30	3.48	1.75	2.67	3.56	3.17	3.08
Black Redstart	0.87	2.55	1.97	2.30	0.67	0.97	1.66	3.14	1.40	1.00	1.58	2.26	1.68
Brown Rock Chat	3.91	3.65	1.57	4.60	4.67	3.57	3.31	2.09	3.16	2.67	1.58	3.17	3.18
Common Swallow	1.74	2.19	1.97	0.77	-	0.32	1.32	0.70	2.11	2.33	-	0.45	1.16
House Swift	0.43	0.73	-	-	0.33	0.97	1.32	0.70	0.35	-	0.79	-	0.49
Common Golden-backed Woodpecker	0.43	-	-	-	0.33	-	0.66	-	-	0.33	-	-	0.15
Asian Koel	0.87	1.82	-	1.53	-	0.65	1.99	-	2.81	3.00	2.77	-	1.31
Greater Coucal	1.74	3.28	3.94	0.38	1.67	2.27	2.98	1.39	2.11	3.33	1.58	2.26	2.26
Common Babbler	5.65	3.65	4.33	3.07	3.67	4.87	4.64	5.57	6.32	6.33	7.91	6.33	5.16
Common Hoopoe	0.87	1.46	1.97	0.38	2.00	2.27	1.32	1.74	2.11	1.33	1.58	1.81	1.59
Indian Roller	0.87	2.19	0.79	1.92	2.67	1.30	1.99	3.14	2.81	2.33	1.58	0.90	1.92
Baya Weaver	-	-	-	-	1.67	2.60	2.98	3.48	4.21	3.67	1.98	2.71	2.02
Black Kite	-	0.73	1.18	1.53	1.67	0.97	1.99	1.39	0.70	1.67	0.79	1.36	1.19
Wire- tailed Swallow	2.61	1.46	1.97	2.30	1.67	1.30	1.99	1.74	1.75	1.33	1.58	0.90	1.71
Indian Treepie	1.30	-	-	-	-	0.65	0.33	1.05	0.35	0.67	0.40	-	0.40
Indian Peafowl	3.48	3.28	1.18	1.92	3.33	4.87	4.64	3.14	2.11	4.67	4.74	2.26	3.36
Species Richness	35	34	33	35	35	36	38	36	37	37	36	34	
Species Diversity	3.38	3.40	3.33	3.35	3.37	3.42	3.48	3.45	3.45	3.45	3.37	3.38	
Species Evenness	0.95	0.96	0.95	0.94	0.95	0.95	0.96	0.96	0.96	0.96	0.94	0.96	

was the most abundant species. Common Myna (6.32%) was the second most abundant species. Blue Rock Pigeon and Rose-ringed Parakeet were the third most abundant species with equal relative abundance of 5.93%. In the month of December, Common Myna and Common Babbler were the most abundant species with equal relative abundance of 6.33%. Rose-ringed Parakeet (5.43%) was the second most abundant species. Purple Sunbird, Cattle Egret and Blue Rock Pigeon were the third most abundant species with equal relative abundance of 4.98%.

4.2.2 Bird Community characteristics

The Species richness was highest (38) in the month of July. Highest (3.48) and lowest (3.33) species diversity was noted in the month of July and March respectively. Species evenness was at peak (0.96) in the month of February, July, August, September, October and December. Lowest species eveness (0.94) was noted in the months of April and November.

4.3 Location C

4.3.1 Bird Composition

A total of 33 bird species were recorded at village Ladian Khurd i.e. location C during the observation from January 2017 to December 2017 (Table 3). Blue Rock Pigeon (6.44%) was the most abundant species. House Crow (5.98%) and House Sparrow (5.66%) were second and third most abundant species followed by Common Myna (5.07%) and Red-vented Bulbul (4.85%). White-breasted Kingfisher constituted less than 1% of total birds as observed throughout the year (Table 12).

In the month of January, Common Myna was the most abundant species with relative abundance of 9.04%. Cattle Egret and Purple Sunbird were the second most abundant species with equal relative abundance of 8.43%. Blue Rock Pigeon, House Crow and Black Drongo were the third most abundant species with relative abundance of 6.02%. In the month of February, five species namely Common Myna, Blue Rock Pigeon, Common Babbler, Purple Sunbird and Black Drongo were the most abundant species with equal relative abundance of 6.03%. House Crow (5.53%) and Cattle Egret (5.03%) were the second and third most abundant species respectively. In the month of March, three species namely Blue Rock Pigeon, Red-vented Bulbul and Black Drongo were the most abundant species with equal relative abundance of 6.22%. Common Babbler (5.39%) was the second most abundant species. Rose-ringed Parakeet and House Crow were the third most abundant species with equal relative abundance of 4.98%. In the month of April, House Crow and Blue Rock Pigeon were the most abundant species with equal relative abundance of 8.03%. Rose-ringed Parakeet was the second most abundant species with relative abundance of 6.43%. House Sparrow and Common Babbler were third most abundant species with equal relative abundance of 6.02%. In the month of May, Blue Rock Pigeon (9.21%) was the most abundant species. House Sparrow (7.53%) and Red-vented Bulbul (6.69%) were the second and third

most abundant species respectively.

In the month of June, House Crow (8.33%) was the most abundant species followed by Blue Rock Pigeon (7.50%) and House Sparrow (6.25%) as the second and third most abundant species respectively. In the month of July, Red-vented Bulbul was the most abundant species with relative abundance of 7.12%. Blue Rock Pigeon (6.05%) and House Crow (5.34%) were the second and third most abundant species respectively. In the month of August, House Sparrow (8.14%) was the most abundant species. Blue Rock Pigeon, Purple Sunbird and Baya Weaver Bird were the second most abundant species with equal relative abundance of 5.81%. Common Babbler, Red-vented Bulbul and House Crow were the third most abundant species with equal relative abundance of 5.43%. In the month of September, Baya Weaver and House Crow were the most abundant species with relative abundance of 6.15%. Common Myna and Red-vented Bulbul were the second most abundant species with equal relative abundance of 5.77%. Rose-ringed Parakeet (5.38%) was the third most abundant species. In the month of October, Baya Weaver (6.32%) was the most abundant species. House Sparrow and Rose-ringed Parakeet were second most abundant species with equal relative abundance of 5.95%. House Crow was third most abundant species with relative abundance of 5.58%. In the month of November, Blue Rock Pigeon and Rose-ringed Parakeet were the most abundant species with equal relative abundance of 6.38%. Black Drongo (5.96%) was the second most abundant species followed by House Sparrow (5.11%), Common Myna (5.11%) and Common Babbler (5.11%). In the month of December, Blue Rock Pigeon and Rose-ringed Parakeet were the most abundant species with equal relative abundance of 6.80%. House Crow (5.83%) was the second most abundant species followed by Common Myna (5.34%).

4.3.2 Bird Community characteristics

The Species richness was highest (33) in the months of March, April, July, August, September, October and December. Highest (3.37) and lowest (3.15) species diversity was noted in the month of July and January respectively. Species evenness was at peak (0.96) in the months of March, June, July, November and December. It was noted that species evenness was lowest (0.92) in the month of January.

4.4 Statistical analysis

Mann-Witney U test carried out to compare the relative abundance of bird species observed at all the studied locations. Significant difference between relative abundance was found at location A and C and location B and C. There was no significant variation found among the number of individuals at all the other studied locations (5% level of significance).

4.5 Comparative Bird Composition

The present study had revealed that highest species richness (39) was found at location A followed by location B (38) and location C (33). Location A supported maximum

bird species diversity, which might be due to the presence of greater tree diversity and better habitat conditions. It had widespread agricultural lands that provided abundant food material such as grains as well as insects to the omnivorous and insectivorous birds. Mariappan *et al* (2013) had stated that majority of the birds hunted their food from the agricultural field areas. Easy food availability might be the reason of less interspecies competition observed at location A. Godoi *et al* (2017) stated that the pastures with more trees and shrubs had greater richness of insectivorous and frugivorous birds. Location B had both uncultivated land and agricultural fields which might be the reason for lesser species richness than location A. At location C, number of uncemented houses, shops and one academic building were present. It consisted of more developed area and less area was under agricultural fields. Deikumah *et al* (2017) mentioned that poor agricultural practices can lead to population declines of forest-dependent birds particularly specialist species. This study revealed that the type of agricultural land use surrounding a tropical rainforest patch could significantly influence bird assemblage structure in forest–agricultural landscapes**.** It was subjected to many anthropogenic activities and traffic movement (proximity to main road) which might have disturbed birds in their daily activities. It resulted in lesser bird diversity at location C. In addition to habitat composition, habitat configuration also affected the foraging behaviour of bird species in a habitat. Authors stated that the typical breeding habitat of nightjar has decreased by 95% due to anthropogenic activities over the last 150 years (Evens *et al* 2018).

It was noted that location A seemed to offer better conditions for bird species namely Common Babbler, Common Myna, Black Drongo and Indian Peafowl with relative abundance of 5.65%, 4.87%, 4.73% and 4.47% respectively. Location A seemed to had fulfilled diverse food habits of different species of birds. At location B, bird species namely House Crow, Rose-ringed Parakeet, Cattle Egret and Common Babbler with relative abundance of 5.25%, 5.22%, 5.19% and 5.16% respectively were found in highest population counts. It might be due to better habitat suitability like cover and presence of food materials. At location B, Brown-headed Barbet was not noted. It might be due to absence of suitable habitat features like trees with dense canopy for its survival. Hamer *et al* (2015) had stated that habitat destruction and degradation led to decreased population counts of bird species in a particular habitat. At location C, bird species namely Blue Rock pigeon, House Crow, House Sparrow and Common Myna with relative abundance of 6.44%, 5.98%, 5.66%, 5.07% respectively were observed in maximum counts. At location C, people were noted to serve food grains to the birds during the morning and evening hours. Bird species namely Brown-headed Barbet, Yellow-legged Green Pigeon, Common Swallow, House Swift and Common Golden-backed Woodpecker were not noted at location C. It might be due to the non-availability of suitable habitat features as a result of human disturbances and anthropogenic activities. Changing habitats due to any developmental work bring about a change in the study

PLATE VIII

Common Golden-backed Woodpecker

Spotted Owlet

Little Green Bee-eater

Common Myna

Table 12: Bird composition and community characteristics from January 2017 to December 2017 at location C

Month / Bird Species	Jan 17	Feb 17	Mar 17	April 17	May 17	June 17	July 17	Aug 17	Sept 17	Oct 17	Nov 17	Dec 17	Relative Abundance (%) of birds
Pied Bushchat	1.81	2.51	1.66	0.80	2.51	1.25	0.71	0.39	0.38	0.74	0.85	3.40	1.34
Spotted Munia	3.01	2.01	3.73	1.20	2.09	1.67	2.14	1.94	1.54	0.74	1.70	0.49	1.83
Oriental Magpie-Robin	1.20	1.51	2.07	1.61	1.67	1.67	2.14	2.71	3.08	2.23	1.70	3.88	2.15
Brown-headed Barbet	-	-	-	-	-	-	-	-	-	-	-	-	-
House Sparrow	4.22	4.52	4.15	6.02	7.53	6.25	4.98	8.14	5.38	5.95	5.11	4.85	5.66
Large Pied Wagtail	3.01	1.51	2.49	1.61	0.84	3.33	1.42	0.78	1.92	2.23	2.55	1.94	1.93
Red-wattled Lapwing	4.22	4.02	2.90	2.01	3.77	2.92	2.14	1.55	1.92	4.46	4.26	1.46	2.92
Cattle Egret	8.43	5.03	1.66	2.01	1.26	3.33	3.20	1.94	2.31	1.49	2.13	1.94	2.71
Pied Myna	3.01	4.52	2.49	1.61	3.35	2.92	1.78	2.33	1.92	1.49	3.40	2.91	2.57
White-breasted Kingfisher	0.60	1.01	0.41	0.40	-	-	0.71	1.16	0.38	0.37	0.85	1.46	0.60
Indian Pond-Heron	1.20	2.51	2.90	3.21	2.51	3.75	2.49	3.88	4.62	5.20	3.83	3.88	3.41
Common Myna	9.04	6.03	4.56	5.22	5.86	3.33	3.20	3.88	5.77	5.20	5.11	5.34	5.07
Bank Myna	4.22	4.02	2.07	1.61	2.51	1.67	2.85	2.33	2.69	1.86	0.85	0.49	2.22
House Crow	6.02	5.53	4.98	8.03	6.28	8.33	5.34	5.43	6.15	5.58	4.26	5.83	5.98
Rose-ringed Parakeet	4.82	3.52	4.98	6.43	2.93	3.33	3.56	3.88	5.38	5.95	6.38	6.80	4.82
Yellow-legged Green Pigeon	-	-	-	-	-	-	-	-	-	-	-	-	-
Eurasian Collared-Dove	1.20	2.51	3.32	2.81	1.67	2.50	3.20	3.10	2.69	1.86	3.40	2.43	2.60
Blue Rock Pigeon	6.02	6.03	6.22	8.03	9.21	7.50	6.05	5.81	4.62	4.83	6.38	6.80	6.44
Little Green Bee-eater	1.20	4.52	2.07	1.61	2.51	1.25	1.78	0.78	0.38	0.74	-	0.49	1.41
Red-vented Bulbul	1.20	2.01	6.22	4.82	6.69	5.42	7.12	5.43	5.77	4.46	4.26	2.43	4.85
Spotted Owlet	-	-	-	-	-	-	-	-	-	-	-	-	-

Indian Robin	1.20	2.51	2.90	2.41	4.18	5.00	4.98	4.65	4.23	3.72	2.55	1.94	3.48
Purple Sunbird	8.43	6.03	4.15	2.41	1.26	2.08	4.98	5.81	4.62	3.72	3.40	4.37	4.15
Black Drongo	6.02	6.03	6.22	4.82	2.09	3.33	3.20	2.33	1.54	4.46	5.96	2.91	3.97
Black Redstart	1.20	0.50	1.24	2.01	1.67	3.33	3.20	2.33	1.92	1.49	2.13	0.97	1.90
Brown Rock Chat	4.22	4.02	2.07	3.61	2.51	5.00	4.98	3.88	1.15	1.86	3.40	1.94	3.20
Common Swallow	-	-	-	-	-	-	-	-	-	-	-	-	-
House Swift	-	-	-	-	-	-	-	-	-	-	-	-	-
Common Golden-backed Woodpecker	-	-	-	-	-	-	-	-	-	-	-	-	-
Asian Koel	1.20	0.50	2.07	1.61	3.77	2.08	2.14	1.16	1.54	2.97	2.13	2.91	2.04
Greater Coucal	0.60	-	0.83	1.61	3.35	-	1.78	1.16	2.31	2.60	2.13	1.94	1.58
Common Babbler	6.02	6.03	5.39	6.02	5.02	3.33	3.20	5.43	4.23	3.72	5.11	3.88	4.71
Common Hoopoe	1.20	2.01	2.07	2.41	-	0.83	2.85	2.33	1.54	1.86	3.83	3.40	2.04
Indian Roller	1.20	2.01	2.07	1.20	2.51	3.33	1.42	1.94	3.46	2.23	1.70	2.43	2.15
Baya Weaver	-	-	1.66	2.01	3.77	5.00	4.98	5.81	6.15	6.32	2.98	3.88	3.76
Black Kite	1.81	2.01	3.32	2.01	2.51	1.67	1.78	2.33	3.08	3.35	2.55	1.94	2.39
Wire-tailed Swallow	1.20	1.51	1.66	2.01	2.51	1.67	1.42	1.94	2.31	0.74	1.70	3.88	1.86
Indian Treepie	-	1.01	1.66	2.01	-	1.67	2.14	1.94	3.08	3.35	1.70	2.91	1.86
Indian Peafowl	1.20	2.51	3.73	4.82	1.67	1.25	2.14	1.55	1.92	2.23	1.70	3.88	2.39
Species Richness	31	31	33	33	30	31	33	33	33	33	32	33	
Species Diversity	3.15	3.27	3.36	3.29	3.25	3.29	3.37	3.32	3.33	3.33	3.34	3.35	
Species Evenness	0.92	0.95	0.96	0.94	0.95	0.96	0.96	0.95	0.95	0.95	0.96	0.96	

PLATE IX

Oriental Magpie-Robin

Red-wattled Lapwing

Indian Peafowl

House Sparrow

of the relationship between birds and their habitat. The distribution and number of birds has been mainly dependent on its habitat**.** But the agricultural lands are getting depleted by extensive urbanization and ever increasing population which has resulted in the habitat loss of many species (Mariappan *et al* 2013). The land-use composition affected bird species richness more than trophic levels and abundance. The heterogeneity of land uses in a habitat consistently promoted species richness (Pellisier *et al* 2017).

Girma *et al* (2016) had mentioned that bird abundance and richness is higher in less distributed areas where the vegetation cover is relatively better than severely degraded areas like over grazed habitats by livestock and deforested habitats. Birds on farmlands have exhibited the largest declines compared to birds that prefer other habitats. The decline in bird species may be significantly correlated to the environmental factors (Glemnitz *et al* 2015). Authors had mentioned that a total of thirty eight bird species and 699 individuals were recorded during the survey in fifty sampling plots in pure oak forests. They noted a total of nine feeding guilds namely carnivore (3 species), carnivore-insectivore (1 species), granivore (2 species), granivore- frugivore (2 species), insectivore (8 species), insectivore-frugivore (8 species), insectivore-granivore (7 species),insectivore-granivore-frugivore (5 species) and omnivore (Beskardes *et al* 2017). Workers stated that the distribution, abundance and composition of bird species are often associated with gradients such as vegetation cover and habitat availability (Cushing *et al* 2018).

4.5 Breeding Biology

Breeding biology of Black Drongo (*Dicrurus macrocercus*) and Indian Robin (S*axicolides fulicata*) was studied in nine transects of the selected location A, location B and location C. During the study period, all the breeding activities of Black Drongo and Indian Robin were studied.

4.5.1 Breeding season

The breeding season of Black Drongo was observed to extend from May to August in the present study. Previous studies have mentioned that Black Drongo breeding was between March to June (Ali *et al* 2010). In our study, the breeding activities of Indian Robin commenced in March and continued till July. Kumar (2011) mentioned that Indian Robin was found breeding between March to July.

4.5.2 Location A

4.5.2.1 Nesting

Three tree species namely Indian mahogany (*Chukrasia tabularis*), Sukh Chain (*Pongamia pinnata*) and Neem (*Azadirachta indica*) were found to be utilised by Black Drongo for nesting at transects IA, IIA and IIIA respectively. At both transects IVA and VA, Dhek (*Melia azedarach*) was utilized for nesting purposes (Table 13). Total of nine nesting sites were observed in PAU campus (transects IA, IIA, IIIA, IVA and VA). Two nesting sites

were located on Indian Mahogany, two on Sukh Chain, one on Neem and four on Dhek. It was found that the nesting trees were always in close proximity to agricultural field areas and electric power lines. Two nests of Black Drongo were not found on a single tree which reflected intra species competition and antagonistic behaviour between breeding pairs at studied locations.

Table 13: Mean tree height and mean nest height of Black Drongo at location A

Transects	Nests located	Tree species utilized for nesting	Mean tree height (m)	Mean nest height (m)
IA	2	Indian mahogany (*Chukrasia tabularis*)	13.50	7.50
IIA	2	Sukh Chain (*Pongamia pinnata*)	16.00	8.50
IIIA	1	Neem (*Azadirachta indica*)	13.50	9.10
IVA	1	*Dhek* (*Melia azedarach*)	14.50	6.90
VA	3	*Dhek* (*Melia azedarach*)	10.70	7.50

***Only one nest was observed on one tree**

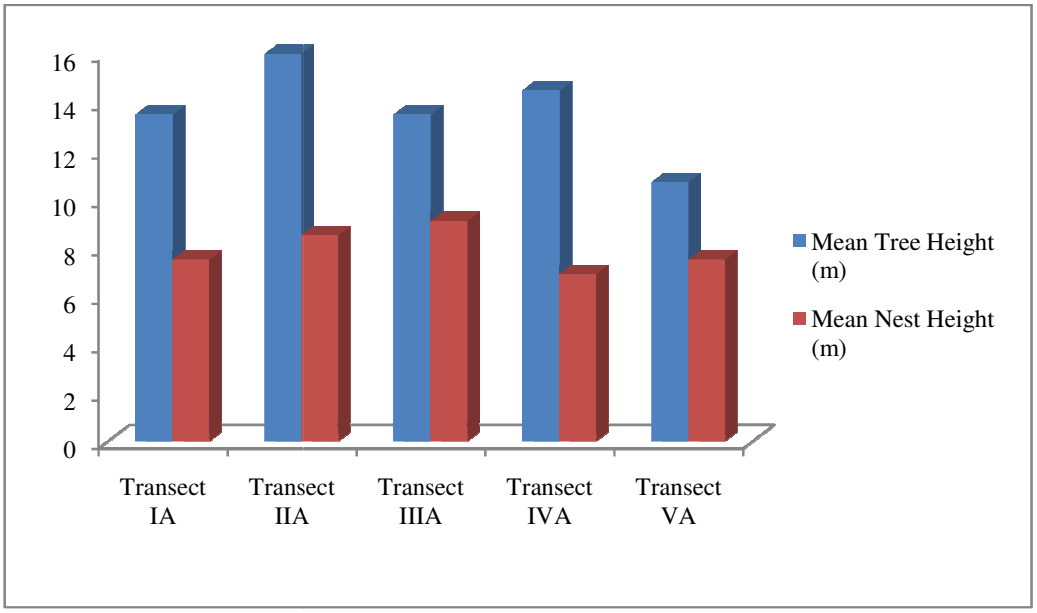


Fig 1: Mean tree height and mean nest height of Black Drongo at location A

The mean tree height of Indian mahogany (transect IA), Sukh Chain (transect IIA), Neem (transect IIIA), Dhek (transect IVA) and Dhek (transect VA) was 13.50 m, 16.00 m, 13.50 m, 14.50 m and 10.70 m respectively. The mean nest height of Black Drongo on Indian

PLATE X

Nest construction by Black Drongo

Nest of Black Drongo

PLATE XI

Bottom-cup shaped nest of Black Drongo

Mahogany (transect IA), Sukh Chain (transect IIA), Neem (transect IIIA), Dhek (transect IVA) and Dhek (transect VA) was 7.50 m, 8.50 m, 9.10 m, 6.90 m and 7.50 m respectively (Fig 1). All the observed nests were bottom cup shaped, constructed in the forked branch of the tree (Plate VIII). The nests were noted to consist of the nesting materials such as grass, dry fibres and twigs (Plate IX).

In the present study, it was noted that Indian Robin has been found to be a solitary mover and formed pairs only during the breeding season from March to July at studied locations. Both the parents participated in the nest formation (Plate XII). Six nesting sites were observed at location A out of which four ground nests were located in the undergrowth of hedges near roadside (transect IA, IIA and IIIA) and two ground nests were found in wild bushes (transect IVA) (Table 14).

Table 14: Type of nests and nesting sites of Indian Robin at location A

Location	Transects	Number of nests	Type of nests		Nesting sites
			Ground nest	Cavity nest	
A	IA	1	√	-	In undergrowth of hedge near roadside
	IIA	2	√	-	In undergrowth of hedge near roadside
	IIIA	1	√	-	In undergrowth of hedge near roadside
	IVA	2	√	-	On ground in wild bushes
	VA	-	-	-	-

√ signifies Indian Robin nest observed
- signifies Indian Robin nest not observed

4.5.2.2 Egg laying

The morphometerical characteristics of the eggs of Black Drongo in different clutches were measured at all the studied locations. Eggs from various transects of the selected location A was measured. It was noted that the eggs were creamish in colour with brown spotting of varying sizes (Plate X). Clutch size of 3–4 eggs was commonly observed; but clutches of 4 eggs were more frequent. The clutch size of 4 eggs was noted at transect IA (nest number 1A and 2A), IIA (nest number 3A and 4A), IIIA (nest number 5A), and VA (nest number 7A). The clutch size of 3 eggs was noted at transect IVA (nest number 6A) and VA (nest number 8A and 9A).

In the present study, it was found that the eggs of Indian Robin were pale greenish in background with specks and small reddish brown blotches (Plate XIII). The female was involved in egg incubation while the male was observed to guard the nests against the predators. Both the male and female Indian Robin performed the parental duties after

hatching of the eggs. The clutch size varied from 2 to 4, but clutches of 3 eggs and 4 eggs were more frequent. At transect IA, the clutch size was of 2 eggs. Clutch size of 4 eggs was noted at transect IIA and transect IIIA. Clutch size of 3 eggs was noted at transect IVA (Fig 2).

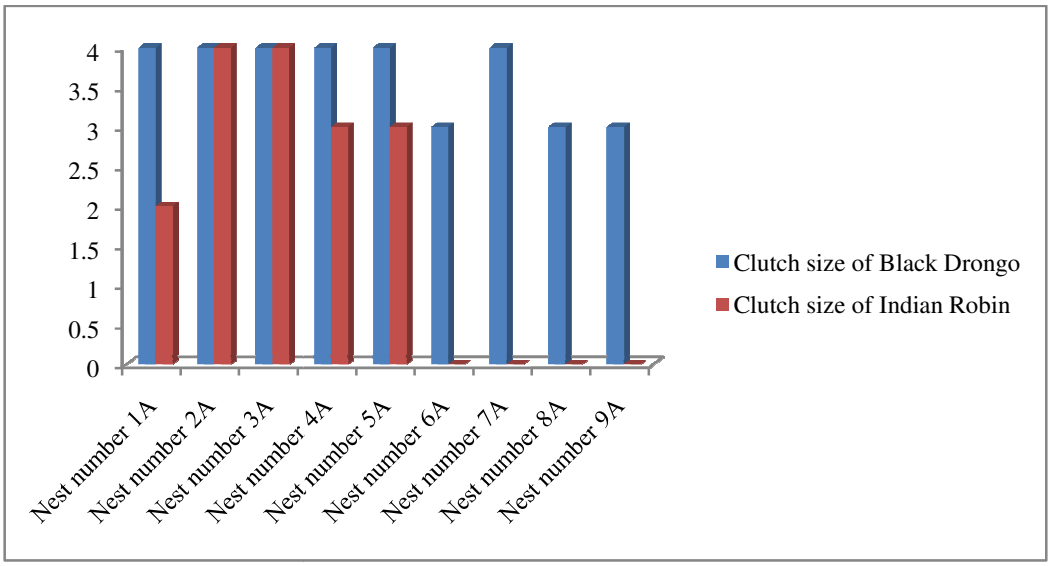


Fig 2: Clutch size of Black Drongo and Indian Robin at location A

4.5.2.3 Incubation period

In the present study, it was observed that both the sexes of Black Drongo shared all the parental duties during the nest formation and incubation period. While one of the parent was incubating the eggs, the other parent perched outside the nest. It was observed that after hatching of the eggs, one parent was always found around the nest, guarding the hatchlings from the invading predators while the other parent collected the food material to feed the hatchlings (Plate XI). The chicks were fed by both the parent birds. At transect IA, the incubation period of eggs of Black Drongo was of 12 days (nest number 1A) and 11 days (nest number 2A). At transect IIA, the incubation period was of 13 days (nest number 3A and 4A). At transect IIIA, the incubation period was of 16 days (nest number 5A). At transect IVA, the incubation period was of 14 days (nest number 6A). At transect VA, the incubation period was of 13 days (nest number 7A), 15 days (nest number 8A) and 12 days (nest number 9A).

It was noted that both the parent Indian Robin were observed to share the parental duties during incubation. Both sexes took care of the young ones but the eggs were incubated by the females (Plate XIV and Plate XV). The male Indian Robin was always observed guarding the nest, while female Indian Robin collected the food to feed the young ones (Plate XVI, Plate XVII and Plate XVIII). At transect IA, the incubation period of eggs of Indian Robin was of 11 days, 12 days, 10 days, 11 days and 12 days at transect IA, transect IIA, transect IIIA and transect IVA respectively (Fig 3).

PLATE XII

Eggs of Black Drongo

Black Drongo incubating the eggs in the nest

PLATE XIII

Chicks of Black Drongo

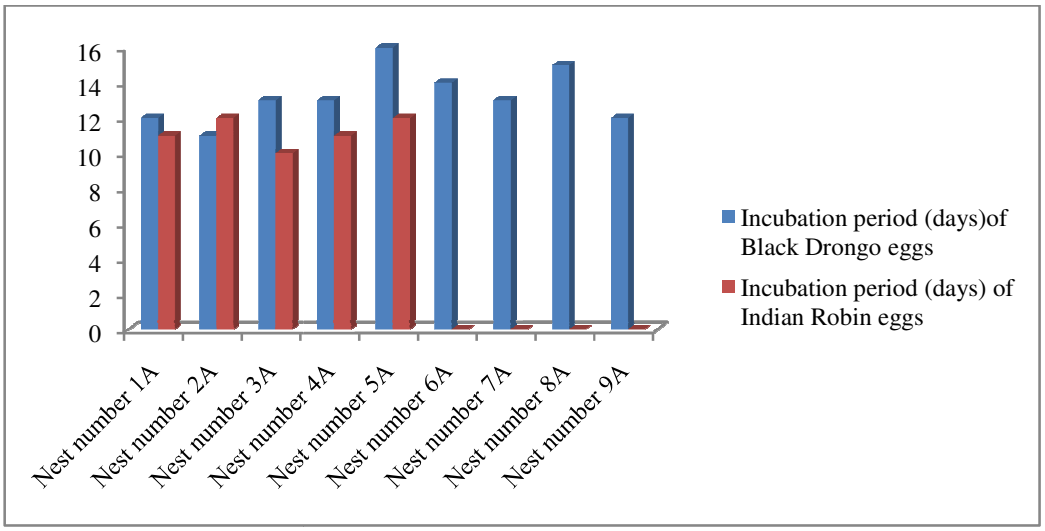


Fig 3: Incubation period (days) of eggs of Black Drongo and Indian Robin at location A

4.5.2.4 Hatching Success and Fledging Success

In Black Drongo, hatching success ranged from 75% to 100% at location A. Hatching success was observed 100% in nest number 3A, 4A, 6A 7A, 8A, 9A. Hatching success was noted 75% in nest numbers 1A, 2A and 5A. The fledging success ranged from 66.67 to 100 percent. Fledging success was noted 100 % in all the nest number 3A, 4A, 6A, 7A, 9A. Fledging success was noted 66.67% in nest numbers 1A, 2A, 5A and 8A (Table 15).

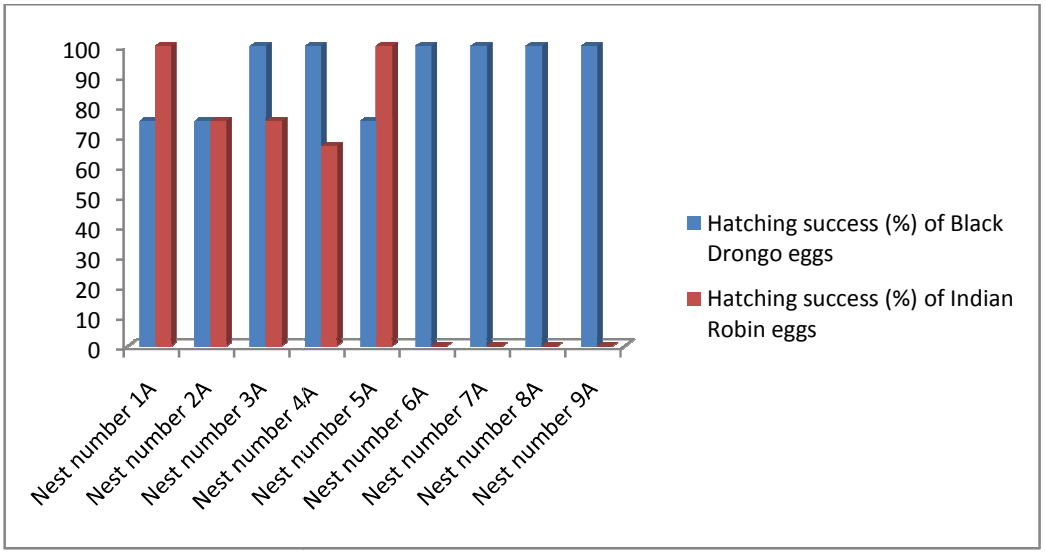


Fig 4: Hatching success (%) of eggs of Black Drongo and Indian Robin at location A

In Indian Robin, hatching success ranged from 66.67% to 100% at location A. Hatching success of eggs of Indian Robin was noted 100% in nest number 1A and 5A (Table 16). Hatching success was noted 75% in nest numbers 2A and 3A. Hatching success was noted 66.67% in nest number 4A (Fig 4). The fledging success ranged from 66.67 to 100 percent. Fledging success was noted 100 % in all the nest number 1A, 3A, 4A and 5A. Fledging success was noted 66.67% in nest numbers 2A (Fig 5).

Table 15: Hatching Success and Fledging Success of Black Drongo at location A

Locations	Transects	Number of Nests	Nest Number	Clutch Size	Incubation Period (Days)	Number of eggs hatched	Hatching success (%)	Nestling Period (Days)	Number of young fledged	Fledging success (%)
A	IA	2	1A	4	12	3	75.00	18	2	66.67
			2A	4	11	3	75.00	20	2	66.67
	IIA	2	3A	4	13	4	100	21	4	100
			4A	4	13	4	100	21	4	100
	IIIA	1	5A	4	16	3	75.00	22	2	66.67
	IVA	1	6A	3	14	3	100	19	3	100
	VA	3	7A	4	13	4	100	17	4	100
			8A	3	15	3	100	20	2	66.67
			9A	3	12	3	100	20	3	100

Table 16: Hatching and fledging success of Indian Robin at location A

Location	Transects	Nest Number	Clutch Size	Incubation Period (Days)	Number of eggs hatched	Hatching success (%)	Nestling Period (Days)	Number of young fledged	Fledging success (%)
A	IA	1A	2	11	2	100	7	2	100
	IIA	2A	4	12	3	75	8	2	66.67
	IIIA	3A	4	10	3	75	9	3	100
	IVA	4A	3	11	2	66.67	6	2	100
		5A	3	12	3	100	8	3	100

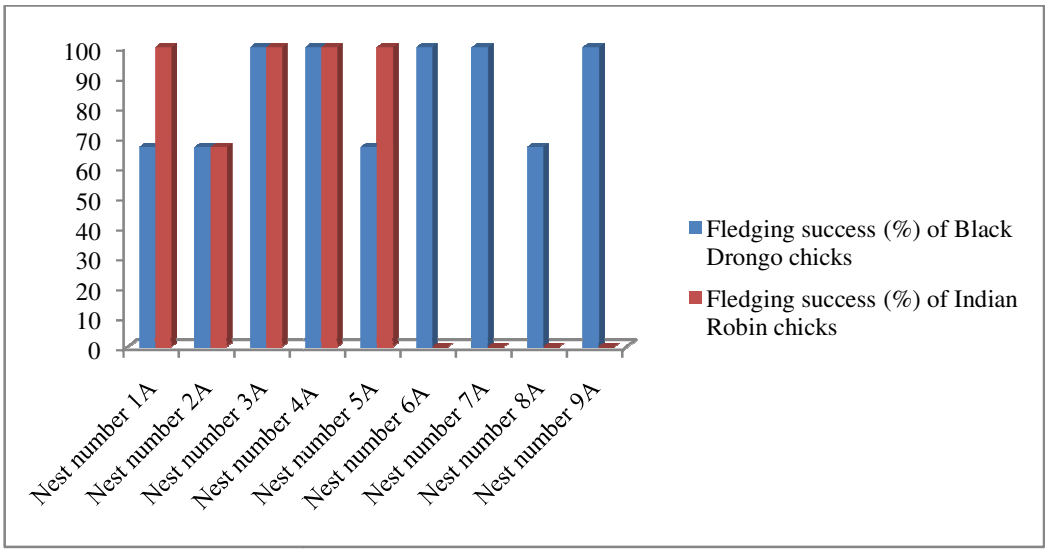


Fig 5: Fledging success (%) of chicks of Black Drongo and Indian Robin at location A

4.5.3 Location B

4.5.3.1 Nesting

Tree species namely Neem (*Azadirachta indica*) and Dhek (*Melia azedarach*) were noticed to be utilized by Black Drongo for nesting purposes at transects IB and IIB respectively. Five nesting sites were observed at location B (transect IB and IIB) out of which

Table 17: Mean tree height and mean nest height of Black Drongo at location B

Transects	Nests located	Tree species utilized for nesting	Mean tree height (m)	Mean nest height (m)
IB	2	Neem (*Azadirachta indica*)	13.50	10.50
IIB	3	Dhek (*Melia azedarach*)	15.00	11.25

*** Only one nest was observed on one tree**

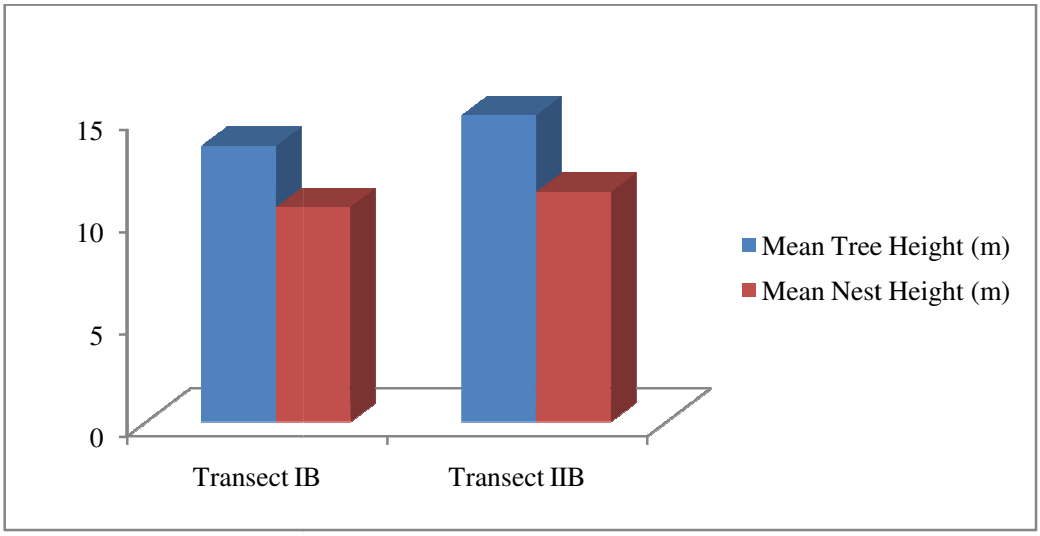


Fig 6: Mean tree height and mean nest height of Black Drongo at location B

two were located on Neem and three on Dhek tree (Table 17). The mean tree height of Neem (transect IB) and Dhek (transect IIB) was 13.50 m and 15.00 m respectively. The mean nest height of Black Drongo on Neem and Dhek was 10.50 m and 11.25 m respectively (Fig 6).

Five nesting sites were observed on the terrace of the underconstructed buildings at location B (transect IB and IIB). The buildings were under construction at four nesting sites located in transects IB and IIB (Table 18). The parent birds were busy in performing various breeding activities like collection of nesting materials and incubation of eggs inspite of human disturbance due to construction activity. At number of places, the observer had to convey to construction site labourers not to disturb the nesting sites of Indian Robin. At all the studied locations, buildings under construction were having the presence of wild shrubs in their immediate vicinity. The ubiquitous feature of shrub vegetation seemed to provide shelter from stray dogs as well as adequate insect food to parent birds.

Table 18: Type of nests and nesting sites of Indian Robin at location B

Location	Transects	Number of nests	Type of nests		Nesting sites
			Ground nest	Cavity nest	
B	IB	3	-	√	On the terrace of underconstructed buildings
	IIB	2	-	√	On the terrace of underconstructed buildings

√ **signifies Indian Robin nests observed**
- **signifies Indian Robin nests not observed**

4.5.3.2 Egg Laying

The clutch size of Black Drongo consisted of 4 eggs at location I. The clutch size of Indian Robin varied from 3 to 4 eggs, but clutches of 3 eggs were more frequent (Fig 7).

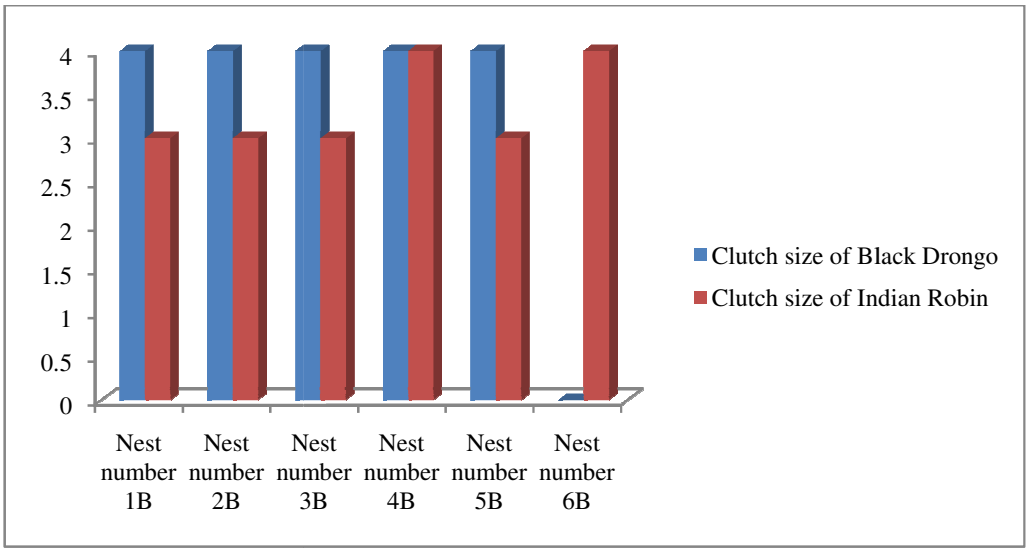


Fig 7: Clutch size of Black Drongo and Indian Robin at location B

PLATE XIV

Collection of nesting material by both male and female Indian Robin

Collection of nesting material by male Indian Robin

Collection of nesting material by female Indian Robin

PLATE XV

Nest of Indian Robin built in the crevices of underconstructed buildings

Egggs of Indian Robin in the nest

4.5.3.3 Incubation Period

At transect IB, the incubation period of eggs of Black Drongo was of 14 days (nest number 1B and 2 B) and 11 days (nest number 2A). At transect IIB, the incubation period was of 12 days (nest number 3B), 11 days (nest number 4B) and 13 days (nest number 5B).

At transect IB, the incubation period of eggs of Indian Robin was of 10 days (nest number 1B), 11 days (nest number 2B) and 12 days (nest number 3 B). At transect IIB, the incubation period was of 12 days (nest number 4B) and 13 days (nest number 5B and nest number 6B) (Fig 8).

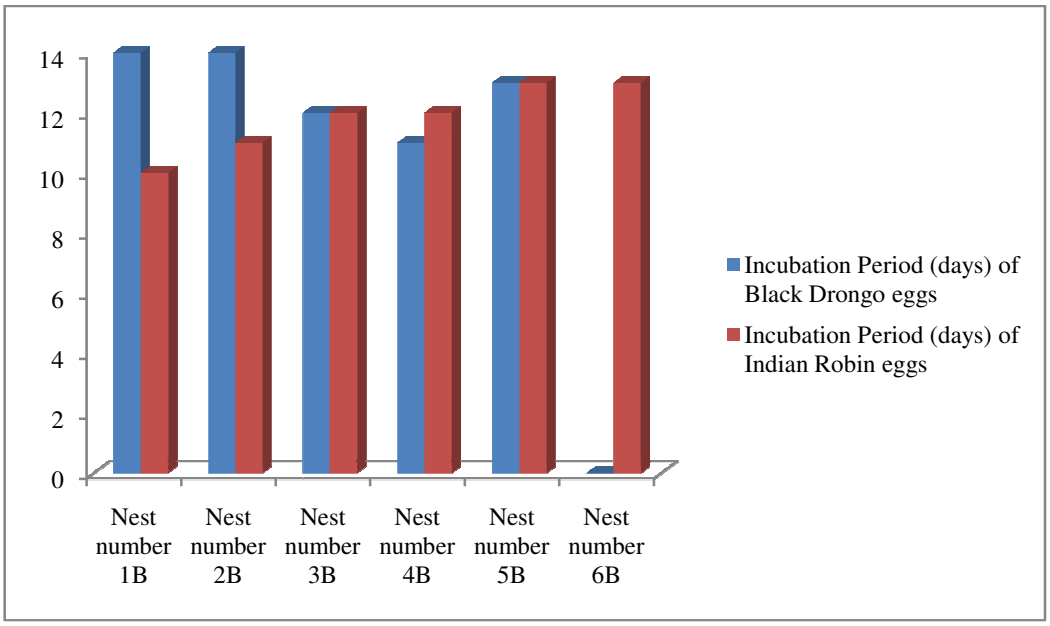


Fig 8: Incubation period (days) of eggs of Black Drongo and Indian Robin at location B

4.5.3.4 Hatching Success and Fledging Success

In Black Drongo, hatching success ranged from 50 to 100 percent. Hatching success was noted 100% in transect IIB (nest number 3B, nest number 4B and nest number 5B). At transect 1B, hatching success was 75% and 50% in nest number 1B and 2B respectively (Table 19). The fledging success ranged from 75 to 100 percent. Fledging success was observed 100% in nest number 1B, 2B, 3B 5B. Fledging success was noted 75% in nest number 4B (Fig 9).

In Indian Robin, hatching success ranged from 50 to 100 percent. Hatching success was noted 100% in transect IB (nest number 1B and nest number 2B) and IIB (nest number 5B and nest number 6B). Hatching success was 66.67% and 50% at transect IB (nest number 3B) and transect IIB (nest number 4B). Fledging success ranged from 66.67 to 100 percent. Fledging success was observed 100% in nest number 1B, 3B, 4B, 5B and 6B (Table 20). Fledging success was noted 66.67% in nest number 2B (Fig 10).

Table 19: Hatching and fledging success of Black Drongo at location B

Location	Transects	Number of Nests	Nest Number	Clutch Size	Incubation Period (Days)	Number of eggs hatched	Hatching success (%)	Nestling Period (Days)	Number of young fledged	Fledging success (%)
B	IB	2	1B	4	14	3	75.00	19	3	100
			2B	4	14	2	50.00	18	2	100
	IIB	3	3B	4	12	4	100	20	4	100
			4B	4	11	4	100	19	3	75.00
			5B	4	13	4	100	20	4	100

Table 20: Hatching and fledging success of Indian Robin at location B

Locations	Transects	Nest Number	Clutch Size	Incubation Period (Days)	Number of eggs hatched	Hatching success (%)	Nestling Period (Days)	Number of young fledged	Fledging success (%)
B	IB	1B	3	10	3	100	11	3	100
		2B	3	11	3	100	11	2	66.67
		3B	3	12	2	66.67	10	2	100
	IIB	4B	4	12	2	50	9	2	100
		5B	3	13	3	100	9	3	100
		6B	4	13	4	100	12	4	100

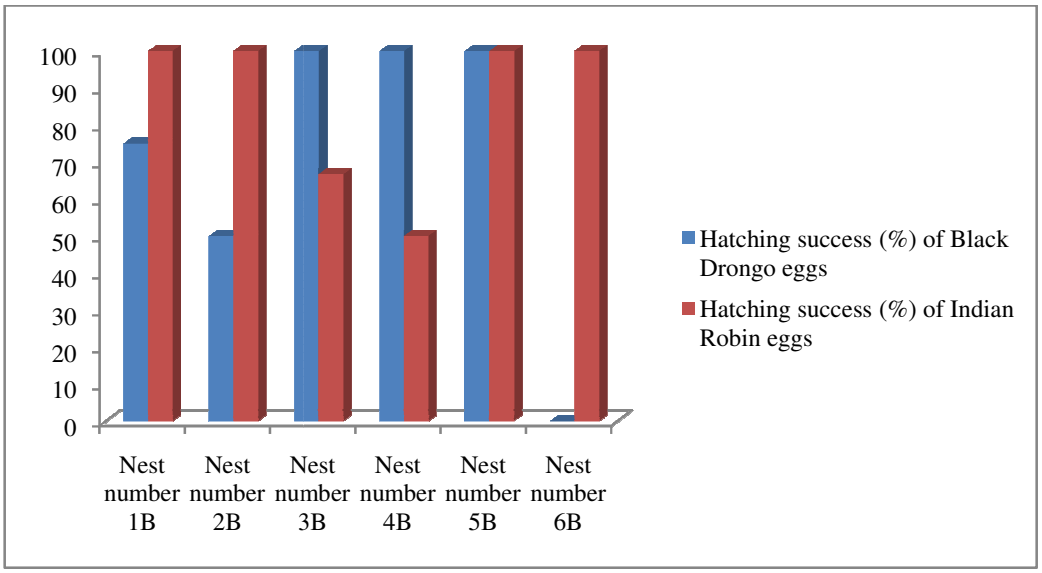


Fig 9: Hatching success (%) of eggs of Black Drongo and Indian Robin at location B

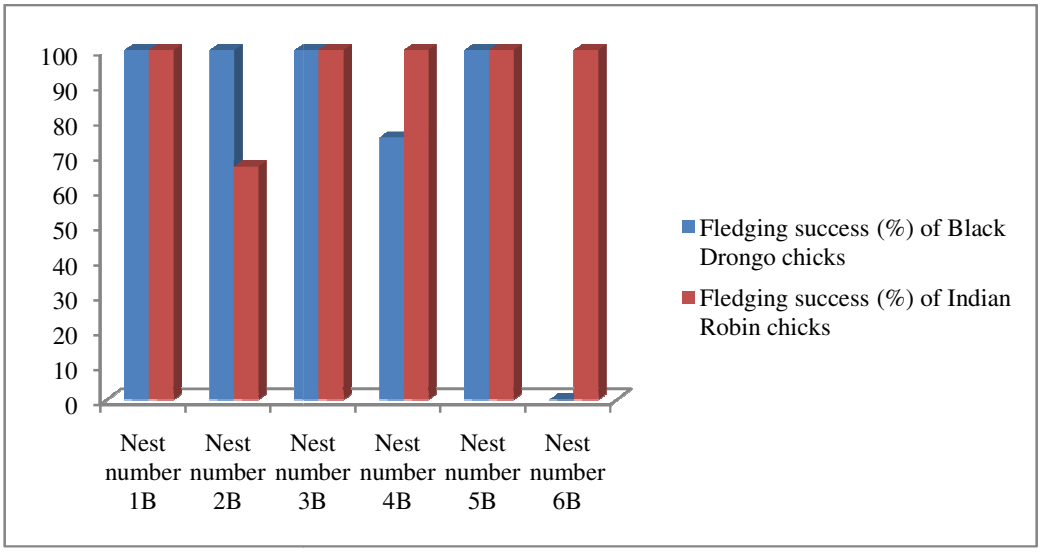


Fig 10: Fledging success (%) of eggs of Black Drongo and Indian Robin at location B

4.5.4 Location C

4.5.4.1 Nesting

Tree species namely Poplar (*Populus deltoids*) and Dhek (*Melia azedarach*) were observed to be utilized by Black Drongo for nesting purposes at transects IC and IIC respectively (Table 21). At location C (transect IC and IIC), a total of four nesting sites were observed out of which two were located on Poplar and two on Dhek. The mean tree height of Poplar (transect IC) and Dhek (transect IIC) was 15.00 m and 16.00 m respectively. The mean nest height of Black Drongo on Poplar and Dhek was 11.50 m and 12.25 m respectively (Fig 11).

Table 21: Mean tree height and mean nest height of Black Drongo at location C

Transects	Nests located	Tree species utilized for nesting	Mean tree height (m)	Mean nest height (m)
IC	2	Poplar (*Populus deltoids*)	15.00 `	11.50
IIC	2	Dhek (*Melia azedarach*)	16.00	12.25

*** Only one nest was observed on one tree**

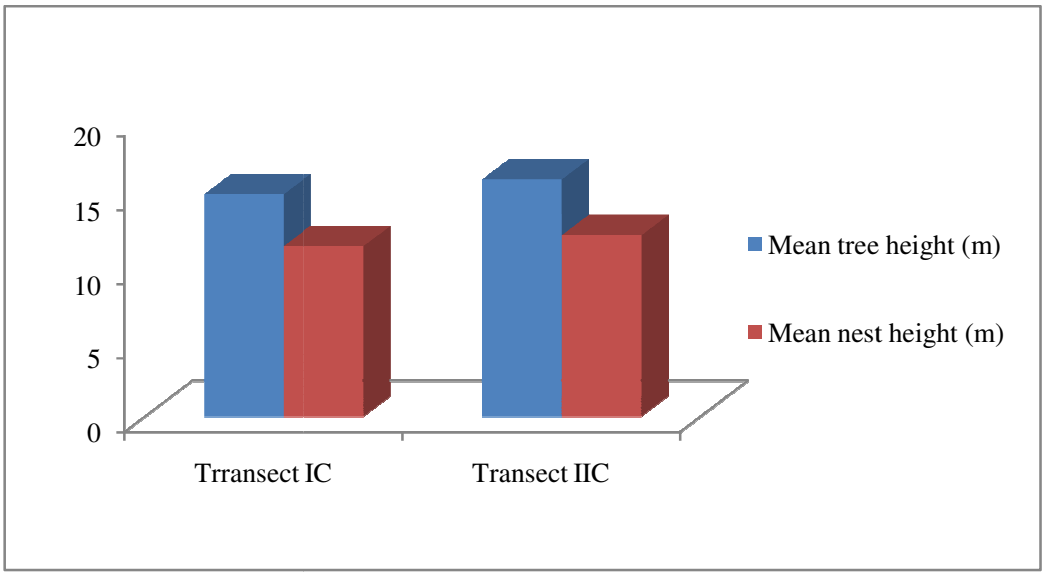


Fig 11: Mean tree height and mean nest height of Black Drongo at location C

At location C (transect IC and IIC) a total of six nesting sites of Indian Robin were observed in the crevices of underconstructed buildings. The observation at transect IA, IIA, IIIA and IVA has been found in contrast to the eleven nesting sites found in transect IB, IIB, IC and IIC (Table 22).

Table 22: Type of nests and nesting sites of Indian Robin at location C

Location	Transects	Number of nests	Type of nests		Nesting sites
			Ground nest	Cavity nest	
C	IC	4	-	√	In crevices of underconstructed buildings
	IIC	2	-	√	In crevices of underconstructed buildings

√ **signifies Indian Robin nest observed**
- **signifies Indian Robin nest not observed**

4.5.4.2 Egg Laying

Clutch size of Black Drongo consisted of 3–4 eggs, but clutches of 3 eggs were more

PLATE XVI

Newly hatched young ones of Indian Robin

PLATE XVII

Chicks of Indian Robin

PLATE XVIII

Male and female Indian Robin collecting food material to feed young ones

PLATE XIX

Male Indian Robin collecting food material to feed the young ones

PLATE XX

Female Indian Robin collecting food material to feed the young ones

frequent. At transect IC, the clutch size was of 3 eggs (nest number 1C and nest number 2C). At transect IIC, the clutch size was of 4 eggs and 3 eggs in nest number 3C and 4C respectively. The clutch size of Indian Robin varied from 2 to 4, but clutches of 3 eggs were more frequent (Fig 12).

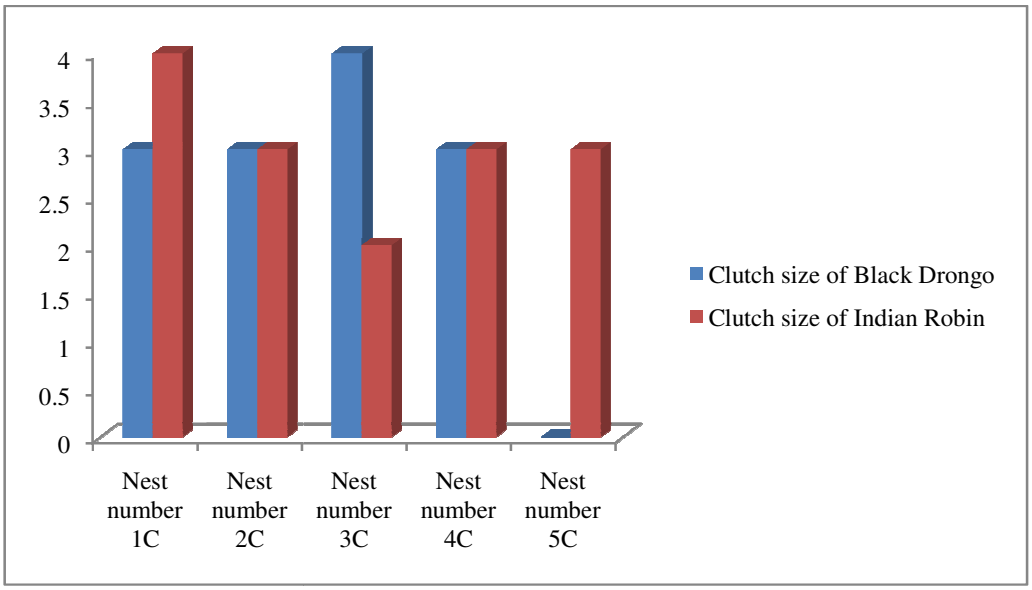


Fig 12: Clutch size of Black Drongo and Indian Robin at location C

4.5.4.3 Incubation Period

At transect IC, the incubation period of eggs of Black Drongo was of 15 days (nest number 1C) and 12 days (nest number 2C). At transect IIC, the incubation period was of 11 days (nest number 3C) and 13 days (nest number 4C).

At transect IC, the incubation period of eggs of Indian Robin was of 12 days (nest number 1C) and 11 days (nest number 2C) and 12 days (nest number 3C). At transect IIC, the incubation period was of 11 days (nest number 4C and nest number 5C) (Fig 13).

4.5.4.4 Hatching Success and Fledging Success

In Black Drongo, hatching success ranged from 66.67% to 100% at location C. Hatching success was noted 100% in transect IC (nest number 1C) and transect IIC (nest number 3C and 4C). At transect 1C, hatching success was 66.67% in nest number 2C. The fledging success ranged from 75 to 100 percent. Fledging success was observed 100% in nest number 1C, 2C and 4C (Table 23). Fledging success was noted 75% in nest number 3C (Fig 14).

In Indian Robin, hatching success ranged from 66.67% to 100% at location C. Hatching success of eggs of Indian Robin was noted 100% in transect IC (nest number 1C, nest number 2C and nest number 3C) and transect IIC (nest number 4C). At transect IIC, hatching success was 66.67% in nest number 5C (Table 24). Fledging success was observed 100% at both transects IC and transect IIC (Fig 15).

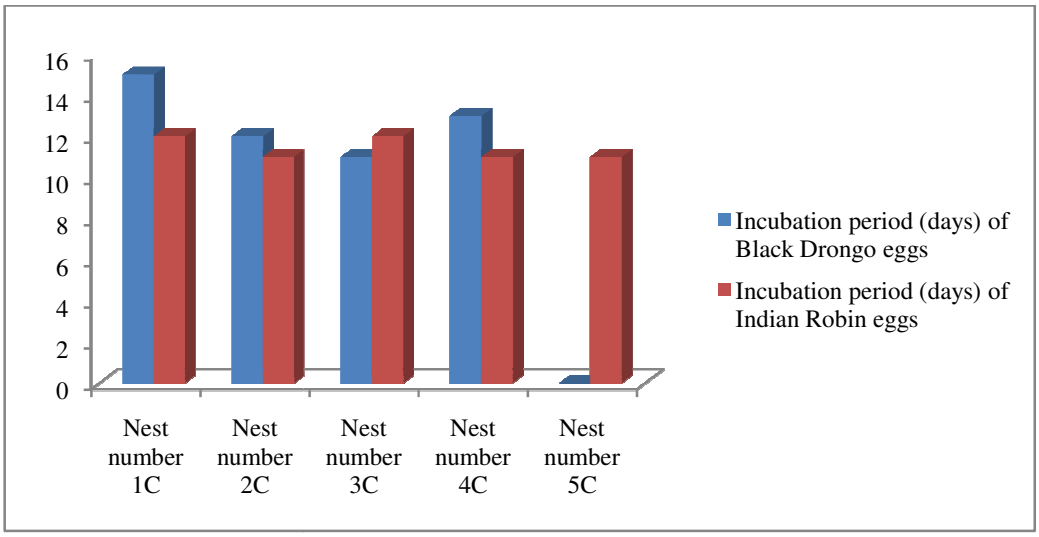


Fig 13: Incubation period (days) of eggs of Black Drongo and Indian Robin at location C

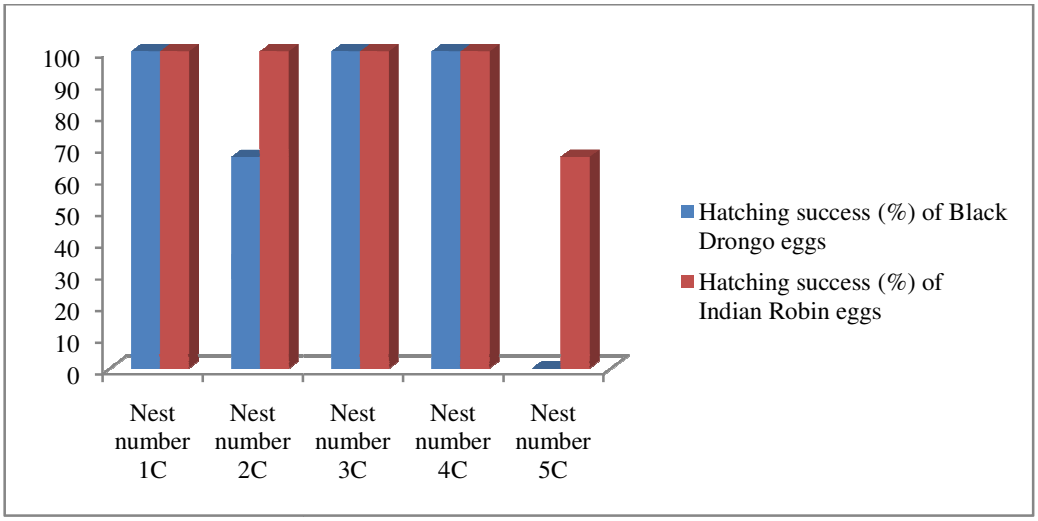


Fig 14: Hatching success (%) of eggs of Black Drongo and Indian Robin at location C

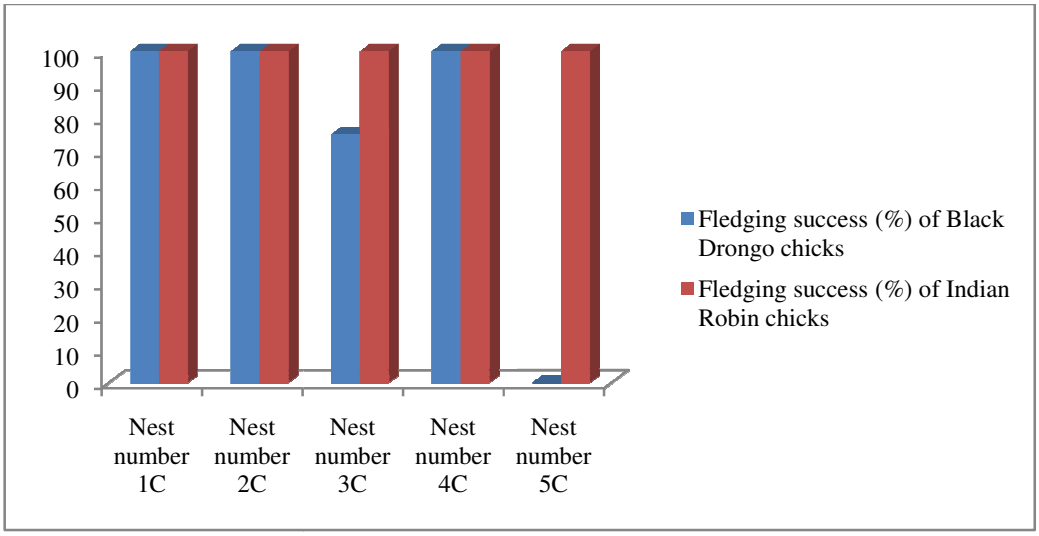


Fig 15: Fledging success (%) of Black Drongo and Indian Robin at location C

Table 23: Hatching and fledging success of Black Drongo at location C

Location	Transects	Number of Nests	Nest Number	Clutch Size	Incubation Period (Days)	Number of eggs hatched	Hatching success (%)	Nestling Period (Days)	Number of young fledged	Fledging success (%)
C	IC	2	1C	3	15	3	100	21	3	100
			2C	3	12	2	66.67	20	2	100
	IIC	2	3C	4	11	4	100	19	3	75.00
			4C	3	13	3	100	19	3	100

Table 24: Hatching and fledging success of Indian Robin at location C

Locations	Transects	Number of nests	Nest Number	Clutch Size	Incubation Period (Days)	Number of eggs hatched	Hatching success (%)	Nestling Period (Days)	Number of young fledged	Fledging success (%)
C	IC	3	1C	4	12	4	100	12	4	100
			2C	3	11	3	100	10	3	100
			3C	2	12	2	100	11	2	100
	IIC	2	4C	3	11	3	100	11	3	100
			5C	3	11	2	66.67	9	2	100

4.6 Morphometry of Eggs

4.6.1 Location A

4.6.1.1 Egg Length, Egg Breadth and Egg Weight

The mean egg length (in mm), mean egg breadth (in mm) and mean egg weight (in g) of Black Drongo ranged between 23.75±0.75 to 27.00±0.58, 15.67±0.0.29 to 19.67±0.33 and 4.53±0.03 to 5.13±0.09 respectively (Table 25). The mean egg length (in mm), mean egg breadth (in mm) and mean egg weight (in g) of Indian Robin ranged between 19.5±0.59 to 20.87±0.53, 14.5±0.59 to 15.43±0.44 and 5.55±0.19 to 5.85±0.18 at location A respectively (Table 26).

4.6.1.2 Egg Volume and Egg Shape Index

The egg volume (in cm^3) and egg shape index of Black Drongo ranged between 2.77 to 4.77 and 63.52 to 74.75 respectively. The egg volume (in cm^3) and egg shape index of Indian Robin ranged between 1.87 to 2.25 and 72.35 to 75.53 respectively.

4.6.1.3 Egg Specific Gravity

The specific gravity of eggs (gm/cm^3) of Black Drongo ranged between 1.04 to 1.85, 1.06 to 1.85 and 0.99 to 1.09 at location A. The specific gravity of eggs (gm/cm^3) of Indian Robin ranged between 2.52 to 2.97 at location A.

4.6.2 Location B

4.6.2.1 Egg length, Egg Width and Egg Weight

The mean egg length (in mm), mean egg breadth (in mm) and mean egg weight (in g) of Black Drongo ranged between 23.75±0.75 to 25.67±0.88, 15.75±0.95 to 19.67±0.33 and 4.60±0.09 to 5.13±0.09 respectively (Table 27). The mean egg length (in mm), mean egg breadth (in mm) and mean egg weight (in g) of Indian Robin ranged between 19.53±0.37 to 20.37±0.39, 14.60±0.42 to 15.40±0.42 and 5.43±0.33 to 5.60±0.37 respectively (Table 28).

4.6.2.2 Egg Volume and Egg Shape Index

The egg volume (in cm^3) and egg shape index of Black Drongo ranged between 2.77 to 4.54 and 64.28 to 76.63 respectively. The egg volume (in cm^3) and egg shape index of Indian Robin ranged between 1.90 to 2.19 and 73.76 to 76.12 respectively.

4.6.2.3 Egg Specific Gravity

The specific gravity of eggs (gm/cm^3) of Black Drongo ranged between 1.06 to 1.85. The specific gravity of eggs (gm/cm^3) of Indian Robin ranged between 2.52 to 2.91 at location B.

4.6.3 Location C

4.6.3.1 Egg Length, Egg Width and Egg Weight

The mean egg length (in mm), mean egg breadth (in mm) and mean egg weight (in g) of Black Drongo ranged 23.67±0.29 to 25.00±0.50, 19.00±0.50 to 19.67±0.76 and 4.23±0.13 to 4.40±0.09 respectively (Table 29). The mean egg length (in mm), mean egg breadth

Table 25: Morphometrical characteristics of eggs of Black Drongo in different clutches during breeding season in 2017 at location A

Egg characteristics → / Transects ↓	Number of trees used for nesting	Nest number	Clutch size	Mean egg length ± S.E. (mm)	Mean egg breadth ± S.E. (mm)	Mean egg weight ± S.E. (g)	Egg volume (cm^3)	Egg shape index	Specific Gravity of Eggs (gm/cm^3)
IA	2	1A	4	24.75±0.85	18.50±0.65	4.60±0.09	3.88	74.75	1.18
		2A	4	23.75±0.75	17.25±0.48	4.65±0.10	3.22	72.63	1.44
IIA	2	3A	4	24.50±0.65	15.75±0.95	5.13±0.09	2.77	64.28	1.85
		4A	4	25.25±0.85	16.25±0.63	5.05±0.06	3.05	64.36	1.65
IIIA	1	5A	4	27.00±0.58	19.67±0.33	4.97±0.03	4.77	72.85	1.04
IVA	1	6A	3	24.67±0.76	15.67±0.29	4.67±0.03	2.77	63.52	1.68
VA	3	7A	4	25.33±0.88	17.33±0.33	4.53±0.03	3.48	68.42	1.30
		8A	3	26.003±0.58	17.003±0.58	4.703±0.06	3.43	65.38	1.37
		9A	3	26.33±0.88	18.33±0.33	5.07±0.07	4.04	69.62	1.25

Table 26: Morphometrical characteristics of eggs of Indian Robin in different clutches during breeding season in 2017 at location A

Egg characteristics → / Transects ↓	Number of nests located	Nest number	Clutch size	Mean egg length ± S.E. (mm)	Mean egg breadth ± S.E. (mm)	Mean egg weight ± S.E. (g)	Egg volume (cm^3)	Egg shape index	Specific Gravity of Eggs (gm/cm^3)
IA	1	1A	2	19.5±0.59	14.5±0.59	5.55±0.19	1.87	74.36	2.97
IIA	1	2A	4	20.19±0.41	15.25±0.40	5.68±0.27	2.14	75.53	2.65
IIIA	1	3A	4	20.4±0.60	15.28±0.50	5.85±0.18	2.18	74.90	2.68
IVA	2	4A	3	20.73±0.55	15.43±0.44	5.67±0.23	2.25	74.43	2.52
		5A	3	20.87±0.53	15.10±0.48	5.60±0.26	2.17	72.35	2.58

Table 27: Morphometrical characteristics of eggs of Black Drongo in different clutches during breeding season in 2017 at location B

Egg characteristics → / Transects ↓	Number of trees used for nesting	Nest number	Clutch size	Mean egg length ± S.E. (mm)	Mean egg breadth ± S.E. (mm)	Mean egg weight ± S.E. (g)	Egg volume (cm^3)	Egg shape index	Specific Gravity of Eggs (gm/cm^3)
IB	2	1B	4	24.75±0.85	18.50±0.65	4.60±0.09	3.88	74.75	1.18
		2B	4	23.75±0.75	17.25±0.48	4.65±0.10	3.22	72.63	1.44
IIB	3	3B	4	24.50±0.65	15.75±0.95	5.13±0.09	2.77	64.28	1.85
		4B	4	25.25±0.85	16.25±0.63	5.05±0.06	3.05	64.36	1.65
		5B	4	25.67±0.88	19.67± 0.33	4.83± 0.03	4.54	76.63	1.06

Table 28: Morphometrical characteristics of eggs of Indian Robin in different clutches during breeding season in 2017 at location B

Egg characteristics → / Transects ↓	Number of nests located	Nest number	Clutch size	Mean egg length ± S.E. (mm)	Mean egg breadth ± S.E. (mm)	Mean egg weight ± S.E. (g)	Egg volume (cm^3)	Egg shape index	Specific Gravity of Eggs (gm/cm^3)
IB	3	1B	3	19.53 ± 0.37	14.60±0.42	5.53 ± 0.29	1.90	74.76	2.91
		2B	3	19.93±0.41	14.70±0.46	5.60±0.37	1.97	73.76	2.84
		3B	3	20.23±0.39	15.40±0.42	5.53±0.37	2.19	76.12	2.52
IIB	3	4B	4	19.50 ±0.35	14.73±0.26	5.43±0.33	1.93	75.54	2.81
		5B	3	19.90±0.35	15.07±0.36	5.53±0.29	2.06	75.73	2.68
		6B	4	20.37±0.39	15.13±0.29	5.50±0.35	2.13	74.27	2.58

Table 29: Morphometrical characteristics of eggs of Black Drongo in different clutches during breeding season in 2017 at location C

Egg characteristics → / Transects ↓	Number of trees used for nesting	Nest number	Clutch size	Mean egg length ± S.E. (mm)	Mean egg breadth ± S.E. (mm)	Mean egg weight ± S.E. (g)	Egg volume (cm^3)	Egg shape index	Specific Gravity of Eggs (gm/cm^3)
IC	2	1C	3	25.00 ±0.50	19.67±0.76	4.40±0.09	4.42	78.68	0.995
		2C	3	24.00 ±0.50	19.00±0.87	4.23±0.13	3.96	79.17	1.07
IIC	2	3C	4	24.75±0.63	19.50±0.87	4.33±0.10	4.30	78.79	1.01
		4C	3	23.67±0.29	19.00±0.50	4.27±0.10	3.90	80.27	1.09

Table 30: Morphometrical characteristics of eggs of Indian Robin in different clutches during breeding season in 2017 at location C

Egg characteristics → / Transects ↓	Number of nests located	Nest number	Clutch size	Mean egg length ± S.E. (mm)	Mean egg breadth ± S.E. (mm)	Mean egg weight ± S.E. (g)	Egg volume (cm^3)	Egg shape index	Specific Gravity of Eggs (gm/cm^3)
IC	3	1C	4	19.48±0.41	14.98±0.31	5.50±0.25	2.00	76.90	2.75
		2C	3	20.00±0.39	15.27±0.20	5.73±0.23	2.13	76.35	2.69
		3C	2	19.60±0.19	15.40±0.27	5.65±0.23	2.12	78.57	2.66
IIC	2	4C	3	19.93±0.35	14.93±0.25	5.00±0.27	2.03	74.91	2.46
		5C	3	19.93±0.41	15.50±0.27	5.53±0.28	2.19	77.77	2.52

(in mm) and mean egg weight (in g) of Indian Robin ranged between 19.48±0.41 to 20.00±0.39, 14.93±0.25 to 15.50±0.27 and 5.00±0.27 to 5.73±0.23 respectively (Table 30).

The egg volume (in cm^3) and egg shape index of Black Drongo ranged between 3.90 to 4.42 and 78.68 to 80.27 respectively. The egg volume (in cm^3) and egg shape index of Indian Robin ranged between 2.00 to 2.19 and 74.91 to 78.57 respectively.

4.6.3.3 Egg Specific Gravity

The specific gravity of eggs (gm/cm^3) of Black Drongo ranged between 0.99 to 1.09 at location C. The specific gravity of eggs (gm/cm^3) of Indian Robin ranged between 2.46 to 2.75 at location C.

4.6.4 Egg Shell Composition

In the present study, it was observed that albumen, yolk and shell weights of Black Drongo ranged from 1.27 gm to 2.81 gm, 2.58 gm to 2.95 gm and 0.28 gm to 0.52 gm, respectively (Table 31). It was observed that proportions of yolk, albumen and shell weights ranged from 56.73% to 61.43%, 28.13% to 55.10% and 5.96 % to 10.21 % respectively (Table 32). Average albumen, yolk and shell proportions of Black Drongo were 1.61±0.08, 2.80±0.03, 0.39±0.02 respectively.

Table 31: Weights (gm) of egg components of Black Drongo at selected locations

Locations	Nest number	Whole egg (gm)	Egg albumen (gm)	Egg yolk (gm)	Egg shell (gm)
A	1A	4.70	1.59	2.70	0.33
	2A	4.80	1.35	2.82	0.38
	3A	5.10	2.81	2.92	0.40
	4A	5.05	1.73	2.90	0.42
	5A	4.90	1.76	2.79	0.35
	6A	4.70	1.61	2.81	0.28
	7A	4.60	1.55	2.75	0.30
	8A	4.80	1.57	2.78	0.45
	9A	5.05	1.6	2.95	0.50
B	1B	4.70	1.34	2.88	0.48
	2B	4.75	1.44	2.86	0.45
	3B	5.20	1.73	2.95	0.52
	4B	5.00	1.59	2.92	0.49
	5B	4.90	1.64	2.87	0.39
C	1C	4.45	1.46	2.62	0.37
	2C	4.20	1.27	2.58	0.35
	3C	4.40	1.47	2.63	0.30
	4C	4.30	1.41	2.58	0.31
Mean±SE		4.76±0.07	1.61±0.08	2.80±0.03	0.39±0.02

Table 32: Proportion (%) of egg components to the weight of whole eggs of Black Drongo in selected locations

Locations	Nest number	Albumen (%)	Yolk (%)	Shell (%)
A	1A	33.83	57.45	7.02
	2A	28.13	58.75	7.92
	3A	55.10	57.25	7.84
	4A	34.26	57.43	8.32
	5A	35.92	56.94	7.14
	6A	34.26	59.79	5.96
	7A	33.70	59.78	6.52
	8A	32.71	57.92	9.38
	9A	31.68	58.42	9.90
B	1B	28.51	61.28	10.21
	2B	30.32	60.21	9.47
	3B	33.27	56.73	10.00
	4B	31.80	58.40	9.80
	5B	33.47	58.57	7.96
C	1C	32.81	58.88	8.31
	2C	30.24	61.43	8.33
	3C	33.41	59.77	6.82
	4C	32.79	60.00	7.21

In the present study, it was observed that albumen, yolk and egg shell weights of Indian Robin ranged from 1.35 gm to 1.60 gm, 3.27 gm to 3.79 gm and 0.39 gm to 0.51 gm respectively (Table 33). It was noted that proportions of yolk, albumen and shell weights ranged from 63.50% to 68.07%, 24.64% to 28.93% and 7.19% to 8.89%, respectively (Table 34). Average albumen, yolk and shell proportions of Indian Robin were 1.51±0.02, 3.64±0.03, 0.45±0.01 respectively.

Table 33: Weights (gm) of egg components of Indian Robin in selected locations

Locations	Nest number	Whole egg (gm)	Egg albumen (gm)	Egg yolk (gm)	Egg shell (gm)
A	1A	5.52	1.52	3.56	0.44
	2A	5.70	1.54	3.75	0.41
	3A	5.88	1.60	3.79	0.49
	4A	5.72	1.50	3.79	0.43
	5A	5.65	1.48	3.72	0.45
B	1B	5.50	1.51	3.51	0.48
	2B	5.74	1.58	3.65	0.51
	3B	5.62	1.47	3.66	0.49
	4B	5.48	1.35	3.73	0.40
	5B	5.57	1.45	3.69	0.43
	6B	5.53	1.52	3.56	0.45
C	1C	5.54	1.55	3.53	0.46
	2C	5.77	1.58	3.72	0.47
	3C	5.69	1.53	3.73	0.43
	4C	5.15	1.49	3.27	0.39
	5C	5.58	1.47	3.64	0.47
Mean±SE		5.60±0.04	1.51±0.02	3.64±0.03	0.45±0.01

Table 34: Proportion (%) of egg components to the weight of whole eggs of Indian Robin in selected locations

Locations	Nest number	Albumen (%)	Yolk (%)	Shell (%)
A	1A	27.54	64.49	7.97
	2A	27.02	65.79	7.19
	3A	27.21	64.46	8.33
	4A	26.22	66.26	7.52
	5A	26.19	65.84	7.96
B	1B	27.45	63.82	8.73
	2B	27.53	63.59	8.89
	3B	26.16	65.12	8.72
	4B	24.64	68.07	7.30
	5B	26.03	66.25	7.72
	6B	27.49	64.38	8.14
C	1C	27.98	63.72	8.30
	2C	27.38	64.47	8.15
	3C	26.89	65.55	7.56
	4C	28.93	63.50	7.57
	5C	26.34	65.23	8.42

4.6.5 Egg Shell thickness and $CaCO_3$ Content

The egg shell thickness and $CaCO_3$ content of the eggs of Black Drongo was estimated from the eggs collected from different areas. The shell thickness ranged from 0.14 mm to 0.27 mm (Fig 16, Fig 17 and Fig 18). The egg shell was thickest in nest number 7A thinner in eggs collected from nest number 5B (Table 35). The $CaCO_3$ weight and proportion were ranged from 0.16 gm to 0.38 gm and 51.35% to 89.29% respectively (Fig 19, Fig 20 and Fig 21). Eggs collected from nest number 3C had the lowest $CaCO_3$ weight while eggs collected from nest number 9A had the highest $CaCO_3$ weight.

Table 35: Eggshell thickness (mm) and $CaCO_3$ (%) content of eggs of Black Drongo at selected locations

Locations	Nest Number	Thickness (mm)	$CaCO_3$ (gm)	$CaCO_3$ (%)
A	1A	0.22	0.28	84.85
	2A	0.25	0.27	71.05
	3A	0.23	0.31	77.50
	4A	0.21	0.33	78.57
	5A	0.19	0.30	85.71
	6A	0.25	0.25	89.29
	7A	0.27	0.25	83.33
	8A	0.24	0.34	76.44
	9A	0.26	0.38	76.00
B	1B	0.17	0.37	77.08
	2B	0.15	0.33	73.56
	3B	0.16	0.37	71.15
	4B	0.19	0.35	71.43
	5B	0.14	0.31	79.49
C	1C	0.17	0.19	51.35
	2C	0.18	0.24	68.57
	3C	0.16	0.16	53.33
	4C	0.19	0.19	61.29

The egg shell thickness and $CaCO_3$ content of the eggs of Indian Robin was estimated from the eggs collected from different areas. The shell thickness ranged from 0.19 mm to 0.34 mm (Table 36). The egg shell was thickest in nest number 2B thinner in eggs collected from nest number 5C. The CaCO3 weight and proportion were ranged from 0.27 gm to 0.41 gm

and 61.70% to 81.40% respectively. Eggs collected from nest number 15 had the lowest CaCO3 weight while eggs collected from nest number 7 had the highest CaCO3 weight.

Table 36: Eggshell thickness (mm) and $CaCO_3$ (%) content of eggs of Indian Robin at selected locations

Locations	Nest number	Thickness (mm)	$CaCO_3$ (gm)	$CaCO_3$ (%)
A	1A	0.29	0.31	70.45
	2A	0.25	0.3	73.17
	3A	0.27	0.38	77.55
	4A	0.26	0.35	81.40
	5A	0.28	0.36	80.00
B	1B	0.24	0.35	72.92
	2B	0.34	0.41	80.39
	3B	0.31	0.35	71.43
	4B	0.30	0.31	77.50
	5B	0.32	0.33	76.74
	6B	0.31	0.35	77.78
C	1C	0.27	0.31	67.39
	2C	0.21	0.29	61.70
	3C	0.24	0.29	67.44
	4C	0.20	0.27	69.23
	5C	0.19	0.29	61.70

4.7 Statistical Analysis

One-way ANOVA was used to compare the various egg parameters like egg length, egg width, egg weight and egg volume at studied locations. Significant difference was found between egg length, egg width and egg volume at all the studied locations. Statistical analysis was insignificant between egg weights at all the studied locations. Significant variation was found between egg yolk weight and egg albumen weight at the studied locations (5 % level of significance). The results were significant for the egg shell weight and egg shell thickness. High values of significant results were found between calcium carbonate content at the studied locations.

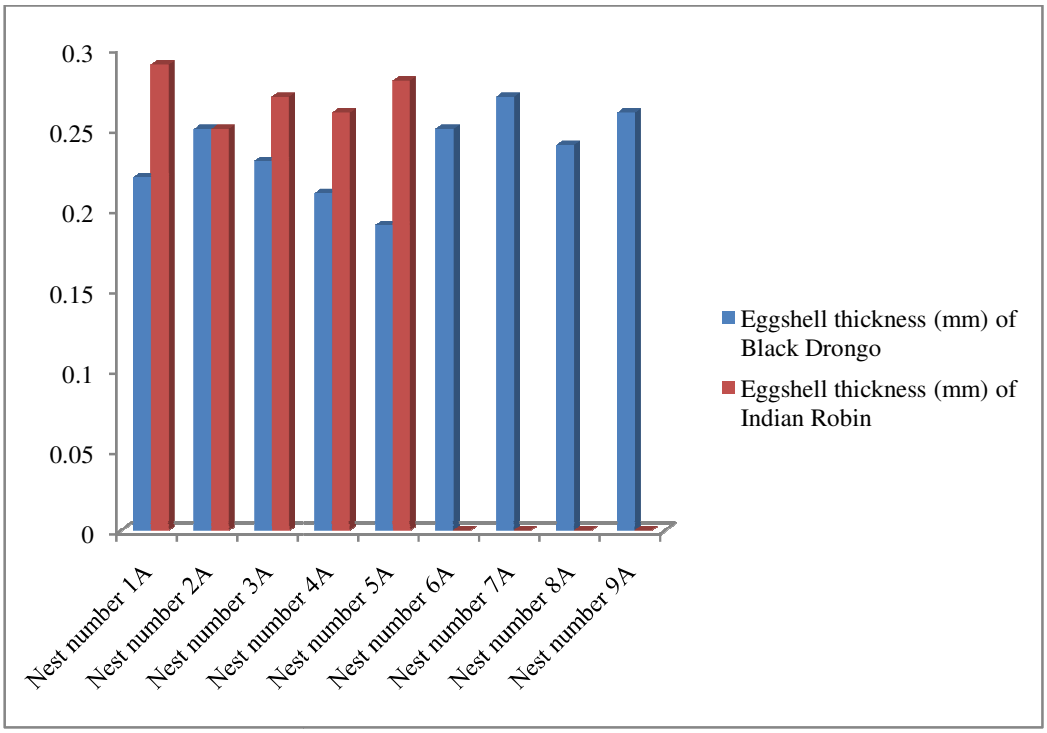


Fig 16: Eggshell thickness (mm) of Black Drongo and Indian Robin at location A

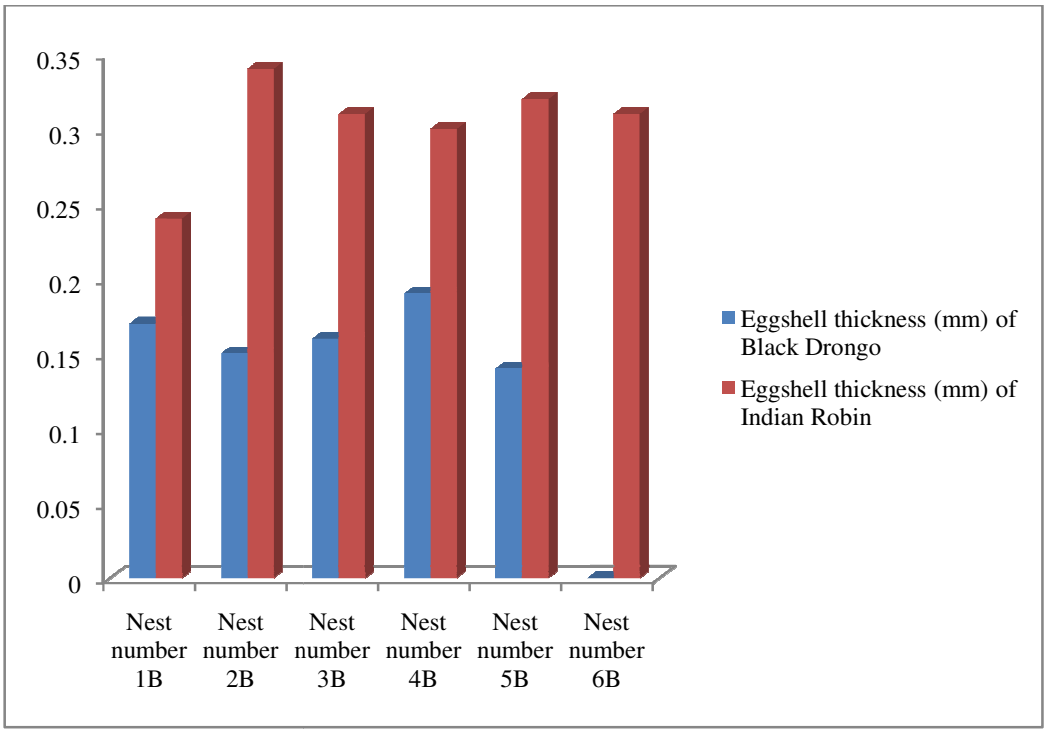


Fig 17: Eggshell thickness (mm) of Black Drongo and Indian Robin at location B

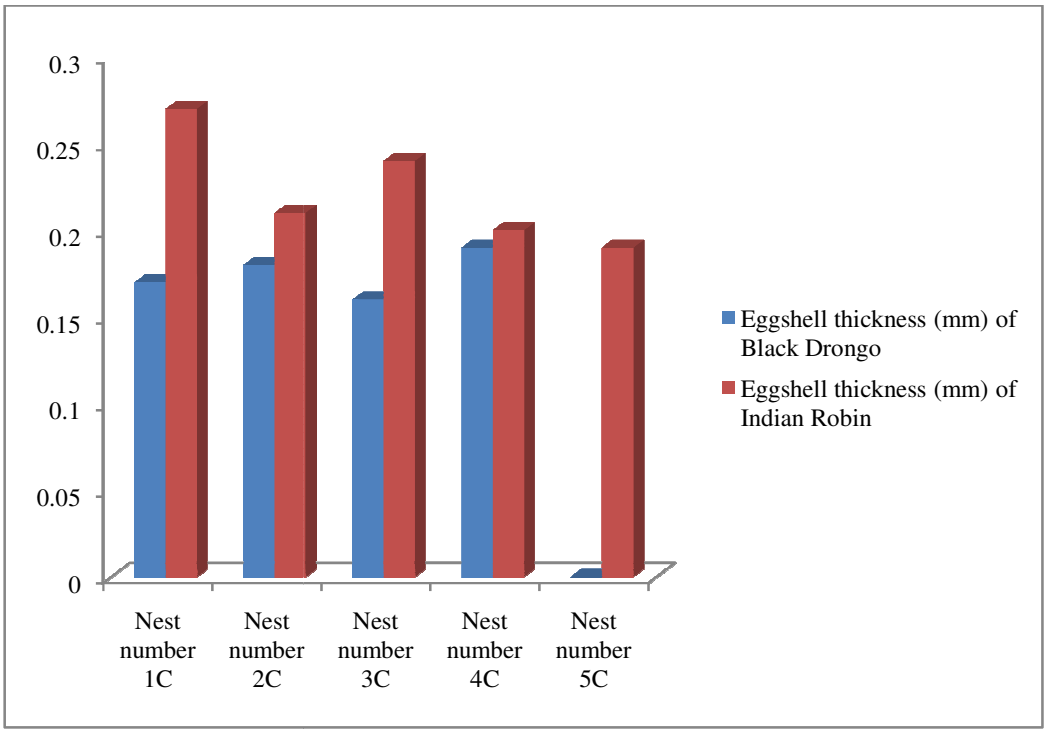


Fig 18: Eggshell thickness (mm) of Black Drongo and Indian Robin at location C

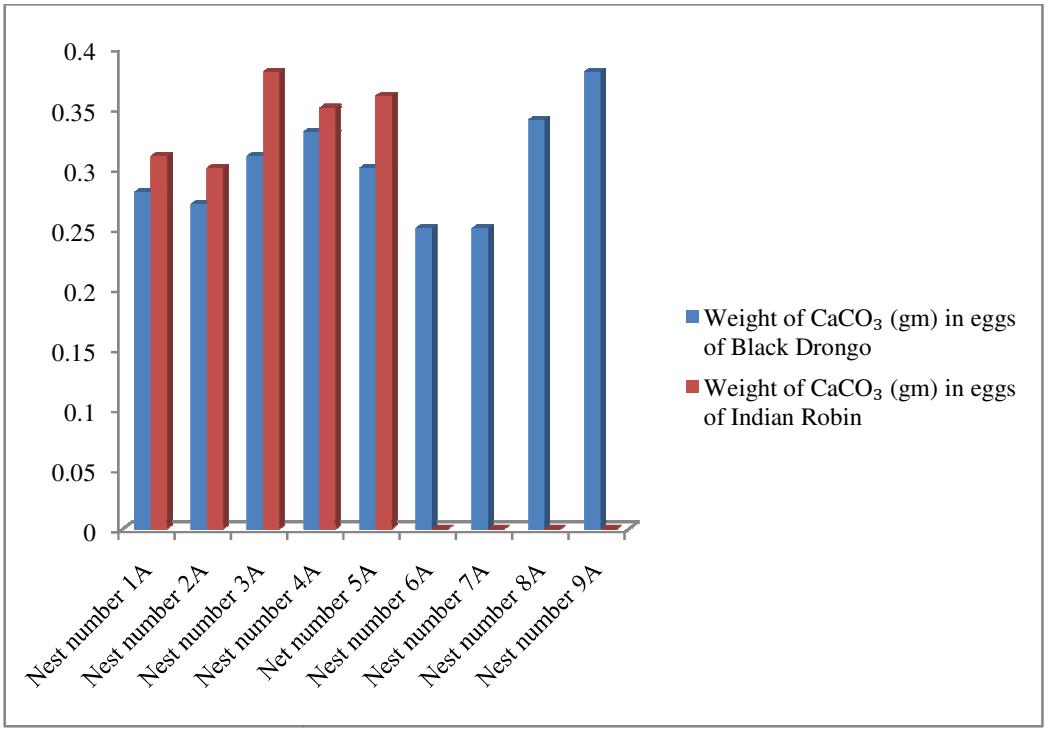


Fig 19: Weight of $CaCO_3$ (gm) in eggs of Black Drongo and Indian Robin at location A

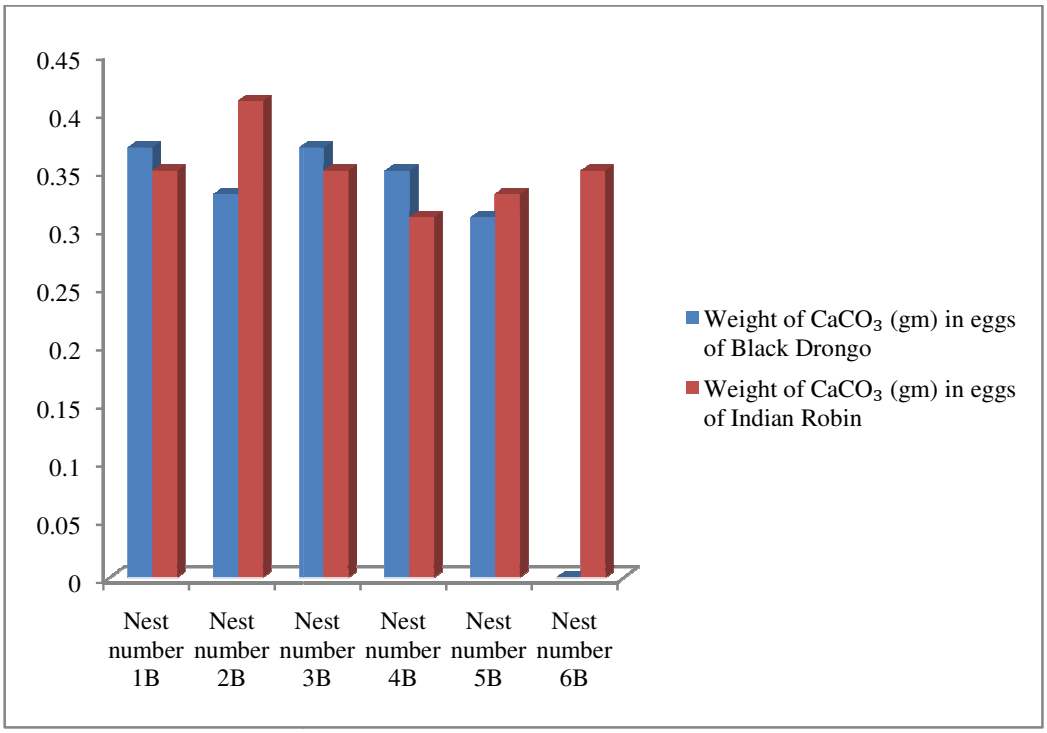


Fig 20: Weight of $CaCO_3$ (gm) in eggs of Black Drongo and Indian Robin at location B

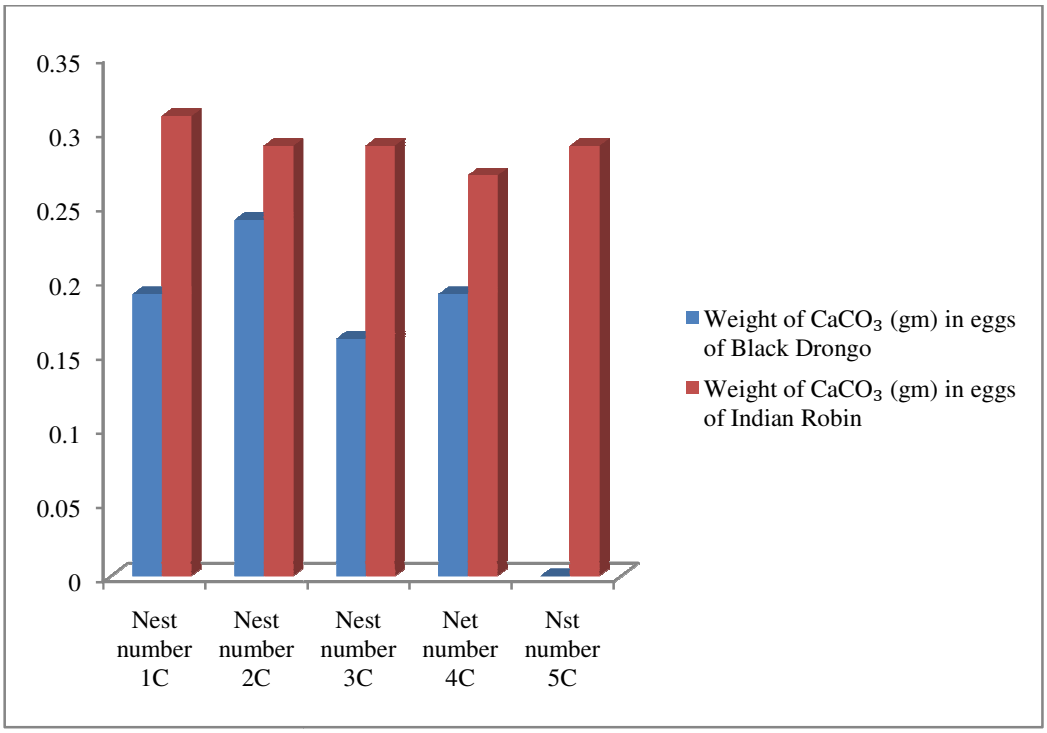


Fig 21: Weight of $CaCO_3$ (gm) in eggs of Black Drongo and Indian Robin at location C

In the present study, the breeding season of Black Drongo was noted to extend from May to August at all locations. In contrast, Shukkur and Joseph (1978) stated that the breeding season of Black Drongo extended from April to June in Calicut University Campus, Kerala. It was observed that Black Drongo preferred tall trees for the nest construction. The results correlated with Santisteban *et al* (2002) that Black Drongo constructed nests at tall trees as increased nest height might safe guard it from invading predators. Lammers and Collopy (2007) mentioned that the avian predators are attracted to electric power lines that provided better perches for prey detection and prey hunting. Authors had monitored the breeding success of House Sparrow in artificial nest boxes which showed that its breeding season extended from early April and mid- August in England (Peach *et al* 2008). Narayana *et al* (2014) mentioned the interlink between the perch types and perch height the habitat and availability of surrounding food resources. Workers had mentioned that Black Drongo preferred perching on trees and electric power lines during breeding and non-breeding season respectively (Kaur and Kler 2018).

During present investigations, it was found that Black Drongo built a thin bottomed cup shaped nest in the forked branch of a tree. The nest was made up of nesting materials i.e. fibres, grass, twigs and no vegetative material. Black Drongo preferred those trees for nesting that were in close proximity to agricultural field areas and nearby electric power lines. Shukkur and Joseph (1978) mentioned that majority of the nests of Black Drongo were located on the Jackfruit trees *Artocarpus integrifolia* at the Calicut University campus. Factors namely suitable mate, temperature, rainfall and nesting materials determine the nesting season of Black Drongo (Sokal and Rohlf 1981). Author had stated that Black Drongo preferred trees for nesting near the electric power lines as they provide sites for perching, prey detection and prey hunting (Ali 2003). Radhakrishnan (2006) mentioned that out of the total 21nests of Black Drongo, 48% were present on Rain tree (*Enterolobium saman*), 28% on Babool tree (*Acacia nilotica*), 19 % on Neem tree (*Azadirachta indica*) and 5% on Tamarind tree (*Tamarindus indicus*). Asokan *et al* (2009) also reported that the preference of electric power lines in nesting tree selection in Common Mynas (*Acridotheres tristis*) and Baya Weavers (*Ploceus philippinus*). Similar findings were stated by Ali *et al* (2010) that the nesting tree of Black Drongo had the potential habitats namely agricultural field areas and perching sites i.e. trees proximal to electric power lines. Workers had mentioned that the main nesting trees utilized by Indian Pond Heron were Bamboo (*Bambusa longispiculata*) and Mango (*Mangifera indica*). Nesting materials utilized by Indian Pond Heron were chiefly small sticks of Mango, Tamarind (*Tamarindus indica*), Bel (*Aegle marmelos*) and leaves of Bamboos (Jaman *et al* 2012).

In the present study, the breeding season of Indian Robin was observed to extend from March to July. The results are in line with previous studies that the breeding season of

Indian Robin began in March (George 1963). Ali (2002) had stated that the nests of Indian Robin were mainly located below the stone, tree stump hole or inside an earthen pot. During present investigation, it was noted to inhabit the undergrowth of hedges and crevices/terrace of under constructed buildings for nesting activities. It seemed that changing land use practices i.e. establishment of new colonies in periphery of cities encroaching on agricultural field areas of villages which have added constraints on the nesting activities. It was noted that some degree of change in case of Indian Robin would be due to landuse changes like developing colonies at outskirts of villages. Kler (2003) had mentioned that Brownbacked Indian Robin had been noted to aggressively defend its territory. It was noted that habitat alteration may be considered as most potent and dominant factor which seemed to limit the preferred nesting sites of Indian Robin at studied locations. Practices such as conversion of the agroecosystem into another landuse will make these sites limited in number for avian insectivorous bird species (Osborn 2005). It has been mentioned in literature that the nesting preferences of Indian Robin in various habitats such as wall covered with dense creeper plant, near roadside, in wild bushes, in iron dumping in lantana bushes mud hole. Birds use a variety of strategies for successful execution of their breeding activities. It is carried out by the investment of a lot of energy to find a suitable mate, safe nesting site and pair bond-formation (Kumar 2011). In present work, it was noted that the nests of Indian Robin were located in the terrace tops and crevices of under constructed buildings. In our study, conflicts had been recorded at feeding sites between Indian Robin and Common Babbler. Authors had stated that the relative abundance of Indian Robin ranging from 1.27% to 4.38 % in and around village ponds of district Barnala, Punjab. It was further stated that Indian Robin had occupied insectivorous trophic level (Kaur *et al* 2018). Authors had mentioned that low relative abundance of Indian Robin was noted in total bird population studied in orchids of Ludhiana district, Punjab (Sidhu and Kler 2018)

In present study, it was noted that both the parents of Black Drongo shared parental duties during nest formation. Authors had mentioned that female Indian Robin was usually accompanied by their mates in nest building (Weatherhead and Montgomerie 1991). It was also noted to defend its nests against the invading predators. Similar results were noted by Ali (2002) that both the sexes share all the domestic duties and were bold in defence of their nest during the breeding activity. It was observed that both the parents of Indian Robin shared parental duties during nest formation. It was noted that the average clutch size of Black Drongo ranged from 3 to 4. Authors had stated that the clutch size of birds had been mostly dependent on the age of the parents, with younger parents laying less number of eggs (Ndithia *et al* 2007). In the present study, the incubation of the eggs of Black Drongo was done by both the parents. While one of the parents was incubating the eggs, the other parent was noted in close proximity to the nest. It was noted that the average incubation period of Black

Drongo was 13±0.34 days. Authors stated that the incubation period of Black Drongo lasted mostly from 13 to 16 days and both the parents took equal part in the nestling period and in feeding of chicks (Ali *et al* 2010). Authors reported that house sparrow had an average clutch size of 2-6 eggs in Haryana (Chopra *et al* 2012). Workers had mentioned that both the sexes of Black Drongo were not observed on ground together during the breeding season. They took turns for foraging and food, while one of them was always near the nesting site. House Crows were noticed attacking the nests of Black Drongo, during the incubation period (Kaur and Kler 2018).

During the present study, variation in the clutch size of Indian Robin ranged from 2 to 4 at studied locations. Authors had well illustrated that eventual clutch size in birds was determined by the nutrient reserves of the female (Ankney and Macinnes 1978) and availability of food rich in protein (Krapu 1981). Hussell and Quinney (1987) had stated that in many bird species, the clutch size variation had been related with abundance of food materials in the surroundings. In the present observations, the egg of Indian Robin was incubated by the female and the male was noted in close proximity to the nest during egg laying. The results correlated with those given by (Weatherhand and Montgomerie 1991). Kumar (2011) mentioned that the average incubation period and nestling period of Indian Robin was 11.86±0.03 days and 13.25±0.27 days respectively. Authors stated that the clutch size of Indian Pond Heron varied from 3 to 4 eggs with an average of 3.7 eggs (Jaman *et al* 2012). Author reported that Indian Robin was a human loving bird and was very sensitive to any disturbance in nest building and egg laying as they leave the nest if disturbed (Das *et al* 2017). Authors mentioned that the average clutch size of Black-crowned Night Heron (*Nycticorax nycticorax)* was 3.1±0.6 eggs (Ashoori *et al* 2017).

Author had emphasised need to study nesting and foraging ecology of common bird species like Brownbacked Indian Robin and House Sparrow in the residential areas so as to study alterations in the habitat accompanied by interspecies avian competition in urban areas. Brownbacked Indian Robin is a familiar and confiding bird species found around villages and towns in addition to other bird species like Purple Sunbird *Nectarinia asiatica*, Little Brown Dove *Streptopelia senegalensis* and Blue Rock Pigeon *Columba livia* (Kler 2003). Pidgeon *et al* (2003) mentioned that the vegetative composition and micro-habitat around nesting tree have been important factors in relation to nest placement and success of avian species. The vegetation and micro-habitat not only provided food and nesting site to the avian species but also provided nesting materials for the construction of the nest. Sangha and Naoroji (2004) had stated that birds built their nests at odd places (gas pipes, sewage, at top of buildings and inter space among girders). Evens *et al* (2018) stated that the landscape heterogeneity affected the connectivity between nightjars' functional habitats and influenced their foraging behaviour that determined the individual health and their population processes.

Workers had reported that habitat changes lead to adaptation in various bird species (Johnson and Mangalaraj 2001). Wotton *et al* (2002) determined that houses built between 1945 and 1984 were more suitable for House Sparrows if no recent roof repairs had been undertaken. Kler (2005) had recorded 64 species of birds constituting 11 orders and 29 families in different villages falling under 6 different districts. Kaur *et al* (2018) had stated that Black Drongo belonged to trophic level comprising of invertebrates. The habitat features of transect V and transect VII constituted agricultural field areas having abundant invertebrate food which might be the reason that the number of nests were higher at these studied sites. Kler and Kumar (2015) mentioned that Black Drongo was found most abundant in the agricultural habitats Indian Robin was often seen hunting for caterpillars and insects in wild bushes and agricultural areas at all the studied locations. It was also noted to feed on the grains and bread crumbs which depicted that it has omnivorous type of habits to survive and flourish in urban areas. It could be inferred from the present study that Indian Robin is undeterred by human presence and various construction activity. Author had mentioned that Indian Robin constituted a major group of 20 bird species that had cumulative abundance ranging from 10% to 15 % of total bird population. Author had stated that the House Sparrow preferred small crevices or holes near roofs for nesting sites (Vincent 2005). Authors had mentioned that presence of human beings also affected the nest placement of avian species (Eggers *et al* 2006). Jaman *et al* (2012) stated that the Pond Heron selected the nesting sites surrounding the human settlements near the pond and other water bodies. Authors had reported that adaptations in nesting behaviour of bird species namely House Crow, Spotted Munia, Baya Weaver Bird, Red-vented Bulbul in cultivated crops, shrubs, exotic trees, indigenous trees and manmade structures (Sohi and Kler 2017).

Out of all the studied locations, maximum and minimum values of mean egg length of Black Drongo were noted at transect III and IX respectively. Maximum of mean egg breadth of Black Drongo were noted at transect III and VII. Minimum values of mean egg breadth were noted at transect IV. Maximum values of mean weight of Black Drongo were noted at transect II and VII while minimum was noted at transect VIII. The highest egg volume was recorded at transect III while lowest was noted at transect II, IV and VII. The highest and lowest egg shape index was noted at transect IX and IV respectively. The highest egg specific gravity of Black Drongo was noted at transect VII, II and lowest was noted at transect IX. Waste food dumps were found at transect III. In addition, people were also observed offering food to birds during the lunch hours which might be the possible reason for increase in the egg length and egg weight at transects III and II respectively in comparison to other transects. The maximum and minimum values of mean egg length of Indian Robin were noted at transect IV and VIII respectively. Maximum and minimum values of mean egg breadth were noted at transect IX and I respectively. Maximum and minimum values of mean

weight were noted at transect III and IX respectively. The highest egg volume of Indian Robin was recorded at transect IV. Lowest egg volume was found at transect I. The highest and lowest egg shape index was noted at transect VIII and IV respectively. The highest and lowest egg specific gravity was noted at transect I and IX respectively. The egg shape index is essential for the estimation of eggshell quality. It also determined that the eggs (hens eggs) with optimal shape and without any defects were effective and safe for transportation (Nikolova and Kocevski 2006). Sahan *et al* (2003) stated that the egg shape, resistance and shell structure i.e. traits that are essential for a normal hatching processes are indirectly determined by the egg specific gravity. It served as an indicator of eggshell quality. Authors had mentioned that specific gravity for three broilers of different age (30 weeks, 45 weeks and 60 weeks) were 1.085, 1.082 and 1.082 gm/cm^3, respectively (Luquett *et al* 2004).

Authors further stated that the the ratio of yolk to albumin was highest in pheasant (0.65) followed by chukar (0.60), guinea fowl (0.55) and quail (0.52). The proportion of yolk to the total egg weight was highest in pheasant (35.7%) followed by chukar (33.9%) and quail (30.6%). The albumin content was highest in quail (61.2%). The albumin content in chukar, pheasant and guinea fowl was in the range of 55.6– 57.4 percent. The egg shell thickness of chukar, pheasant, quail and guinea fowl were 0.0231 cm, 0.0241 cm, 0.0174 cm and 0.0462 cm respectively (Song *et al* 2000). Ardia *et al* (2006) stated that the egg quality variation was determined by a combination of environmental conditions, food resources and individual quality during the laying period. Authors had stated that eggshell thickness has been examined in various populations of *Falcon peregrinus* subjected to different levels of environmental contamination (Falk *et al* 2006, Wegner *et al* 2005). Castilla *et al* (2010) mentioned that the clutches from heavier females of Falcon taxa consisted of larger and harder eggs with thicker shells and thicker egg membranes. Eggs laid later in the laying sequence and produced by older females were relatively smaller and softer with relatively thin egg membranes and eggshells. If this observation extrapolated to Indian Robin, it could be suggested that thinnest egg shell in nest number 5C might be related to the fact that the eggs were laid by the older female.

Workers stated that the eggshells are mainly composed of calcium and magnesium carbonates (Mora *et al* 2011). Authors had studied inorganic elements in egg shell of some wild birds namely House Sparrow, White-eared Bulbul, Collared Dove and Rock Dove. They observed that Calcium percentage was the highest percentage among the other elements which were 97.3, 97.4, 97.8 and 97.8% respectively. The CaCO3 percentage was significantly less than that noted for eggs of other wild bird species (Faris *et al* 2012). Authors stated that the calcium percentage in House Sparrow, White- eared Bulbul, Collared dove and Rock dove was 97.3%, 97.4%, 97.8% and 97.8 % respectively (Al-Obaidi *et al* 2012). Authors mentioned that the association between the availability of dietary or environmental calcium

and eggshell maculation led to calcium shortage that resulted in localized eggshell thinning. It was further stated that the egg shell thickness decreased in the course of embryonic development (Orlowski *et al* 2015). Stoddard *et al* (2017) mentioned the correlation of egg shape with flight ability on broad taxonomic scales, suggesting that adaptations for flight may have been critical drivers of egg-shape variation in birds. Authors had mentioned that the breeding sites and incubation posture influenced the ability of parent birds to manipulate egg position. The posture selection during the incubation period might influence the egg-shape variation across birds as a whole (Birkhead *et al* 2018).

It could be inferred from the present study that the nests of Black Drongo were higher in number as it seemed to have the ideal habitat requirements for its successful breeding at location A. Location B and location C provided more favourable features like nesting materials, nesting sites, vegetation cover as per the needs of breeding pair of Indian Robin as compared to Black Drongo. It could be concluded that the habitat requirements of Black Drongo for breeding purposes include Indian Mahogany (*Chukrasia tabularis*), Sukh Chain (*Pongamia pinnata*), Neem (*Azadirachta indica*) and Dhek (*Melia azedarach*). It had been further observed from the present study that the best suited habitat of Indian Robin must consist of undergrowth of hedges/bushes and crevices/holes in the buildings.

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CHAPTER – V

SUMMARY

The present study on the nesting and breeding behaviour of Black Drongo and Indian Robin was carried out for twelve months from January to December 2017 in the campus of Punjab Agricultural University (PAU), Ludhiana i.e. location A, village Baranhara (district Ludhiana) i.e. location B and village Ladian Khurd (district Ludhiana) i.e. location C. Observations were taken on the weekly basis during the morning and evening hours during the study period. At location A, a total of 39 bird species were noted. Common Babbler (5.65%) was the most abundant species in the bird community followed by the Common Myna (4.87%), Black Drongo (4.73%), Indian Peafowl (4.47%) and Blue Rock Pigeon (4.04%). The other species recorded in appreciable numbers were Purple Sunbird (4.00%), Red-vented Bulbul (3.80) and House Crow (3.25%). Asian Koel (2.94%), Rose-ringed Parakeet (2.85 %), Brown Rock Chat (2.85%) were found to be most equally abundant species. Pied Myna (1.60 %), Oriental Magpie-Robin (1.29%) and Cattle Egret (1.10 %) were less than 2%. Four bird species namely Brown-headed Barbet, House Sparrow, White-breasted Kingfisher and Spotted Owlet constituted less than 1% of total birds. A total of 38 bird species were recorded at village Baranhara i.e. location B. House Crow was the most abundant species. Rose-ringed Parakeet (5.22%), Cattle Egret (5.19%) was second and third most abundant species followed by Common Babbler (5.16%) and Common Myna (5.10%). Four species namely Spotted Owlet, House Swift, Common Golden-backed Woodpecker and Indian Treepie constituted less than 1% of total birds. A total of 33 bird species were recorded at village Ladian Khurd i.e. location C. Blue Rock Pigeon (6.44%) was the most abundant species. House Crow (5.98%) and House Sparrow (5.66%) were second and third most abundant species followed by Common Myna (5.07%) and Red-vented Bulbul (4.85%). White-breasted Kingfisher constituted less than 1% of total birds.

The breeding season of Black Drongo was noted to extend from May to August at all the studied locations. Detailed observations on 18 nests of Black Drongo were made on its breeding parameters and egg characteristics. All the observed nests were bottom cup shaped, constructed in the forked branch of the tree. The nests were built of the nesting material such as grass, dry fibres and twigs. Nine nesting sites were observed in PAU campus (transects IA,IIA,IIIA,IVA and VA) out of which two were located on Indian Mahogany, two on Sukh Chain, one on Neem and four on Dhek. Five nesting sites were observed in the village Baranhara (transect IB and IIB) out of which two were located on Neem and three on Dhek tree. A total of four nesting sites were observed at village Ladian Khurd (transect IC and IIC) out of which two were located on Poplar and two on Dhek. Tree species specificity (four indigenous and one exotic) of Black Drongo for nesting preferences was recorded. It was

noted that Black Drongo preferred tall trees for the nest construction. It was observed that the nesting trees were always in close proximity to agricultural fields and electric power lines. Two nests of Black Drongo were not found on a single tree at studied locations which showed intra species competition and antagonistic behaviour between breeding pairs.

Detailed observations on 18 nests of Black Drongo were made on its breeding parameters and egg characteristics. Clutch size (3-4 eggs), incubation period (13±0.34 days), hatching and fledging success of Black Drongo were noted. It was observed that both the parents shared all the parental duties during the nest formation and incubation period. While one of the parent was incubating the eggs, the other parent perched outside the nest. It was observed that after hatching of the eggs, one parent was always found around the nest, guarding the hatchlings from the invading predators while the other parent collected the food material to feed the hatchlings. The chicks were fed by both the parents. Both the hatching pattern and hatching success of eggs of Black Drongo was studied in 18 clutches at the studied locations.

The breeding season of Indian Robin was observed to extend from March to July at studied locations. Both the parents participated in the nest formation. In the present study, six nesting sites were observed in PAU campus out of which four ground nests were located in the undergrowth of hedges near roadside (transect IA, IIA and IIIA) and two ground nests were found in wild bushes (transect IVA). Five nesting sites were observed in the village Baranhara (transect IB and IIB) on the terrace of the underconstructed buildings. A total of six nesting sites were observed at village Ladian Khurd (transect IB and IIB) in the crevices of underconstructed buildings. The observation at transect IA, IIA, IIIA and IVA has been found in contrast to the eleven nesting sites found in transect IB, IIB, IC and IIC. The clutch size varied from 2 to 4, but clutches of 3 eggs were more frequent. Eggs were pale greenish in background with specks and small reddish brown blotches. The female was noted to incubate the eggs while the male were observed to guard the nests against the predators. Indian Robin was found close to human habitation and perched on the rooftops, water tanks, wooden poles and electric wires. The average incubation period was 11.5±0.22 days. The hatching and fledging success of eggs of Indian robin was studied in 16 clutches at the studied locations.

In the present study, it was observed that albumen, yolk and shell weights of Black Drongo ranged from 1.27 gm to 2.81 gm, 2.58 gm to 2.95 gm and 0.28 gm to 0.52 gm, respectively.

It was observed that proportions of yolk, albumen and shell weights ranged from 56.73% to 61.43%, 28.13% to 55.10% and 5.96 % to 10.21 %, respectively. Average albumen, yolk and shell proportions of Black Drongo were 1.61±0.08, 2.80±0.03, 0.39±0.02. The egg shell thickness and $CaCO_3$ content of the eggs of Black Drongo was estimated from the eggs collected from different areas. The shell thickness ranged from 0.14 mm to 0.27 mm. The CaCO3 weight and proportion were ranged from 0.16 gm to 0.38 gm and 51.35% to 89.29%

respectively. It was noted that albumen, yolk and egg shell weights of Indian Robin ranged from 1.35 gm to 1.60 gm, 3.27 gm to 3.79 gm and 0.39 gm to 0.51 gm respectively. It was noted that proportions of yolk, albumen and shell weights ranged from 63.50% to 68.07%, 24.64% to 28.93% and 7.19% to 8.89%, respectively. Average albumen, yolk and shell proportions of Indian Robin were 1.51±0.02, 3.64±0.03, 0.45±0.01 respectively. The egg shell thickness and $CaCO_3$ content of the eggs of Indian Robin was estimated from the eggs collected from different areas. The shell thickness ranged from 0.19 mm to 0.34 mm. The $CaCO_3$ weight and proportion were ranged from 0.27 gm to 0.41 gm and 61.70% to 81.40% respectively.

Black Drongo had selected five tree species (four indigenous and one exotic) as nesting sites. It could be concluded that plantations of four indigenous trees species (Indian mahogany, Sukh Chain, Neem and Dhek) and one exotic tree species (Poplar) are required in agricultural habitats to provide nesting sites for Black Drongo, thereby resulting in its conservation. The data generated on breeding biology of Black Drongo along with habitat characteristics may provide impetus to conservation efforts of this species in agricultural ecosystem. It could be inferred from the present study that Indian Robin showed adaptive breeding behaviour like shift in the nest site selection in relation to habitat features like available nesting sites and habitat cover have been observed at border line of developing colonies and village outskirts. It seemed that bird species like Indian Robin have learned to adapt to human development in areas having constraint of resource requirements. Detailed studies are required to assess the development in the breeding activities of common bird species in response to anthropogenic activities at the margin line of rural and urban habitat so as to give their remedial location species conservation measures in agroecosystem of Punjab.

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ANNEXURE - I

Scientific names of all the bird species observed during study period

S. No.	Species (Common names)	Species (Scientific names)
1	Pied Bushchat	*Saxicola caprata*
2	Spotted Munia	*Lonchura punctulata*
3	Oriental Magpie-Robin	*Copsychus saularis*
4	Brown-headed Barbet	*Megalaima zeylanica*
5	House Sparrow	*Passer domesticus*
6	Large Pied Wagtail	*Motacilla maderaspatensis*
7	Red-wattled Lapwing	*Vanellus indicus*
8	Cattle Egret	*Bubulcus ibis*
9	Pied Myna	*Gracupica contra*
10	White-breasted Kingfisher	*Halcyon smyrnensis*
11	Indian Pond-Heron	*Ardeola grayii*
12	Common Myna	*Acridotheres tristis*
13	Bank Myna	*Acridotheres ginginianus*
14	House Crow	*Corvus splendens*
15	Rose-ringed Parakeet	*Psittacula krameri*
16	Yellow-legged Green Pigeon	*Treron phoenicoptera*
17	Eurasian Collared-Dove	*Streptopelia decaocto*
18	Blue Rock Pigeon	*Columba livia*
19	Little Green Bee-eater	*Merops orientalis*
20	Red-vented Bulbul	*Pycnonotus cafer*
21	Spotted Owlet	*Athene brama*
22	Indian Robin	*Saxicoloides fulicata*
23	Purple Sunbird	*Cinnyris asiaticus*
24	Black Drongo	*Dicrurus macrocercus*
25	Black Redstart	*Phoenicurus ochruros*
26	Brown Rock Chat	*Cercomela fusca*
27	Common Swallow	*Hirundo rustica*
28	House Swift	*Apus nipalensis*
29	Common Golden-backed Woodpecker	*Dinopium javanense*
30	Asian Koel	*Eudynamys scolopaceus*
31	Greater Coucal	*Centropus sinensis*
32	Common Babbler	*Turdoides caudata*

33	Common Hoopoe	*Upupa epops*
34	Indian Roller	*Coracias benghalensis*
35	Baya Weaver	*Ploceus philippinus*
36	Black Kite	*Milvus migrans*
37	Wire-tailed Swallow	*Hirundo smithii*
38	Indian Treepie	*Dendrocitta vagabunda*
39	Indian Peafowl	*Pavo cristatus*

ANNEXURE II

Bird Composition at the studied locations during the study period

S. No.	Bird Species	PAU Campus	Village Baranhara	Village Ladiankhurd
1	Pied Bushchat	+	+	+
2	Spotted Munia	+	+	+
3	Oriental Magpie-Robin	+	+	+
4	Brown-headed Barbet	+	-	-
5	House Sparrow	+	+	+
6	Large Pied Wagtail	+	+	+
7	Red-wattled Lapwing	+	+	+
8	Cattle Egret	+	+	+
9	Pied Myna	+	+	+
10	White-breasted Kingfisher	+	+	+
11	Indian Pond-Heron	+	+	+
12	Common Myna	+	+	+
13	Bank Myna	+	+	+
14	House Crow	+	+	+
15	Rose-ringed Parakeet	+	+	+
16	Yellow-legged Green Pigeon	+	+	-
17	Eurasian Collared-Dove	+	+	+
18	Blue Rock Pigeon	+	+	+
19	Little Green Bee-eater	+	+	+
20	Red-vented Bulbul	+	+	+
21	Spotted Owlet	+	+	-
22	Indian Robin	+	+	+
23	Purple Sunbird	+	+	+
24	Black Drongo	+	+	+
25	Black Redstart	+	+	+
26	Brown Rock Chat	+	+	+
27	Common Swallow	+	+	-
28	House Swift	+	+	-
29	Common Golden-backed Woodpecker	+	+	-
30	Asian Koel	+	+	+
31	Greater Coucal	+	+	+
32	Common Babbler	+	+	+

33	Common Hoopoe	+	+	+
34	Indian Roller	+	+	+
35	Baya Weaver	+	+	+
36	Black Kite	+	+	+
37	Wire-tailed Swallow	+	+	+
38	Indian Treepie	+	+	+
39	Indian Peafowl	+	+	+

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