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# Influence of Various Factors on Nest Box Occupancy and Reproductive Parameters of House Sparrow, *Passer domesticus*: A Case Study at Jangareddigudem Urban, India

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**Abstract:** Secondary cavity nesting birds utilize nest boxes for breeding activity. Several factors influence the occupancy of nest box and also the reproductive success. By our conservational studies of House Sparrow at Jangareddigudem town (India), we have observed the influence of direction and other nest box installation factors on nest box occupancy and on reproductive parameters (clutch size, hatching success, fledging success and overall breeding success). A simple random sampling method is used for the selection of 100 nest boxes from a total of 690 nest boxes installed in the study area, to study the influence of factors such as height at which nest box is placed from the ground, farness from roof/slab edge, nest box location far from vegetation and light illumination at the nest box. East and north directions favoured occupancy of the nest boxes with a good reproductive success ( $p < 0.05$ ) when tested by Univariate procedure and ANOVA using SAS software. Quick occupancy (within 30 days after nest box installation) was observed with nest boxes installed at a height of 13.48 feet ( $SD \pm 5.32$ ), at 4.2 feet ( $SD \pm 2.08$ ) depth from roof edge, at an average distance of 59.5 m ( $SD \pm 46.21$ ) from vegetation, and at places with a light illumination of 53.66% ( $SD \pm 14.01\%$ ). The regression procedure (ANOVA) employed as a test of hypothesis indicated a statistically significant influence of all studied factors on overall reproductive success ( $p$  value  $< 0.0001$ ). Our study clearly indicated the importance of consideration of nest box installation factors for both the occupancy of the nest boxes by House Sparrows and for their breeding success. Both occupancy and reproductive success were good with nest boxes installed at a height range of 10-19 feet from the ground; 2.5 – 6.5 feet depth/farness from roof edge; boxes installed between 50-100 m radius from vegetation; and at a light illumination range between 40-60%.

**Keywords:** House Sparrow, *Passer domesticus*, Nest boxes, Nest box installation factors, Occupancy, Reproductive success

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## Introduction

Several long-term studies on secondary cavity nesters showed utilization of nest boxes for their breeding activity (Møller, 1992). Nest-site selection by birds is a complex phenomenon that is influenced by several factors such as availability of nesting site, availability of food, devoid of predators etc. (Alatalo *et al.*, 1985). Light illumination found to have positive effect on various aspects of bird physiology. Exposure to more illumination accelerates the growth of embryo (Maurer *et al.*, 2011)

We have started conservation of House Sparrow (*Passer domesticus*) by providing nest boxes at Jangareddigudem town, Andhra Pradesh state of India. During our initial conservation studies, we have noticed that the nest boxes installed in south and west directions showed delayed occupancy and less utilization compared to the nest boxes installed in the other two directions *viz.*, east and north. This observation made us to study the influence of direction on the nest box occupancy and reproductive success by installing 40 nest boxes with 10 boxes in each of the four directions (east, north, west and south).

The method of installation of the nest box plays an important role in the occupancy of the nest box. Besides direction, some other nest box installation factors too were considered to study their influence on occupancy and breeding success. On random selection, 100 installed nest boxes were observed to study the influence of four selected other factors on occupancy of the nest box, and on breeding success of sparrows. The factors/parameters studied are- height at which nest box is placed from the ground, farness from roof/slab edge, nest box location far from vegetation and light illumination at the nest box.

To study the influence of direction on nest box occupancy and breeding success, the following hypotheses were framed:

H<sub>01</sub>: Direction at which nest box is installed does not play any significant role on the occupancy of the nest boxes by House Sparrows.

H<sub>a1</sub>: Direction at which nest box is installed plays a significant role on the occupancy of the nest boxes by House Sparrows.

H<sub>02</sub>: Direction does not play any significant role on breeding success of House Sparrows.

H<sub>a2</sub>: Direction plays a significant role on breeding success of the House Sparrows.

To study the influence of height at which nest box is installed, farness or depth at which nest box installed from roof/slab edge, nest box location from vegetation, and light illumination at the nest box installed location on nest box occupancy and breeding success, the following hypotheses are framed:

H<sub>03</sub>: The factors *viz.*, height at which nest box is installed, farness or depth at which nest box installed from roof/slab edge, nest box location from vegetation, and light illumination at the nest box installed location do not show any influence on occupancy of the nest box

H<sub>a3</sub>: The factors *viz.*, height at which nest box is installed, farness or depth at which nest box installed from roof/slab edge, nest box location from vegetation, and light illumination at the nest box installed location show influence on occupancy of the nest box.

H<sub>04</sub>: The reproductive parameters *viz.*, clutch size, hatching success, fledging success, and overall breeding success were not affected by the studied nest box installation factors.

H<sub>a4</sub>: The reproductive parameters *viz.*, clutch size, hatching success, fledging success, and overall breeding success were affected by the studied nest box installation factors.

## Materials and Methods

### *Nest Box installation:*

Direction of the nest box is related to wall surface. In the study area, the houses are constructed according to the traditional Indian architecture (Vāstu), with directional alignment. Main entrance faces towards east direction in most of the houses.



Fig. 1: Measuring light illumination by Lux meter.



Fig.2: Survey for Clutch size at Nest Box 23.



Fig. 3: Nestlings and eggs found in an Inbox nest.

As a result surface of the wall coincides the compass.

Height at which nest box installed from the ground is measured in feet from the floor (nearest ground). Carpenter's measuring tape is used to measure the height in feet. The farness (depth) of the nest box from the edge of the slab or roof is measured in feet. Distance from the vegetation is measured in meters using metal wired tape. Light illumination at the nest box is measured by using Lux meter (Fig. 1), and expressed in percentage for easy understanding (% of Light illumination = the illumination of light at nest box/the

illumination of light present at roof edge X100).

*(i) Survey for Nest Box Occupancy and reproductive success with reference to Direction:*

For studying the influence of direction, 40 nest boxes installed (10 in each of the four directions) were monitored to find out which direction better suits for quick occupancy and for reproductive success. A regular monitoring of installed 40 nest boxes was carried out on a daily basis during morning hours in between 8 a.m. to 10 a.m. for their occupancy. A periodical check-up was conducted to study the breeding aspects viz. clutch size (Fig. 2), hatching success (Fig. 3), fledging



Fig. 4: Nest Box designed with a front door to study the reproduction parameters.

success and overall breeding success at 40 installed nests. To study the influence of direction on reproductive success, the 40 installed nests were made with a front door (Fig. 4) to open the box without any disturbance to the nests and nestlings.

*(ii) Survey for Nest Box Occupancy and Breeding Success with reference to height at which nest box is installed, farness or depth at which nest box installed from roof/slab edge, nest box location from vegetation, and light illumination at the nest box installed location:*

A simple random sampling technique is used for the selection of 100 nest boxes from a total of 690 nest boxes installed in the study area, to study the influence of various said factors. The survey is carried out in the same manner as mentioned above.

#### *Reproductive Parameters:*

For each nest box, we recorded (a) Clutch size (i.e. number of eggs laid per attempt) (b) Hatchlings (baby sparrow that came out from the egg) and (c) Number of fledged chicks. By these parameters, we calculated the hatching success (chicks hatched /eggs laid) fledging success (number of chicks fledged out/total hatchlings) and annual breeding success (total number of eggs laid/ total chicks fledged out/ at each nest box/ one year) at each nest box.

#### *Statistical Analysis:*

Means procedure, Univariate procedure and ANOVA are applied as tests of hypotheses and analysis was carried out using SAS (Statistical

Analysing Software) to find out whether the studied factors have significant impact on the occupancy of the nest box by sparrows and on their breeding success.

## **Results**

### *Influence of Direction on Occupancy and Breeding Activity:*

#### *Results of Analysis by Means Procedure:*

Initially the influence of direction on nest box occupancy and reproductive success was studied by placing 10 nest boxes each in all the four directions viz., east, north, south, and west. Table 1 shows the statistical analysis by means procedure to find out influence of direction on nest box occupancy and on reproductive parameters. From the table, it is clearly evident that out of 10 nest boxes placed in east and north directions, all were occupied by sparrows (in the table, the symbol '1' is given to denote nest boxes occupied by sparrows and '0' for non-occupation). Whereas only 2 nest boxes were occupied out of the total 10 installed in case of both south and west directed nest boxes. This clearly indicates the influence of direction on nest box occupancy, and both east and north directions are favouring for occupancy. The same is the case with reproductive parameters. Only east and north directed nest boxes showed good reproductive success.

#### *Results of ANOVA (Analysis of Variance):*

Among the four directions, east and north placed nest boxes showed good reproductive success (Table 2 a,b,c,d,e) with a statistical significance ( $p < 0.05$ ) when tested by ANOVA using SAS

Table 1: The means procedure table to study the influence of direction on nest box occupancy by House Sparrows and on their reproductive parameters

| DIRECTION | Occupancy    | No. Obs | Variable                   | N  | Mean | Minimum | Maximum | Coeff of Variation |
|-----------|--------------|---------|----------------------------|----|------|---------|---------|--------------------|
| East      | Occupied     | 10      | CLUTCH_SIZE                | 10 | 3.3  | 3.0     | 4.0     | 14.6               |
|           |              |         | EGGS_HATCHED               | 10 | 3.1  | 2.0     | 4.0     | 18.3               |
|           |              |         | FLEDGINGS                  | 10 | 2.4  | 2.0     | 3.0     | 21.5               |
|           |              |         | BREEDING_ACTIVITY_PER_YEAR | 10 | 3.2  | 2.0     | 5.0     | 24.7               |
| North     | Occupied     | 10      | CLUTCH_SIZE                | 10 | 3.3  | 2.0     | 5.0     | 28.7               |
|           |              |         | EGGS_HATCHED               | 10 | 2.8  | 2.0     | 4.0     | 28.2               |
|           |              |         | FLEDGINGS                  | 10 | 2.5  | 2.0     | 4.0     | 28.3               |
|           |              |         | BREEDING_ACTIVITY_PER_YEAR | 10 | 3.5  | 2.0     | 5.0     | 27.8               |
| South     | Not Occupied | 8       | CLUTCH_SIZE                | 8  | 0.0  | 0.0     | 0.0     | .                  |
|           |              |         | EGGS_HATCHED               | 8  | 0.0  | 0.0     | 0.0     | .                  |
|           |              |         | FLEDGINGS                  | 8  | 0.0  | 0.0     | 0.0     | .                  |
|           |              |         | BREEDING_ACTIVITY_PER_YEAR | 8  | 0.0  | 0.0     | 0.0     | .                  |
|           | Occupied     | 2       | CLUTCH_SIZE                | 2  | 2.5  | 2.0     | 3.0     | 28.3               |
|           |              |         | EGGS_HATCHED               | 2  | 0.5  | 0.0     | 1.0     | 141.4              |
|           |              |         | FLEDGINGS                  | 2  | 0.5  | 0.0     | 1.0     | 141.4              |
|           |              |         | BREEDING_ACTIVITY_PER_YEAR | 2  | 1.0  | 1.0     | 1.0     | 0.0                |
| West      | Not Occupied | 8       | CLUTCH_SIZE                | 8  | 0.0  | 0.0     | 0.0     | .                  |
|           |              |         | EGGS_HATCHED               | 8  | 0.0  | 0.0     | 0.0     | .                  |
|           |              |         | FLEDGINGS                  | 8  | 0.0  | 0.0     | 0.0     | .                  |
|           |              |         | BREEDING_ACTIVITY_PER_YEAR | 8  | 0.0  | 0.0     | 0.0     | .                  |
|           | Occupied     | 2       | CLUTCH_SIZE                | 2  | 1.0  | 0.0     | 2.0     | 141.4              |
|           |              |         | EGGS_HATCHED               | 2  | 0.0  | 0.0     | 0.0     | .                  |
|           |              |         | FLEDGINGS                  | 2  | 0.0  | 0.0     | 0.0     | .                  |
|           |              |         | BREEDING_ACTIVITY_PER_YEAR | 2  | 0.5  | 0.0     | 1.0     | 141.4              |

software. Less reproductive activity was observed in south and west directed nest boxes (Fig. 5). On comparison, clutch size, hatching success, fledging success were significantly more in east and north directions than south and west. The mean of clutch size in north and east was 3.30, whereas in south and west was 0.5 and 0.2, respectively. Fig. 6 shows that the clutch size in north and east directed nests is around 3, whereas clutch size is insignificant in west and south directed nest boxes. As the clutch size is less in south and west, the hatching success and fledging success are also less in these directions. (Figs. 7, 8). Breeding success was almost nil in the west directed nest (nest box no. 8). This could be due to the fall of direct sunlight during afternoon to evening hours in those directions which may result in embryonic mortality. Based on the analysed results, further installation of nest boxes was carried out only in east and north directions.

*Influence of Nest Box Installation Factors (Height, Farness from roof edge, far from vegetation and Light illumination) on Occupancy:*

#### *Univariate Analysis Results:*

The analysis of randomly selected 100 nest boxes using Univariate procedure to study the effect of selected parameters like - height at which the nest box installed from floor, farness from the roof edge, location of the nest box from vegetation and light illumination, on occupancy of nest boxes showed that all the studied factors contributed to the occupancy of nest boxes with significant values ( $p < 0.0001$ ).

Based on univariate procedure, we have observed that the height at which the nest box is installed from the ground has showed statistical significance on occupancy ( $p < 0.0001$ ). The quick occupancy within 30 days was observed at the height of 13.48 feet ( $SD \pm 5.32$ ), with the best

Table 2 a,b,c,d,e: Influence of the direction at which nest box is installed on the reproductive parameters of House Sparrow (ANOVA procedure)

| 2a                 |    |             |         |                  |         |                  |         |                        |         |
|--------------------|----|-------------|---------|------------------|---------|------------------|---------|------------------------|---------|
| Level of Direction | N  | Clutch Size |         | Hatching Success |         | Fledging Success |         | Breeding Activity/Year |         |
|                    |    | Mean        | Std Dev | Mean             | Std Dev | Mean             | Std Dev | Mean                   | Std Dev |
| East               | 10 | 3.300       | 0.483   | 3.100            | 0.567   | 2.400            | 0.516   | 3.200                  | 0.788   |
| North              | 10 | 3.300       | 0.948   | 2.800            | 0.788   | 2.500            | 0.707   | 3.500                  | 0.971   |
| South              | 10 | 0.500       | 1.080   | 0.100            | 0.316   | 0.100            | 0.316   | 0.200                  | 0.421   |
| West               | 10 | 0.200       | .0632   | 0.000            | 0.000   | 0.000            | 0.000   | 0.100                  | 0.316   |

| Table 2b: Dependent variable clutch size |    |          |             |         |        |
|------------------------------------------|----|----------|-------------|---------|--------|
| Source                                   | DF | Anova SS | Mean Square | F Value | Pr > F |
| DIRECTION                                | 3  | 87.47500 | 29.158333   | 43.20   | <.0001 |

| Table 2c: Dependent Variable Hatching |    |          |             |         |        |
|---------------------------------------|----|----------|-------------|---------|--------|
| Source                                | DF | Anova SS | Mean Square | F Value | Pr > F |
| DIRECTION                             | 3  | 84.600   | 28.200000   | 108.00  | <.0001 |

| Table 2d: Dependent variable Fledgings |    |          |             |         |        |
|----------------------------------------|----|----------|-------------|---------|--------|
| Source                                 | DF | Anova SS | Mean Square | F Value | Pr > F |
| DIRECTION                              | 3  | 57.7000  | 19.23333    | 88.77   | <.0001 |

| Table 2e: Dependent variable: Breeding activity / year |    |          |             |         |        |
|--------------------------------------------------------|----|----------|-------------|---------|--------|
| Source                                                 | DF | Anova SS | Mean Square | F Value | Pr > F |
| DIRECTION                                              | 3  | 102.9000 | 34.3000     | 74.39   | <.0001 |

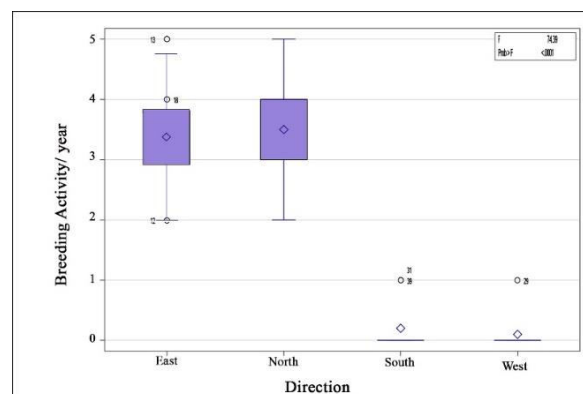


Fig. 5: Influence of direction of the nest box on the breeding activity of House Sparrow.

occupancy observed at the height range of 10-19 feet (Table 3).

Considering the nest location farness from roof edge, the quick occupancy (within 30 days) was observed at 4.2 feet ( $SD \pm 2.08$ ) depth from

roof edge with a significant p value ( $p < 0.0001$ ), with the best occupancy observed in the depth range of 2.5 to 6.5 feet from roof edge (Table 4).

Distance of the location of nest box from vegetation is also a determining factor for quick

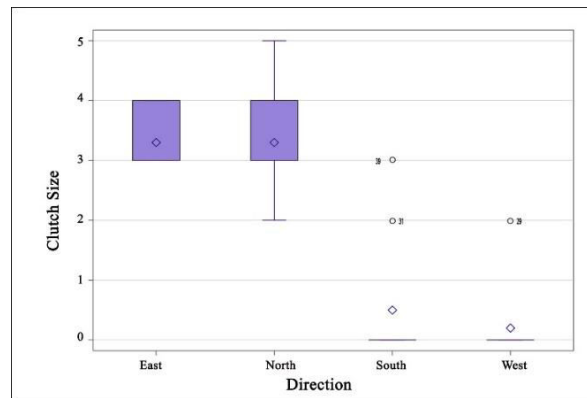


Fig. 6: Influence of direction of the nest box on clutch size of House Sparrow.

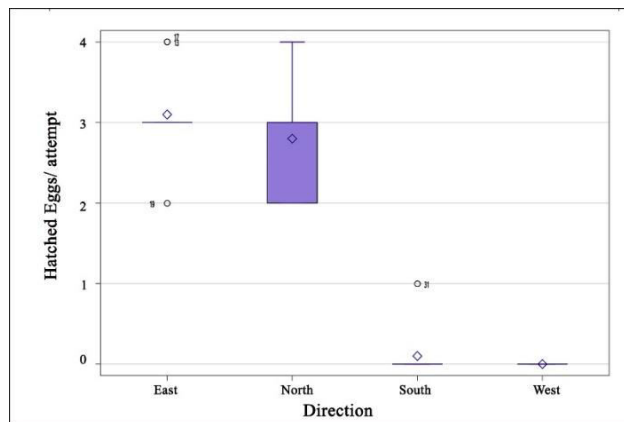


Fig. 7: Influence of direction of the nest box on hatching success of House Sparrow.

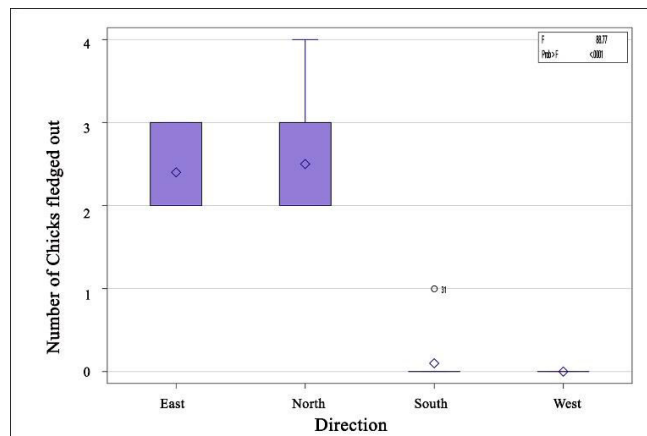


Fig. 8: Influence of direction of the nest box on fledging success of House Sparrow.

occupancy. 60% of the quick occupied nests were located at around 100 m vegetation. The statistical analysis has shown that an average distance of 59.5 m (SD±46.21) from vegetation is best for quick occupancy (Table 5). The best occupancy

was observed with nest boxes placed within a vegetation range of 50-100 m.

The other influencing factor for quick occupancy was light illumination at nest box location. On an average 53.66% of light

Table 3: Univariate Test analysis of Height at which nest boxes placed from ground on nest box occupancy by House Sparrows

| <b>(3a) Basic Statistical measures of nest box occupancy Vs. Height at which nest boxes placed from ground</b> |         |                    |         |
|----------------------------------------------------------------------------------------------------------------|---------|--------------------|---------|
| <b>Location</b>                                                                                                |         | <b>Variability</b> |         |
| Mean                                                                                                           | 13.4833 | Std Deviation      | 5.325   |
| Media                                                                                                          | 10.0000 | Variance           | 28.3556 |
| Mode                                                                                                           | 10.0000 | Range              | 22.0000 |
| Iterquartile Range                                                                                             |         |                    | 8.0000  |

| <b>(3b) Basic Confidence Limits Assuming Normality</b> |                 |                              |          |
|--------------------------------------------------------|-----------------|------------------------------|----------|
| <b>Parameter</b>                                       | <b>Estimate</b> | <b>95% Confidence Limits</b> |          |
| <b>Mean</b>                                            | 13.48333        | 12.10774                     | 14.85893 |
| <b>Std Deviation</b>                                   | 5.32500         | 4.51365                      | 6.49470  |
| <b>Variance</b>                                        | 28.35565        | 20.37307                     | 42.18116 |

| <b>(3c) Tests for Location: Mu0=0</b> |                  |          |                     |        |
|---------------------------------------|------------------|----------|---------------------|--------|
| <b>Test</b>                           | <b>Statistic</b> |          | <b>p Value</b>      |        |
| <b>Student's t</b>                    | <b>t</b>         | 19.61341 | <b>Pr &gt;  t </b>  | <.0001 |
| <b>Sign</b>                           | <b>M</b>         | 30       | <b>Pr &gt;=  M </b> | <.0001 |
| <b>Signed Rank</b>                    | <b>S</b>         | 915      | <b>Pr &gt;=  S </b> | <.0001 |

Table 4: Univariate Test analysis of farness/depth of the nest boxes from roof edge vs. nest box occupancy by House Sparrows

| <b>(4a) Basic Statistical measures of nest box occupancy Vs. Farness/depth of the nest boxes from roof edge</b> |        |                    |        |
|-----------------------------------------------------------------------------------------------------------------|--------|--------------------|--------|
| <b>Location</b>                                                                                                 |        | <b>Variability</b> |        |
| Mean                                                                                                            | 4.2833 | Std Deviation      | 2.0837 |
| Media                                                                                                           | 4.0000 | Variance           | 4.3420 |
| Mode                                                                                                            | 2.0000 | Range              | 8.0000 |
| Iterquartile Range                                                                                              |        |                    | 3.5000 |

| <b>(4b) Basic Confidence Limits Assuming Normality</b> |                 |                              |         |
|--------------------------------------------------------|-----------------|------------------------------|---------|
| <b>Parameter</b>                                       | <b>Estimate</b> | <b>95% Confidence Limits</b> |         |
| <b>Mean</b>                                            | 4.28333         | 3.74504                      | 4.82163 |
| <b>Std Deviation</b>                                   | 2.08377         | 1.76627                      | 2.54149 |
| <b>Variance</b>                                        | 4.34209         | 3.11972                      | 6.45919 |

| <b>(4c) Tests for Location: Mu0=0</b> |                  |          |                     |        |
|---------------------------------------|------------------|----------|---------------------|--------|
| <b>Test</b>                           | <b>Statistic</b> |          | <b>p Value</b>      |        |
| <b>Student's t</b>                    | <b>t</b>         | 15.92238 | <b>Pr &gt;  t </b>  | <.0001 |
| <b>Sign</b>                           | <b>M</b>         | 30       | <b>Pr &gt;=  M </b> | <.0001 |
| <b>Signed Rank</b>                    | <b>S</b>         | 915      | <b>Pr &gt;=  S </b> | <.0001 |

Table 5: Univariate Test analysis of location of the nest boxes from nearest vegetation on nest box occupancy by House Sparrows

| (5a) Basic Statistical measures of nest box occupancy Vs. location of the nest boxes from vegetation |         |               |          |
|------------------------------------------------------------------------------------------------------|---------|---------------|----------|
| Location                                                                                             |         | Variability   |          |
| Mean                                                                                                 | 59.5000 | Std Deviation | 46.2189  |
| Media                                                                                                | 50.0000 | Variance      | 2136     |
| Mode                                                                                                 | 50.0000 | Range         | 190.0000 |
| Iterquartile Range                                                                                   |         |               | 80.0000  |

| (5b) Basic Confidence Limits Assuming Normality |          |                       |          |
|-------------------------------------------------|----------|-----------------------|----------|
| Parameter                                       | Estimate | 95% Confidence Limits |          |
| Mean                                            | 59.50000 | 47.56039              | 71.43961 |
| Std Deviation                                   | 46.21890 | 39.17671              | 56.37143 |
| Variance                                        | 2136     | 1535                  | 3178     |

| (5c) Tests for Location: Mu0=0 |           |          |          |        |
|--------------------------------|-----------|----------|----------|--------|
| Test                           | Statistic |          | p Value  |        |
| Student's t                    | t         | 9.971787 | Pr >  t  | <.0001 |
| Sign                           | M         | 30       | Pr >=  M | <.0001 |
| Signed Rank                    | S         | 915      | Pr >=  S | <.0001 |

illumination ( $SD \pm 14.01\%$ ) was favourable for their nesting ( $p < 0.001$ ). (Table 6). The most preferable light illumination is found in the range of 50-64%.

Table 7 shows summary of Univariate analysis using SAS to find the influence of various nest box installation factors on occupancy of nest boxes by House Sparrows.

#### *Regression (ANOVA) analysis, factors Vs. Occupancy:*

The results of regression analysis (ANOVA) using SAS are also on par with the Univariate procedure results. Sparrows preferred and occupied the nest boxes that were installed at a height range between 10-19 feet (Fig. 9). Nest boxes installed at depth or farness range between 2.5-6.5 feet from roof edge favoured for quick occupancy i.e. nest boxes installed at that range were occupied within 60 days from installation. Any increase or decrease to the said range resulted in delayed occupancy (Fig. 10). This may be due to the fact that when depth/farness increases from roof edge,

the light illumination decreases and when depth decreases, the nest boxes will be exposed to predators such as crows. The sparrows prefer the nest boxes installed within 100 m distance from vegetation (Fig. 11). At the same time, the vegetation distance range from nest box location should be between 50-100 m. Any increase from the said distance range resulted in delayed occupancy of the nest boxes due to non-availability of insect prey. And a distance of below 50 m from vegetation also showed delayed occupancy as vegetation very nearby to the nest boxes installation location may hinder light illumination and as well increases predator exposure. From the regression graph (Fig. 12), it is clearly evident that a light illumination of 50-64% favoured quick occupation.

Though the best occupancy is observed at a height range of 10-19 feet, a delay in occupancy was also observed in 10% of the nest boxes installed at the same height range which might be

Table 6: Univariate Test analysis of light illumination at nest box installed location on nest box occupancy by House Sparrows

| <b>(6a) Basic Statistical measures of nest box occupancy Vs. Light illumination at nest box</b> |         |                    |        |
|-------------------------------------------------------------------------------------------------|---------|--------------------|--------|
| <b>Location</b>                                                                                 |         | <b>Variability</b> |        |
| Mean                                                                                            | 53.3666 | Std Deviation      | 14.017 |
| Media                                                                                           | 50.0000 | Variance           | 196.98 |
| Mode                                                                                            | 60.0000 | Range              | 60.000 |

| <b>(6b) Basic Confidence Limits Assuming Normality</b> |                 |                              |           |
|--------------------------------------------------------|-----------------|------------------------------|-----------|
| <b>Parameter</b>                                       | <b>Estimate</b> | <b>95% Confidence Limits</b> |           |
| <b>Mean</b>                                            | 53.66667        | 50.04550                     | 57.28783  |
| <b>Std Deviation</b>                                   | 14.01775        | 11.88192                     | 17.09691  |
| <b>Variance</b>                                        | 196.49718       | 141.17998                    | 292.30433 |

| <b>(6c) Tests for Location: Mu0=0</b> |                  |          |                     |        |
|---------------------------------------|------------------|----------|---------------------|--------|
| <b>Test</b>                           | <b>Statistic</b> |          | <b>p Value</b>      |        |
| <b>Student's t</b>                    | <b>t</b>         | 29.65528 | <b>Pr &gt;  t </b>  | <.0001 |
| <b>Sign</b>                           | <b>M</b>         | 30       | <b>Pr &gt;=  M </b> | <.0001 |
| <b>Signed Rank</b>                    | <b>S</b>         | 915      | <b>Pr &gt;=  S </b> | <.0001 |

Table 7: Summary table of Univariate analysis using SAS

| Days taken for occupancy and (No. of Nest boxes) | <b>Studied Factors Vs. Nest box occupation</b>              |                                                    |                                            |                                                      |
|--------------------------------------------------|-------------------------------------------------------------|----------------------------------------------------|--------------------------------------------|------------------------------------------------------|
|                                                  | Height at which nest box installed from ground level (feet) | Farness or depth of nest box from roof edge (feet) | Nest box location from vegetation (meters) | Light Illumination at nest box location (percentage) |
| 0-30 (60)                                        | 10-19                                                       | 2-6                                                | 50-106                                     | 60-68%                                               |
| 31-60 (30)                                       | 10-18                                                       | 3-7                                                | 50-107                                     | 40-60%                                               |
| 61-90 (7)                                        | 10-20                                                       | 4-11                                               | 50-134                                     | 40-57%                                               |
| 90-180 (3)                                       | 10-19                                                       | 5-6                                                | 47                                         | 60-65%                                               |
| Range for best occupation (within 60 days)       | 10-19 feet                                                  | 2.5-6.5 feet                                       | 50-100 meters                              | 50-64%                                               |

due to some inevitable causes like entry of house Gecko. Though there was certain delay observed in nest box occupancy by sparrows with respect to variations in nest box installation factors, it only comes to a small per cent, and as a whole, all the nest boxes installed were occupied indicating a greater demand for secured habitats.

*Influence of Nest box Installation Parameters on Breeding Success:*

*Results of ANOVA (Analysis of Variance):*

The effect of above-mentioned nest box installation factors on the reproductive success of House Sparrow were also studied. ANOVA (regression procedure) is used as a test of hypothesis. For the analysis, nest box installation factors were considered as dependent variables and reproductive parameters (clutch size, hatching success, fledging success and overall breeding success) as independent variables. From the results, it is inferred that the nest box installation factors have a significant effect on the

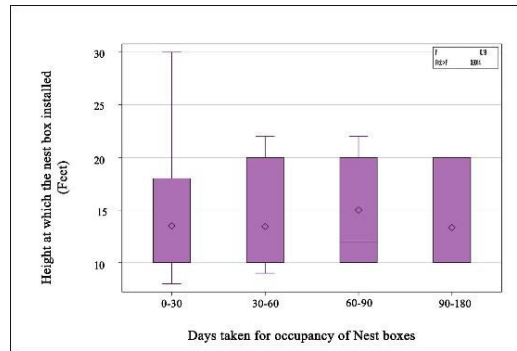


Fig. 9: Influence of the height at which nest box installed from ground on occupancy by House Sparrow.

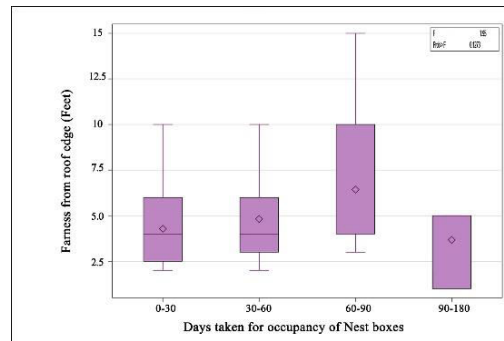


Fig. 10: Influence of location of nest box from roof edge on occupancy by House Sparrow.

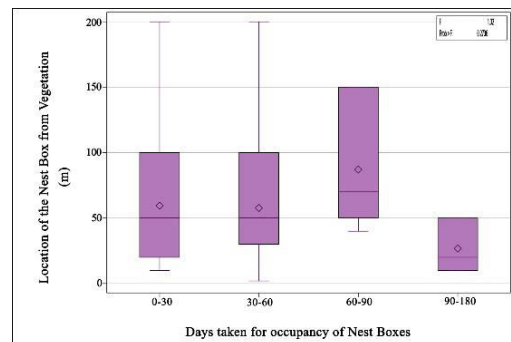


Fig. 11: Influence of nest box location from vegetation on the nest box occupancy by House Sparrow.

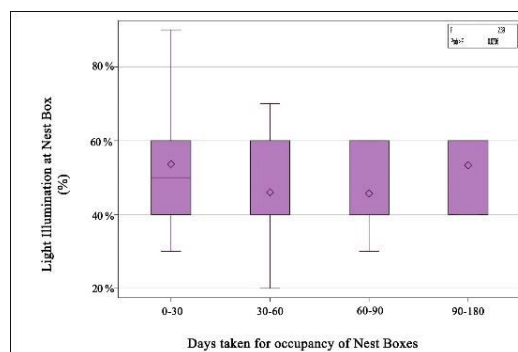


Fig. 12: Influence of light illumination at nest box location on nest box occupancy by House Sparrow.

Table 8: The result of ANOVA – Regression procedure Test on Influence of direction of the nest box on reproductive success of House Sparrow

| <b>(8a) Parameter Estimates: Direction Vs. Reproduction</b> |           |                       |                   |                |              |
|-------------------------------------------------------------|-----------|-----------------------|-------------------|----------------|--------------|
| <b>Variable</b>                                             | <b>DF</b> | <b>Parameter Est.</b> | <b>Std. Error</b> | <b>t-Value</b> | <b>Pr[t]</b> |
| Intercept                                                   | 1         | 2.6013                | 0.7067            | 3.68           | 0.0004       |
| Clutch Size                                                 | 1         | 0.0004                | 0.0006            | 0.07           | 0.9437       |
| Hatching Success                                            | 1         | -1.7314               | 0.9777            | -1.77          | 0.0798       |
| Fledging Success                                            | 1         | -2.3649               | 0.9657            | -2.45          | 0.0162       |
| Breeding Success                                            | 1         | 3.7240                | 1.3490            | 2.76           | 0.0069       |

| <b>(8b) Analysis of Variance</b> |           |                       |                    |                |                  |
|----------------------------------|-----------|-----------------------|--------------------|----------------|------------------|
| <b>Source</b>                    | <b>DF</b> | <b>Sum of Squares</b> | <b>Mean Square</b> | <b>F Value</b> | <b>Pr &gt; F</b> |
| <b>Model</b>                     | 4         | 9.19926               | 2.29981            | 2.33           | 0.0620           |
| <b>Error</b>                     | 95        | 93.96074              | 0.98906            |                |                  |
| <b>Corrected Total</b>           | 99        | 103.16000             |                    |                |                  |

| <b>(8c) Tests for Location: Mu0=0</b> |          |                 |        |
|---------------------------------------|----------|-----------------|--------|
| <b>Root MSE</b>                       | 0.99452  | <b>R-Square</b> | 0.0892 |
| <b>Dependent Mean</b>                 | 1.78000  | <b>Adj R-Sq</b> | 0.0508 |
| <b>Coeff Var</b>                      | 55.87164 |                 |        |

Table 9: Influence of height at which nest box installed from ground on reproductive success of House Sparrow

| <b>(9a) Parameter Estimates: Height of nest from Ground Vs. Reproduction</b> |           |                       |                   |                |              |
|------------------------------------------------------------------------------|-----------|-----------------------|-------------------|----------------|--------------|
| <b>Variable</b>                                                              | <b>DF</b> | <b>Parameter Est.</b> | <b>Std. Error</b> | <b>t-Value</b> | <b>Pr[t]</b> |
| Intercept                                                                    | 1         | 17.9303               | 3.3450            | 3.56           | <0.0001      |
| Clutch Size                                                                  | 1         | 0.0365                | 0.0301            | 1.21           | 0.2288       |
| Hatching Success                                                             | 1         | -9.6546               | 4.6275            | -2.90          | 0.0396       |
| Fledging Success                                                             | 1         | -13.2445              | 4.5708            | -2.90          | 0.0047       |
| Breeding Success                                                             | 1         | 19.2888               | 6.3847            | 3.02           | 0.0032       |

| <b>(9b) Analysis of Variance</b> |           |                       |                    |                |                  |
|----------------------------------|-----------|-----------------------|--------------------|----------------|------------------|
| <b>Source</b>                    | <b>DF</b> | <b>Sum of Squares</b> | <b>Mean Square</b> | <b>F Value</b> | <b>Pr &gt; F</b> |
| <b>Model</b>                     | 4         | 279.95265             | 69.98816           | 3.16           | 0.0175           |
| <b>Error</b>                     | 95        | 2104.79735            | 22.15576           |                |                  |
| <b>Corrected Total</b>           | 99        | 2384.75000            |                    |                |                  |

| (9c) Tests for Location: $\mu_0=0$ |          |          |        |
|------------------------------------|----------|----------|--------|
| Root MSE                           | 4.70699  | R-Square | 0.1174 |
| Dependent Mean                     | 13.35000 | Adj R-Sq | 0.0802 |
| Coeff Var                          | 35.25836 |          |        |

Table 10: Influence of Nest location from roof edge on breeding success

| (10a) Parameter Estimates: Farness to Nest Box from roof edge Vs. Reproduction |    |                |            |         |         |
|--------------------------------------------------------------------------------|----|----------------|------------|---------|---------|
| Variable                                                                       | DF | Parameter Est. | Std. Error | t-Value | Pr>[t]  |
| Intercept                                                                      | 1  | 8.0442         | 1.6790     | 4.79    | <0.0001 |
| Clutch Size                                                                    | 1  | 0.0275         | 0.0151     | 1.82    | 0.0719  |
| Hatching Success                                                               | 1  | -6.2230        | 2.3229     | -2.68   | 0.0087  |
| Fledging Success                                                               | 1  | -7.8568        | 2.2944     | -3.42   | 0.0009  |
| Breeding Success                                                               | 1  | 10.4329        | 3.2049     | 3.26    | 0.0016  |

| (10b) Analysis of Variance |    |                |             |         |        |
|----------------------------|----|----------------|-------------|---------|--------|
| Source                     | DF | Sum of Squares | Mean Square | F Value | Pr > F |
| Model                      | 4  | 92.98439       | 23.24610    | 4.16    | 0.0038 |
| Error                      | 95 | 530.34311      | 5.58256     |         |        |
| Corrected Total            | 99 | 623.32750      |             |         |        |

| (10c) Tests for Location: $\mu_0=0$ |          |          |        |
|-------------------------------------|----------|----------|--------|
| Root MSE                            | 2.36274  | R-Square | 0.1492 |
| Dependent Mean                      | 4.43500  | Adj R-Sq | 0.1133 |
| Coeff Var                           | 53.27495 |          |        |

reproductive success of House Sparrow as it evident from the significant values ( $p < 0.05$ ).

The cumulative effect of direction of the nest box on reproductive success has shown statistically significant influence (Intercept  $p$  value = 0.0004) ( $Pr > F$ , 0.06) (Table 8). However, the  $Pr > F$  value of 0.06 indicates direction has no significant effect on reproductive success. This is because all the nest boxes studied here are installed in east and north directions only based on our previous observational studies placing 10 nest boxes in each of the 4 directions. But, when individual results were observed, there is no significant influence of direction on clutch size ( $p$  value = 0.94) and as well on hatching success ( $p$  = 0.07). But the direction of nest box installation has showed a significant influence on fledging success

( $p$  value = 0.01). But when it comes overall breeding success, the directions (east and north) have showed statistically significant influence with  $p$  value 0.006.

By considering the statistical analysis results, we can infer that direction (east and north) has a significant influence on overall breeding success of House Sparrow.

The overall effect of height at which the nest box is installed from the ground has a statistically significant influence on reproductive success (Intercept  $p$  value < 0.0001) ( $Pr > F$ , 0.0175). But when it comes to individual parameters, with an exception to clutch size ( $p$  value = 0.22), height of nest box installation has shown statistically significant influence on hatching success ( $p$  = 0.03), and fledging success ( $p$  value = 0.004) (Table

Table 11: Influence of nest box location from vegetation on reproductive success of House Sparrow

| <b>(11a) Parameter Estimates: Nest box location from Vegetation Vs. Reproduction</b> |           |                       |                   |                |              |
|--------------------------------------------------------------------------------------|-----------|-----------------------|-------------------|----------------|--------------|
| <b>Variable</b>                                                                      | <b>DF</b> | <b>Parameter Est.</b> | <b>Std. Error</b> | <b>t-Value</b> | <b>Pr[t]</b> |
| Intercept                                                                            | 1         | 104.4580              | 26.2691           | 3.57           | 0.0006       |
| Clutch Size                                                                          | 1         | 0.5118                | 0.2640            | 1.94           | 0.0555       |
| Hatching Success                                                                     | 1         | -88.2204              | 40.4919           | -2.18          | 0.0318       |
| Fledging Success                                                                     | 1         | -124.4803             | 39.9950           | -3.11          | 0.0025       |
| Breeding Success                                                                     | 1         | 164.6140              | 55.8666           | 2.95           | 0.0040       |

| <b>(11b) Analysis of Variance</b> |           |                       |                    |                |                  |
|-----------------------------------|-----------|-----------------------|--------------------|----------------|------------------|
| <b>Source</b>                     | <b>DF</b> | <b>Sum of Squares</b> | <b>Mean Square</b> | <b>F Value</b> | <b>Pr &gt; F</b> |
| <b>Model</b>                      | 4         | 25400                 | 6349.93148         | 3.74           | 0.0071           |
| <b>Error</b>                      | 95        | 161149                | 1696.30141         |                |                  |
| <b>Corrected Total</b>            | 99        | 186548                |                    |                |                  |

| <b>(11c) Tests for Location: <math>\mu_0=0</math></b> |          |                 |        |
|-------------------------------------------------------|----------|-----------------|--------|
| <b>Root MSE</b>                                       | 41.18618 | <b>R-Square</b> | 0.1362 |
| <b>Dependent Mean</b>                                 | 57.42000 | <b>Adj R-Sq</b> | 0.0998 |
| <b>Coeff Var</b>                                      | 71.72793 |                 |        |

Table 12: Influence of light illumination on reproductive success of House Sparrow

| <b>(12a) Parameter Estimates: Light illumination Vs. Reproduction</b> |           |                       |                   |                |                  |
|-----------------------------------------------------------------------|-----------|-----------------------|-------------------|----------------|------------------|
| <b>Variable</b>                                                       | <b>DF</b> | <b>Parameter Est.</b> | <b>Std. Error</b> | <b>t-Value</b> | <b>Pr&gt;[t]</b> |
| Intercept                                                             | 1         | 61.6875               | 9.7112            | 6.35           | <0.0001          |
| Clutch Size                                                           | 1         | 0.1822                | 0.0876            | 2.08           | 0.0402           |
| Hatching Success                                                      | 1         | -24.0102              | 13.4348           | -1.79          | 0.0771           |
| Fledging Success                                                      | 1         | -35.4293              | 13.2699           | -2.67          | 0.0089           |
| Breeding Success                                                      | 1         | 47.5605               | 18.5359           | 2.57           | 0.0119           |

| <b>(12b) Analysis of Variance</b> |           |                       |                    |                |                  |
|-----------------------------------|-----------|-----------------------|--------------------|----------------|------------------|
| <b>Source</b>                     | <b>DF</b> | <b>Sum of Squares</b> | <b>Mean Square</b> | <b>F Value</b> | <b>Pr &gt; F</b> |
| <b>Model</b>                      | 4         | 2458.26546            | 614.56636          | 3.29           | 0.0143           |
| <b>Error</b>                      | 95        | 17740                 | 186.73657          |                |                  |
| <b>Corrected Total</b>            | 99        | 20198                 |                    |                |                  |

| <b>(12c) Tests for Location: <math>\mu_0=0</math></b> |          |                 |        |
|-------------------------------------------------------|----------|-----------------|--------|
| <b>Root MSE</b>                                       | 13.66516 | <b>R-Square</b> | 0.1217 |
| <b>Dependent Mean</b>                                 | 50.76000 | <b>Adj R-Sq</b> | 0.0847 |
| <b>Coeff Var</b>                                      | 26.92112 |                 |        |

9). The height at which nest box installed from ground has showed a statistically significant influence on overall breeding success with p value 0.0032, indicating that the studied factor plays important role in breeding success of House Sparrow.

The same type of effect is observed with respect to farness or depth of nest box installation from roof edge (Intercept p value < 0.0001) ( $Pr > F$  0.0038). The said factor has significant influence on hatching success (p value = 0.008), and on fledging success (0.0009). The overall breeding success showed a statistically significant influence with p value of 0.0016 indicating the importance of nest box installation farness from roof edge (Table 10).

When it comes to the effect of distance of nest box location from vegetation on reproductive success, there is a statistically significant influence as a whole (Intercept  $p=0.0006$ ) ( $Pr > F$ , 0.0071) and as well with other individual parameters (clutch size: p value = 0.05; hatching success: p value = 0.03; and Fledging success: p value 0.0025). The overall breeding success showed a statistically significant p value ( $p=0.004$ ) indicating the significant influence of vegetation on breeding success (Table 11).

In case of light illumination, the cumulative effect is statistically significant (Intercept p value < 0.0001) ( $Pr > F$ , 0.00143), but when it comes to individual factors, with an exception to hatching success ( $p=0.07$ ), all other parameters showed statistically significant effect. (clutch size: p value = 0.04; Fledging success: p value 0.0089) (Table 12). The significant p value of overall breeding success ( $p = 0.01$ ) clearly indicates the influence of light illumination on reproductive success of House Sparrow.

## Discussion

The study clearly indicates that nest box installation factors play key role in the occupancy of the nest boxes by the sparrows and on their breeding success as well. The sparrows prefer the nest boxes facing towards north and east. As the

south and west directions get direct sunlight during afternoon to evening hours, that may result in death of embryos. In our study, we have observed one abandoned nest box facing towards west direction. We noticed the presence of three dried eggs in that nest box. But in north and east directed nest boxes, we did not find such mass mortality.

The results obtained indicate the importance of nest box installation factors on both occupancy of nest boxes by sparrows and on their breeding success. As per the results, the nest box installation to be done between 10 to 19 feet height from the ground level for sparrows to identify and occupy the nest boxes. Considering the farness of the nest box from roof edge, 2.5 – 6.5 feet depth is quite comfortable for their breeding. But the sparrows enter into our houses and make nests in the false roofs or in ventilators, which are too far from roof edge, indicating their need for habitat. Sparrows usually prefer to make their nests nearer to the food resources. The same is reflected in our studies. They have given first preference to the nest boxes located within 100 m radius from the vegetation. On demand, they also occupy to nest boxes placed beyond 100 m to 200 m radius. A great delay is noticed in occupying the nest boxes placed away from 200 m vegetation. The sparrows in general prefer less illumination range for nesting (Pawel and Andrian, 2017), which was also reflected in our studies. All the occupied nest boxes are having a light illumination range between 40-60%.

Our results showed that the breeding rate and success of House sparrow is more in nest boxes than the natural crevices. Our results are consistent with the long-term conservation studies conducted by De León and Míñquez (2003). The authors compared the breeding success of an endangered sea bird species, European Storm-Petrels (*Hydrobates pelagicus*) at Benidorm Island of Spain and in their five year study, they stated that the breeding success is higher in nest boxes than the breeding success at natural open nests (Emmy *et al.*, 2012).

Orientation of the nest box plays an important role in breeding success. In our study area maximum breeding success was observed in north and east directed nest boxes. In the earlier days of our nesting programme, we have installed equal number of nests in all directions, to study which directions better suit for occupation and breeding success of House Sparrow. Less occupancy was observed in south and west directed nest boxes. Breeding success was almost nill in the west directed nest box (nest box no.8). Embryonic mortality occurred in that nest box due to direct fall of sunlight during afternoon to evening hours. This made the sparrows to left that box. We shifted those nests to north side of the houses which resulted in occupancy. The nest box orientation studies conducted by Briggs and Mainwaring (2021) on Great tits (*Parus major*) in deciduous woodland forests in England, reported that the breeding and fledging success was higher in south directed nest boxes than other directions. It is because of the warmth sunlight that is available from west direction during evening hours in temperate regions. But in tropical regions, the intensity of heat of sunlight is more in south and west during afternoon to evening hours.

Delay in the occupancy of the nest boxes by sparrows occurred because of the entry of House Gecko (*Hemidactylus frenatus*) and a frequent disturbance by other bird species like Rose ringed parakeet (*Psittacula krameri*) and Common Myna (*Acridotheris tristis*) in to nest boxes. The entry of lizard also lead to uninhabitation of some of the occupied and used nests. We have noticed this during the survey of the nesting materials of constructed nests in nest boxes. The delay in occupancy was noticed with increase in depth from roof edge, as this could hinder the visibility of the nest boxes by the sparrows and it could as well be an interdependent factor with light illumination. A delay in occupancy with increase in distance of nest box installation location from vegetation could be due to non-availability of food resources (insect prey).

Clutch size depends mainly on internal causes.

It might be affected by hormonal or genetic reasons and also depend on the availability of the type of food in the vicinity. Hence, the studied factors (direction of the nest box, height at which nest box installed from floor, depth or far from roof edge) did not show much influence on the clutch size. As the presence of vegetation near to the nest box installation location provides the birds with required insect preys to meet the protein demand of birds, the vegetation factor has showed a statistically significant effect on clutch size when compared to other factors.

According to Lewis and Gous (2009), the light of shortest wavelengths play an important role in the bone growth of chicks by inducing Vitamin D<sub>3</sub> formation. The observational studies by Ronald and Richard (1997) on Kestrels (*Falco sparverius*) proved a correlation between illumination and other variable in the habitat. Observational studies were also conducted by Pitts (1977) on internal illumination. He observed that House Sparrows and Eastern Blue Birds (*Sialia sialis*) prefer white painted nest boxes than black and unpainted (interior colour) nest boxes. As per our studies, light illumination at nest boxes does not have any negative effect on its breeding success. To avoid predation from other birds, House Sparrow makes nests in deeper cavities in open areas and as well in nest boxes, where the light illumination is almost absent. Cavity-nesting bird species manipulate the height of the nest to get desirable amount of light to the cup of the nest (Pawel and Andrian, 2017). The same phenomenon was observed in our studies. In the nest boxes, the sparrows built their first nest up to a height of three to four inches, to get sufficient light.

The responsive studies of House Sparrow to artificial nests (boxes) conducted by Bhattacharya *et al.* (2011) reported that the House Sparrow prefer low illumination areas for nesting. As per their observations, one of the nests was unoccupied, when it was at maximum illumination, and later it was occupied when changed to low illumination. It could be due to the seasonal impact. Their studies were conducted

from March to May in the year 2010. Direct exposure to sunlight retains excess heat in nest box, which could be the reason for un-occupancy and may lead to mortality of embryo in developing eggs.

With respect to the colour of the nest boxes, studies by Bhattacharya *et al.* (2011) showed a quick occupancy rate with nest boxes painted with green colour. As per their observational studies, the colour though played role in occupancy had not showed any significant effect on breeding success. In another study by Browne (2006), more occupancy by Tits (*Parus spp.*) was observed with Green coloured nest boxes than brown coloured nest boxes. But in our observational study, we did not find any influence of colour of the nest box on occupancy and breeding success.

Ecological factors such as abundance of shrubs influence breeding success, due to the availability of food. As per the studies conducted by Dong-Ho *et al.* (2023), the hatching success and fledging success were comparatively more in the areas which consist qualitative vegetation.

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