The Flying Foresters

Assessing population status, roost site selection and fruit damage by the Indian flying fox, *Pteropus giganteus* in Southern Karnataka.

Dissertation submitted to Saurashtra University, Rajkot,

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By

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CERTIFICATE

Date: 16th June, 2015

Place: Dehra Dun

This is to certify that Ms. Varsha Raj M has carried out an original research titled "**Assessing population status, roost site selection and fruit damage by the Indian flying fox, *Pteropus giganteus*, in Southern Karnataka**" towards partial fulfilment of Master of Science(Wildlife Science) degree from Saurashtra University, Rajkot. The study was carried out under my supervision from December 2014 to May 2015. I hereby certify that this work has not been submitted for any other degree to any other university.

Shri. Qamar Qureshi

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- Varsha Mohan Raj

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SUMMARY

Flying foxes *Pteropus giganteus*, play a key role in pollination and forest regeneration as seed dispersers. Despite this beneficial role, they are persecuted for being an agricultural pest in commercial orchards. More recently in India, they have been known to be reservoirs of deadly zoonotic diseases like Nipah. Over the past two decades rapid urbanization, leading to habitat and roost tree destruction has resulted in decline in population of the Indian flying fox. As a result, incidence of flying foxes visiting commercial orchards has increased which in turn has led to conflict between large-scale commercial fruit growers and flying foxes. Assessing the present population status and identifying the habitat preferences could help in understanding the risk of fruit damage in the surrounding areas, and will help in conservation of the keystone species and there by prevent their persecution also. A total of 51 roosts were identified which were used to assess the population status and change over time. Four methods of population estimation were compared to select the most reliable method. Photographic count method was found to be most reliable for of population estimation. At the landscape level, proximity to water bodies and intensity of urbanization influenced the occurrence of roosts. 11.38 % of the total study area was found to be suitable for roosting (potential habitat). Amongst the individual tree characters, tree GBH and tree height were found to strongly influence the roost selection. In commercial orchards, *Pteropus giganteus* was found to be responsible for significant amount of damage in orchards cultivating Guava, Mango and Sapota. Based on the extent of damage they were ranked second most important animal pest in these commercial orchards after birds. Further work on estimating actual fruit damages would be required to confirm the role of the Indian flying fox as a pest responsible for causing severe fruit damages in commercial orchards, for which they have been constantly persecuted.

1. INTRODUCTION

Bats (Chiroptera), are the second most diverse and widely distributed group of mammals after Rodentia and they are found in all continents except in the Arctic and Antarctic (Kunz & Pierson, 1994). The diversity and abundance of the bats is probably attributed to their unique biology of being the only flying mammal, where some species have the ability to echolocate and also to their wide range of feeding and roosting habits, social behaviours and reproductive strategies.

With about 1116 species (Mickleburgh *et al.*, 2002; Simmons, 2005) worldwide, bats can be divided into two sub-orders, the Megachiroptera and Microchiroptera. Megachiropterans also called fruit bats are found in the Old World tropics and sub-tropics and have only one Family, the Pteropodidae. These bats do not echolocate and have good vision and sense of smell. They feed on fruit, nectar and pollen. Microchiropterans are found worldwide and navigate using echolocation. They are predominantly insectivorous, while some feed on small vertebrates and blood (Hill & Smith, 1984).

The Indian subcontinent is home to 120 species of bats, of which 13 are megachiropterans (Pteropodidae) and the remaining are microchiropterans (Bates & Harrison, 1997). Among the megachiropterans three are common and found throughout the country, they include Indian flying fox (*Pteropus giganteus)*, the Dog-faced fruit bat (*Rousettus leschenaultia*) and the Greater short-nosed fruit bat (*Cynopterus sphinx*).

The Old world fruit bats are important pollinators, seed dispersers in the tropical forests and hence help in maintaining plant community diversity (Fujita, 1991; Whittaker & Jones, 1994; Banack, 1998). They play a crucial role in the survival of at least 300 plant species of nearly 200 genera of the world (Marshall, 1983, 1985; Fujita, 1991) and therefore maybe a 'keystone species' in some communities (Cox *et al.*, 1991;.Fujita, 1991; Rainey *et al.*, 1995). Furthermore, these plants produce more than 500 economically valuable products including fruits, dyes, tannins, timber, medicines, fibers and fuel wood (Fujita, 1991) which the world economy relies on. The importance of fruit bats for the future availability of these products is substantial and has been severely underestimated.

Flying fox populations have declined for a number of reasons, including loss or disturbance of roosting sites (Tuttle, 1979; Makin & Mendelssohn, 1986) loss of feeding habitats, particularly due to the deforestation (Cheke & Dahl, 1981; Carroll, 1984; Fujita, 1991; conflict between bats and fruit-growers (Jacobsen & DuPlessis, 1976; Loebel & Sanewski, 1987). Hence, knowledge of their ecology, habitat and roosting requirements is necessary to facilitate protection of their roosts and foraging areas to enhance their survivability (Nowak, 1994).

1.1 Study Species

The Indian flying fox (*Pteropus giganteus*) is the largest and the most widely distributed among the 13 species of fruit bats found in India (Bates & Harrison, 1997). They weigh around 1 – 1.5 kilos and have a wing span of more than 1m. It is a colonial species, roosting in large aggregations of colonies called 'camps' (Eby 1991; Parry–Jones & Augee 1992). Their diurnal roosts are found in various types of large and tall trees, including *Ficusbengalensis, Ficusreligiosa, Tamarindusindica, Mangiferaindica, Dalbergiasissoo and Eucalyptus sp* (Vendan, 2003). The colonies are usually located in close association with human beings and the size can vary from several hundred to thousand individuals depending upon the availability of food (Parry-Jones & Augee 1992; Eby 1996; Williams *et al*., 2006). It is even considered sacred in many parts of India (Marimuthu, 1988). These camps are usually found in close association with human settlements both in villages and cities and the colony size can vary from several hundred to thousand individuals depending upon the availability of food (Parry-Jones & Augee 1992; Eby, 1996).

The preferred food of Indian flying fox includes pollen, nectar and fruits. Lack of these preferred food source forces the flying foxes into commercial orchards. The lack of preferred food sources maybe due to natural unreliable flowering of native trees or because of clearing of this naturally available food source. As a result incidence of fruit bats visiting commercial orchards have increased (Tidemann & Nelson, 1987) which in turn has lead to conflict between large-scale commercial fruit growers and bats in India (Verghese, 1998; Srinivasulu and Srinivasulu, 2002).

The Indian flying fox plays a pivotal role as pollinators and seed dispersers for a diverse array of plants like *Anacardium occidentale, Borassus flabellifer, Calophylluminophyllum, Carcia papaya, Eugenia jambolana, Ficus sp., Madhuca indica, Mangifera indica, Murraya koenigi, Nerium indicum*etc (Vendan *et al.,* 2011).

Flying foxes are keystone species for the maintenance and re-establishment of natural vegetation in the Old World tropics (Fujita, 1991). The role in seed dispersal and pollination is particularly important in tropical forest succession and vegetation dynamics (Fleming, 1982; Medellin & Gaona, 1999; Henry & Jouard, 2007).

Flying foxes play a key role in forest regeneration because of their ability to retain viable seeds in their gut for several hours (Shilton *et al.*, 1999), their long-distance foraging movements (Tidemann & Nelson 2004; Epstein *et al.*, 2009) and their flight paths over forest clearings that are generally avoided by other forest animals (Fujita, 1991).

Flying foxes are also increasingly recognized as reservoir hosts for viruses that can cause serious human and animal diseases (Calisher *et al.*,2006; Halpin *et al.*,2007). In India and Bangladesh the Indian flying fox has been implicated as a primary reservoir of Nipah virus (Luby *et al.*, 2009) causing outbreaks in humans since 2001.

Over the past two decades rapid urbanization, leading to habitat and roost tree destruction has resulted in decline in population of the Indian flying fox (Venkatesan, 2007). Few ecological studies of fruit bats have been carried out in the Indian subcontinent, but are now more crucial with the accelerating rate of habitat destruction (Wilson & Engbring, 1992).

Besides habitat destruction, there is evidence that rapid anthropogenic changes are responsible for outbreak and spread of most zoonotic emerging infectious diseases. (Jones *et al.*, 2008).

Despite the ecological, economical and public health significance, the Indian flying fox has long been hunted as a source of protein and for medicinal use and is also persecuted as a fruit-eating pest. The Indian Wildlife (Protection) Act, 1972, categorizes the Indian flying fox as vermin (which can be captured or killed) under Schedule V. However, killing of bats with such a low reproductive rate (often only 1–2 young per year) results in a reduction in their numbers with consequent effects on pollination and seed dispersal. A breakdown of plant–pollinator and plant–seed-disperser relationships and subsequent loss of genetic diversity (heterozygosity and allelic diversity) is one of the most threatening consequences (Bawa, 1990).

Hence, understanding their habitat selection can provide information for strategies to preserve roosting and foraging landscapes (Crampton & Barclay 1998; Mildenstein *et al.*, 2005). Also, preventing viral spillover from bats to humans requires an understanding linking bat habitat with human and livestock activity to explain outbreaks (Halpin *et al.*, 2007).

Plate 1: Study species- Indian Flying fox (*Pteropus giganteus*) foraging on fruits of *Ficus sp*.

1.2 Current study

The current study seeks to gain basic ecological information about the Indian flying fox and assess the extent of damage they cause in commercial orchards.

The study addresses 3 aspects:

A. Population Ecology.

    i. To estimate the present population

    ii. To assess abundance with respect to change over time.

B. Roost characteristics and site selection.

    i. To identify factors that influence roost site selection at landscape level (macro) and at individual roosts (micro).

C. Fruit damage

    i. To assess the extent of fruit damage in commercial orchards depending on the availability of commercial fruits (season).

2. STUDY AREA

The study area spans over the region of Southern Karnataka, comprising of seven districts, namely Bengaluru (U), Chamarajanagara, Hassan, Kodagu, Mandya, Mysuru and Ramanagara with an extent of 33,578 km^2. (Fig. 1)

Roost locations of Indian flying fox in S. Karnataka

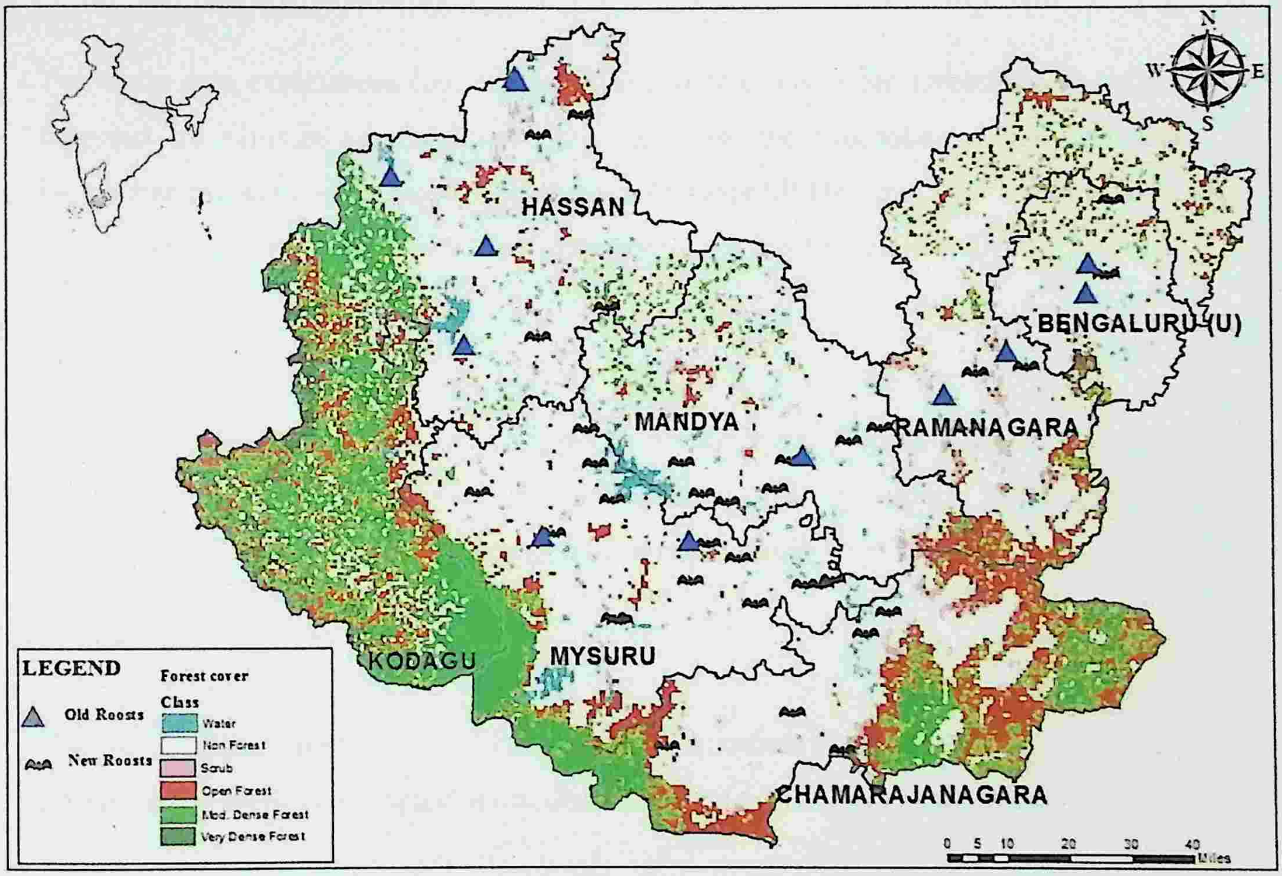


Fig 1: Study Area Map: Roosts of the Indian flying fox with relation to forest cover in Southern Karnataka.

2.1 Geography

Situated between 12°42' North latitudes and 77°56' East longitude, Southern Karnataka represents two geographical zones, a part of Deccan Plateau and a part of Western Ghats. The elevation ranges from 600 -1500 mts above sea level and this region falls under the area of the Cauvery river basin. (Chauhan, 2005)

2.2 Climate

The study area experiences four seasons, the winter season from December to February is followed by summer season from March to May, the monsoon season from June to September and the post-monsoon season from October till December. The annual rainfall in this region varies roughly from 900 to 1126 mm/year. (Weather report, 2014)

2.3 Land use pattern

The study area is a mosaic of protected areas and human dominated landscapes. These districts include highly populated metropolitan cities, vast agricultural landscapes and also vast tracts of forests with low density of human populations. (Fig. 2)

2.4 Vegetation

The major types of forests found in this region of Southern Karnataka are tropical evergreen, tropical semi-evergreen, tropical moist deciduous and tropical dry deciduous.

Roost locations of Indian flying fox in S. Karnataka

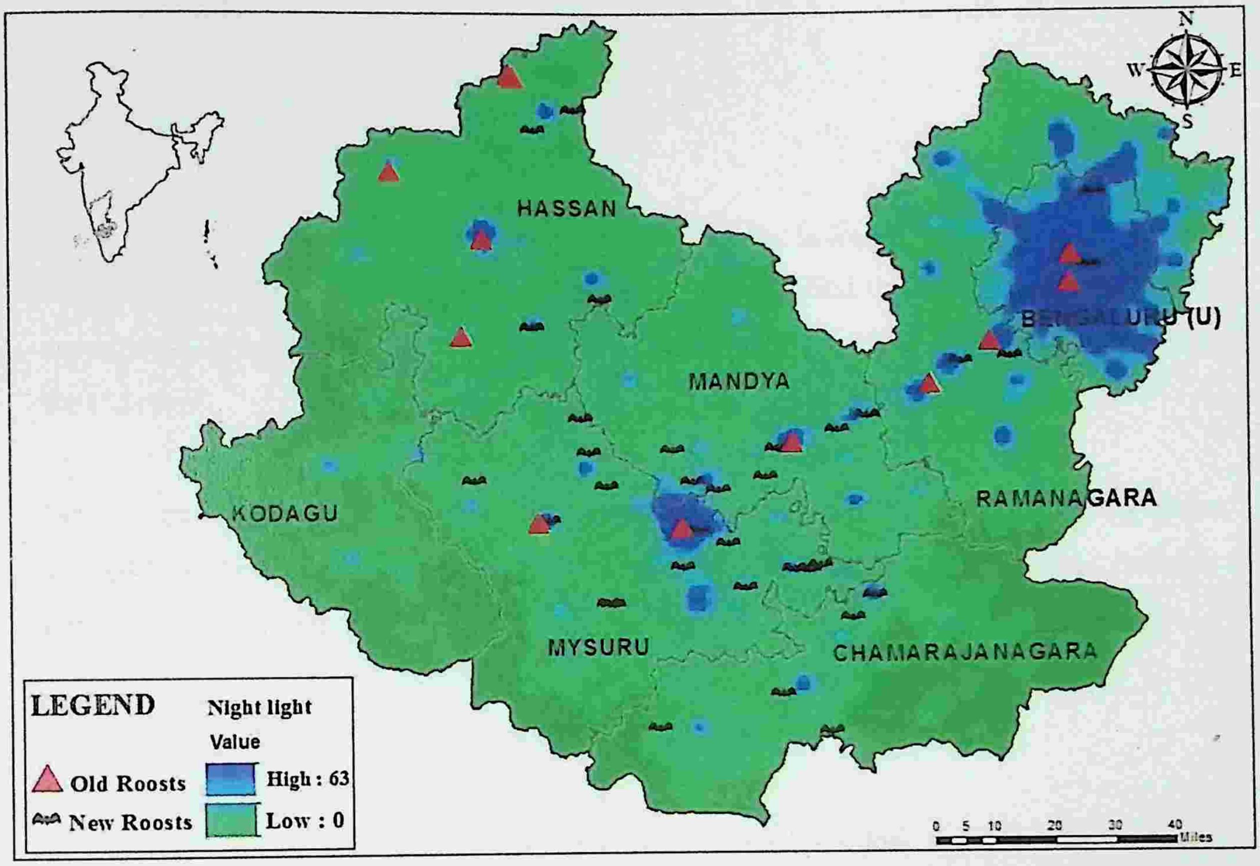


Fig 2: Study Area Map: Roosts of the Indian flying fox with reference to intensity of human habitation.

3 METHODS

3.2 Field methods

3.2.1 Population Estimation

Roost that had been identified in the previous study on the Indian flying foxes (Chakravarthy, 2009) was used as initial locations. New roosts were identified through questionnaire survey among two different age groups of people (10 -25 years and >25 years) in areas surrounding the old roost.

Since direct visual count is the method that is largely followed for counting flying foxes, I wanted to address the issue of detection between multiple observers and multiple methods to correct for variation in detection.

3.1.1 a) Direct Visual Count (Kunz., *et al* 1996)

Direct visual counts were done when the colony size was less than 300 individuals. It involved 2 surveyors circling the roost tree and manually enumerate the number of individuals roosting using a tally counter. Depending on the height of the tree, binoculars were used for enumeration (Bushnell, 8 x40). Each surveyor made 3 repeated counts to reduce visibility bias.

3.1.1 b)Branch Estimate (Project Pterocount, "http://pterocount.org/index.html" accessed September 29.09.2014).

Branch estimation was done when the colony size was more than 300 individuals. This method involved the surveyor identifying the entire major bat roosting branches of the tree followed by selecting a branch which has an average number of bats roosting on it. Then count the number of standard branches and multiply it with the number of roost branches with the standard branch.

3.1.1 c) Photographic Counts

Photographic count method was used when the roost tree canopy width was narrow. It involved clicking a 360 degree panoramic photo of the roost tree which is divided into four quadrants to count the number of bats in each quadrant for total count.

Plate 2: Photographic method of count, *Eucalyptus sp*

3.1.1 d) Evening dispersal count (Kunz., *et al* 1996)

Evening dispersal was used at locations with no tree cover in the immediate vicinity of the roost tree. It involved two surveyors placed in 2 opposite directions recording the emergence of bats from the roost trees, using a camera and a tripod. Later, the video was used to enumerate the total number of bats emerging from the roosts.

Plate 3: Evening dispersal count method.

3.1.2 Roost site selection

All roost locations, both old (Chakravarthy, 2009) and new, were evaluated for various habitat and environmental variables which influence selection of roost sites at macro and at micro level.

3.1.2 a) Macro-level roost site selection

At the landscape level interspersion and juxtaposition on various land-use patterns and habitats around the roost site were mapped using Google Earth and Landsat imagery to understand the distribution pattern of roost sites.

The variables that were mapped to study the land-use pattern influencing roost site selection were distance between roosts and water and distance to orchards.

Remotely sensed data sets that were used include:

a. Nightlight data: The nightlight data shows the intensity of urbanization based on the images captured by the satellite during night. Night light data was used to map the intensity of human habitation (DMSP .NOAA, 2012).

b. Forest cover data: Data obtained from FSI, 2014 was used after masking out the scrub.

c. Trees outside forest area: Forest type data obtained from FSI, 2009 was used after masking out all the forest area except the trees located outside the forest (Plantations and others).

d. MODIS, NDVI (NASA Earth Observing System Data Gateway): Data was downloaded for period Dec 2014 to April 2015 and NDVI of these 5 months were used to generate a PCA using ARCMap 10.3.

e. Tree height: Data of Global forest height (ICEsat , NASA 2010) was taken to analyze the tree height of the trees in S . Karnataka.

f. Distance to water: Water bodies located within 20 km around the roosts were mapped using Google Earth and Euclidean distance was generated using ArcMap 10.3 (ESRI 2014).

g. Distance to orchards: Orchards located around the roosts were identified manually, while visiting the roost locations and the distance between them was mapped using Google earth, the Euclidean distance was generated using ArcMap 10.3 (ESRI 2014).

3.1.3 b) Micro-level roost site selection

To identify factors governing roost site selection, various tree characters were measured at each roost for both roost and non-roost trees. Non-roost trees were identified in quadrant around the roost tree, like in Point centered count method (Cottam and Curtis, 1956), which method involved identifying non-roost trees in four directions around the central roost tree and these non – roost trees will be measured for the above mentioned variables (tree GBH, tree height, canopy cover, and canopy width and canopy height).

i) Tree height

The height of the roost tree was measured using a clinometer and a range finder. Standing at ~20 m distance, readings on the percent scale of the clinometer coinciding with the tip and base of the tree were noted down. And the range finder (Hawke 400) was used to measure the distance between the tree and observer. The total height of the tree was calculated using

Total height (m) = (Top measurement – Base measurement) X distance.

ii) Tree GBH

A measuring tape was used to measure the girth at breast height of various roost trees.

iii) Canopy cover

The canopy cover of the roost tree was measured using a densiometer (Spherical crown densiometer) in four cardinal directions to arrive at the average percent canopy cover of the tree.

iv) **Canopy width**

Measurement of the canopy width involved location of the farthest tip of the branch in all four directions and then measuring the distance between them using either a range finder or a measuring tape.

v) **Canopy height**

The canopy height of the roost trees were measured using a clinometer (Sunto PM-5) and a range finder. The method of measurement is similar to tree height measurement but this involved taking measurements of the lowest and the highest point of the canopy to arrive at the total canopy height.

vi) **Roosting branch**

Identification of the roosting branch in a tree involved classifying the type of branch the bats were found roosting on (primary, secondary, and tertiary) or a combination of these three branches.

vii) **Roosting height**

Measurement of the roosting height involved measuring of lowest and the highest roosting branch using a clinometer and a range finder.

3.1.3 Assessment of perceived fruit damage and loss

Assessment of perceived fruit damage was done at intensive study locations within the radius of 15 kms with roost aggregations and availability of orchards.

It was carried out using a semi-structured questionnaire survey (Webber, 2014) to interview farmers experience fruit damage by flying foxes. The questionnaire addressed crops cultivated, seasons of cropping, investment and risks involved in production in each season and the losses incurred due to fruit damage in each season.

Plate 4: Sapota fruits damaged by *Pteropus giganteus* in a commercial orchard.

3.2 Analysis

3.2.1 Population estimation

The counts from methods used to estimate population; direct visual count, branch estimate and photographic counts were compared using linear regression models in sofware'R' (R Development Core Team , 2015). Similarly branch count and direct visual count were also compared.

Photographic count and branch estimates were compared with direct visual count to account for observer difference and for calibration.

Detection probability between the three estimation methods was accounted for, by comparing the total count of each method, and hence identifying the suitable method with the highest detection probability.

To assess the change of population over time, the count data from the previous study, old roost locations (Chakravarthy, 2009) were compared with the counts from locations identified in the present study. Using the below mentioned equation (Caughley, 1977)

r = [((log.Vpresent – log. V past)/years*100.

3.2.2 Roost site selection

3.2.2 a) Macro site selection

MaxEnt software, version 3.3.3 (Phillips *et al.* 2006) was used to build the ecological niche model. Maximum entropy modeling is a machine learning method that uses only presence only data (Phillips *et al.* 2006).MaxEnt models species distributions from presence-only species records, provided that biases can be dealt with and except for the non-identifiability of prevalence. (Elith., *et al* 2011)

To model general suitability of the study area for roosting sites of the Indian flying fox the variables used were tree height, trees outside forest area, forest cover, MODIS NDVI and nightlight data. Specific suitability of the study area for roosting sites was also done adding distance to water and orchards to the existing variables.

AUC test method was used for assessing the model fit.

3.2.2 b) Micro site selection

The tree attributes measured at individual roost sites were summarized using exploratory data analysis in Microsoft Excel, (2013) to test the underlying assumptions and to uncover underlying structure.

The survivability of the roosts was estimated using Kaplan-Meier estimator (Kaplan & Meier, 1958) after right censoring the roost age data.

Generalized linear models were employed to assess the effects of various tree attributes on selection of roost sites. (Crawley, 2012) The GLM analysis was performed using Binomial and Poisson logistic regression on count data which was the dependent variable with the tree attributes such as tree GBH, height, canopy cover, canopy height and canopy width as independent variables.

Linear regression models were used to compare the influence of distance to water bodies and distance to orchards on occurrence of roosts after log transformation. (Crawley, 2012)

CART (Classification and Regression Tree) was used for gaining a comprehensive understanding on influence of different variables. (Crawley, 2012). Tree attributes were considered as predictor (independent) variables and count data was considered as predictive (dependent) variable.

3.2.3 Assessment of perceived fruit damage and loss

The questionnaire survey data was summarized using exploratory data analysis to uncover the underlying structure. The questionnaire survey addressed questions related to fruits cultivated, extent of land under cultivation cropping pattern, age of the orchard, seasons of yielding, fruit damage due to pest and diseases, fruit damage and loss due to flying foxes and control measures.

Pearson's Chi-square test was used to identify the relationship between extent of fruit damage and the type of orchard. The exploratory data analysis and graphs were done using Microsoft Excel (2013).

4 RESULTS

4.2 a) Population estimation

A total of 300 roost trees were used in population estimation of the flying foxes. Direct visual count, branch estimates and photographic count methods were used to count the individuals based on the roosting location and roost tree species. The count data obtained from photographic count method was compared with direct visual count; branch estimates with direct visual counts to correct for differences in the estimates using linear regression. (Table1and 2).

	Estimate	Std. Error	t value	Pr(>|t|)
(Intercept)	1.53282	1.61597	0.949	0.354
Direct visual count	1.00962	0.03178	31.766	<2e-16 ***
Multiple R-squared: 0.9806		**Adjusted R-squared:** 0.9796		

Table 1: Linear regression model – Comparing direct visual count with photographic count.

	Estimate	Std. Error	t value	Pr(>|t|)
(Intercept)	35.6360	52.5090	0.679	0.519
Direct visual count	1.1751	0.1369	8.586	5.79e-05 ***
Multiple R-squared: 0.9133		**Adjusted R-squared:** 0.9009		

Table 2: Linear regression model- Comparing direct visual count and branch estimates.

Based on the p-value, which is < 0.01, it was evident that there is highly significant relationship between the counts from photographic with direct visual count method and also counts from direct visual count with branch estimates method.

The predicted values were calculated using estimate values on equation $y= a+b.x$, and were plotted using a scatter plot. (Fig. 3 and 4)

Mean detection probability of direct visual counts versus photographic counts was 94 %. And the mean detection probability of branch estimates versus direct visual counts was 74 %.

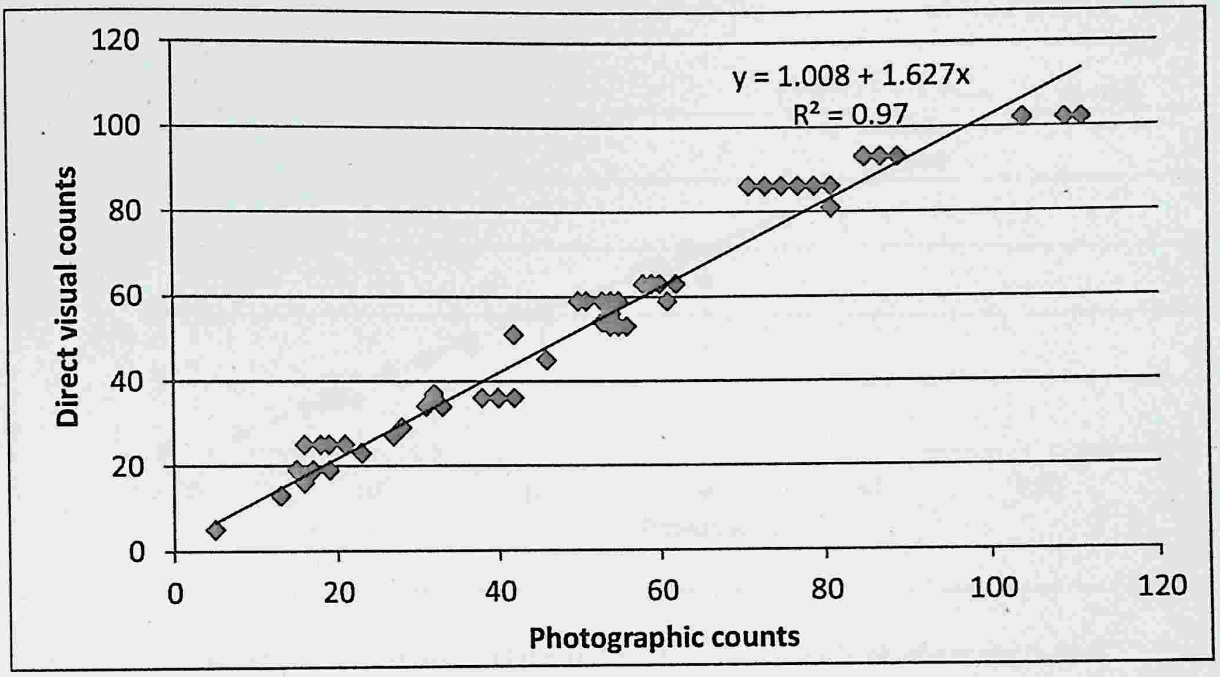


Fig. 3: Relation between direct visual counts and photographic counts.

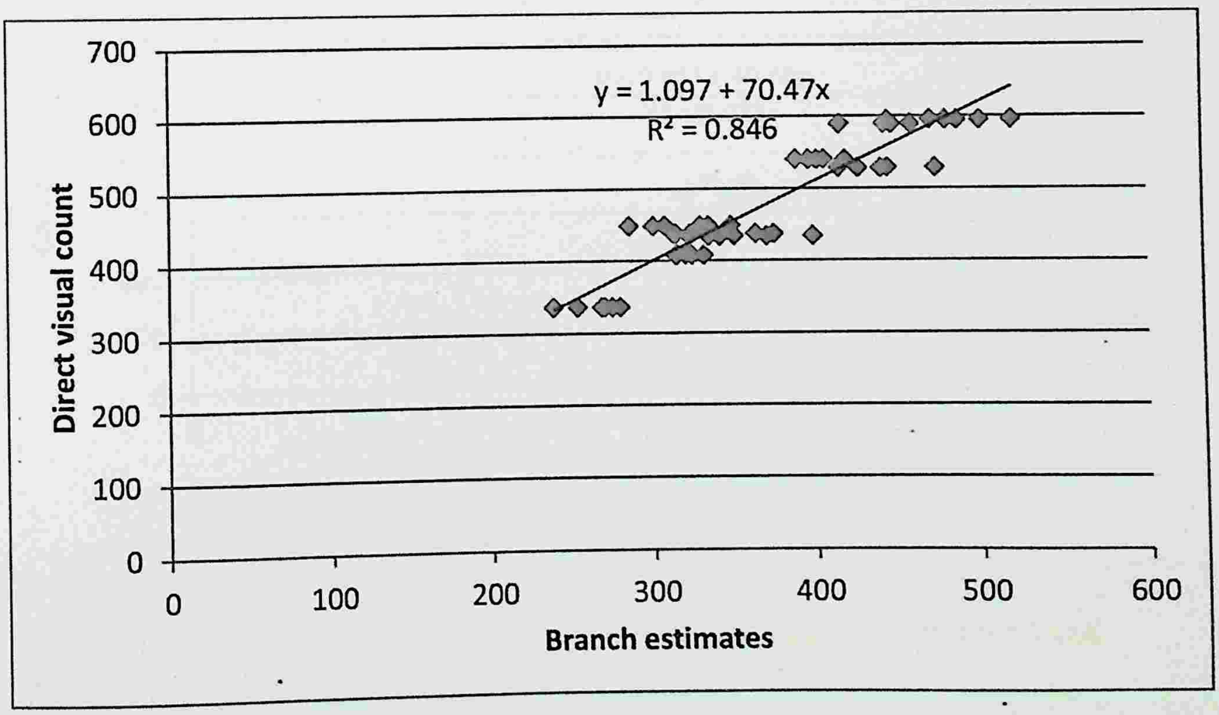


Fig. 4: Relation between direct visual counts and branch estimates.

The inter-observer variability between the two observers employed in the direct visual count method has been depicted in Fig.5 and 6

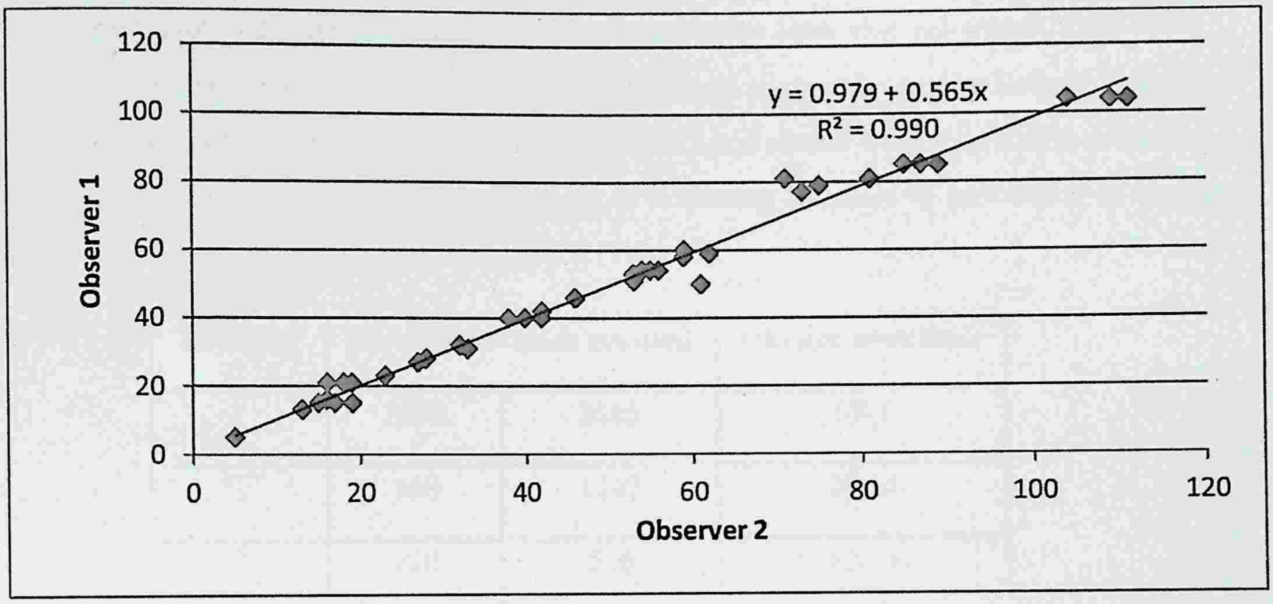


Fig. 5: Inter-observer variability between direct visual counts of observer 1 and observer 2 at roosts with less than 300 individuals.

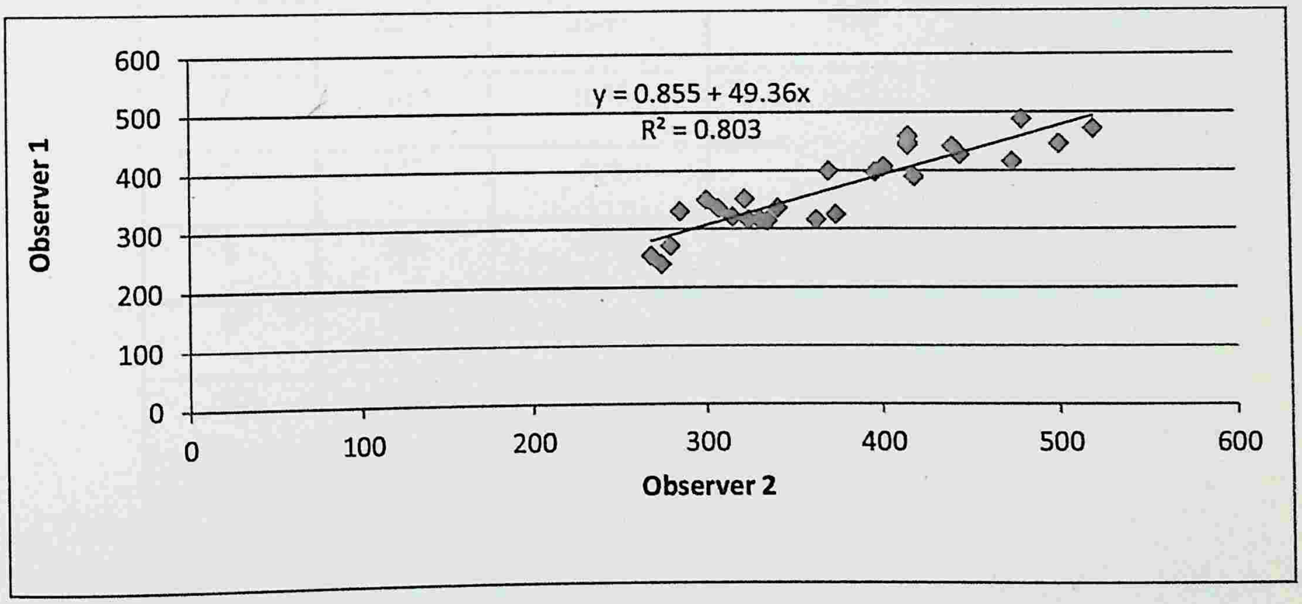


Fig. 6: Inter-observer variability between direct visual counts of observer 1 and observer 2 at roosts with more than 300 individuals.

4.2 b) Roost population decline and roost loss

The counts from the previous study (Chakravarthy, 2009) were compared with counts from the current study and the percent population change over time was calculated. Out of 12 locations, the counts at 9 locations showed positive trend in growth ranging from 0.16 to 20 % indicating increase in population from 2009 to 2015 and counts from 3 locations exhibited negative growth ranging from -0.81 to -10.17 % indicating decrease in population at those particular roosts between year 2009 and 2015. (Table. 3)

Location	**No of individuals counted**		**Change over time**
	2009	**2015**	**(%)**
1	168	1747	20.34
2	128	516	12.13
3	304	747	7.80
4	688	1677	7.74
5	2272	5589	7.82
6	1011	1645	4.23
7	657	904	2.77
8	506	647	2.13
9	809	824	0.16
10	556	507	-0.81
11	355	211	-4.51
12	481	150	-10.12

Table 3: Change in population growth over a period of 5 years.

Among the 21 roost locations that were taken from the previous study (Chakravarthy, 2009) 36 % of the roost were destroyed/ abandoned. The interview conducted revealed that losses and abandoning of roosts were due to many factors, but loss of roost tree was a major reason (68%). (Fig. 7)

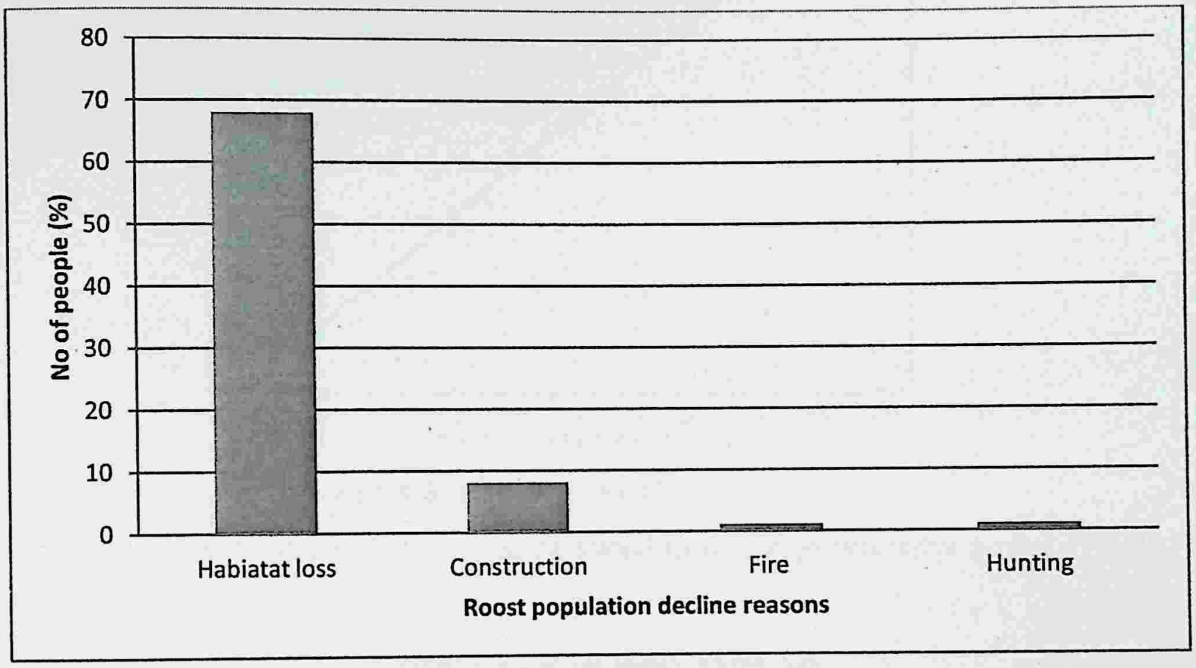


Fig.7: Reasons for decline in population at roosts.

4.3 Roost site selection

4.3.1 Macro site selection

4.2.1 a) Maxent

A) For modeling the general suitability of to identify potential roost areas of the Indian Flying fox, already identified roost location data along with necessary variables were used was used. The model was run with random selection of 75% roost presence location; remaining 25% were used as test data to evaluate model fit.

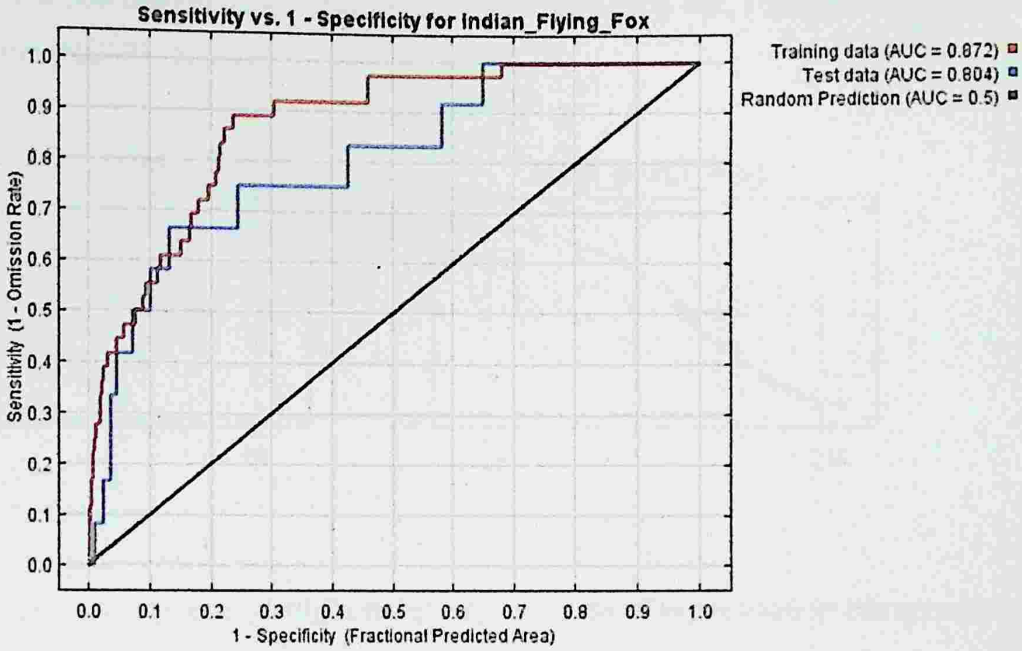


Fig. 8: Area under ROC curve (AUC).

The AUC test data value is 0.80, indicating a good fit with high predictive power. (Fig.8)

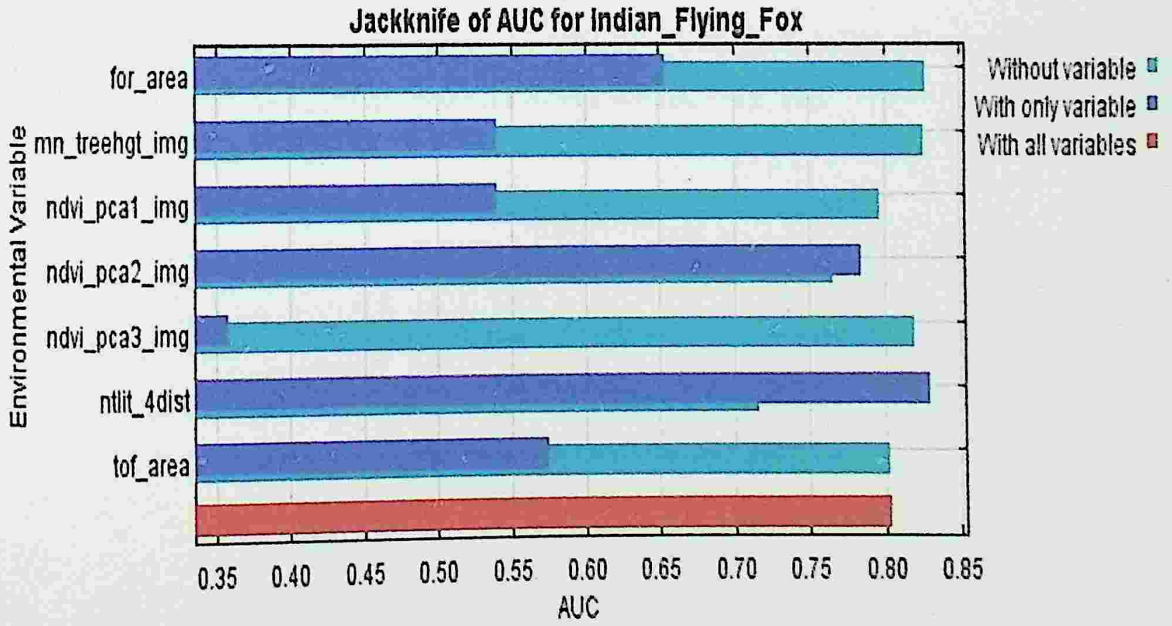
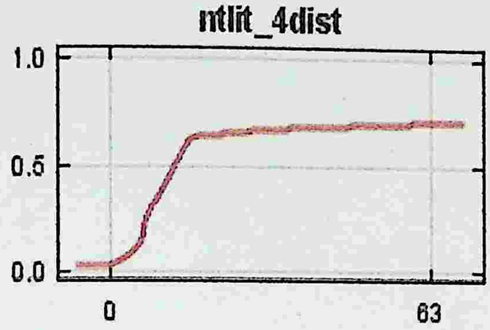
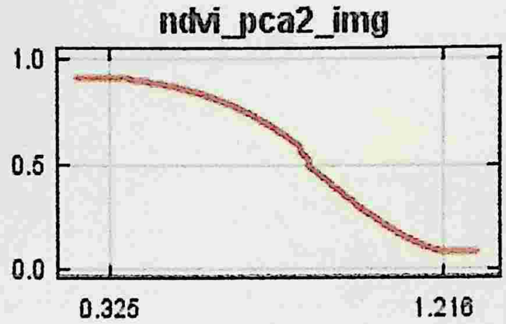


Fig. 9: Jackknife of AUC value

The AUC plot shows that the nightlight(ntlit_4dist) data is the most effective single variable for predicting the distribution of the occurrence of Indian Flying fox, followed by openness of the vegetation (NDVI).(Fig. 9)



a

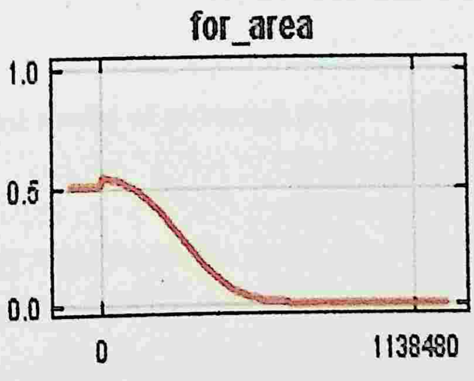


b

Fig. 10: Response curve of nightlight data and openness of vegetation to occurrence of roosts.

a. . Nightlight response curve: The response curve for nightlight indicates that the probability of occurrence of roosts increases with the intensity of nightlight (Fig. 10).

b. MODIS, NDVI: The response curve indicates that probability of occurrence of roost sites decreases with decrease in openness of vegetation. (Fig. 10).



c

Fig. 11: Response curve of forest cover to occurrence of roosts

c. **Forest cover:** The response curve indicates that the probability of roost occurrence decreases with the increase in area under forest cover. (Fig. 11)

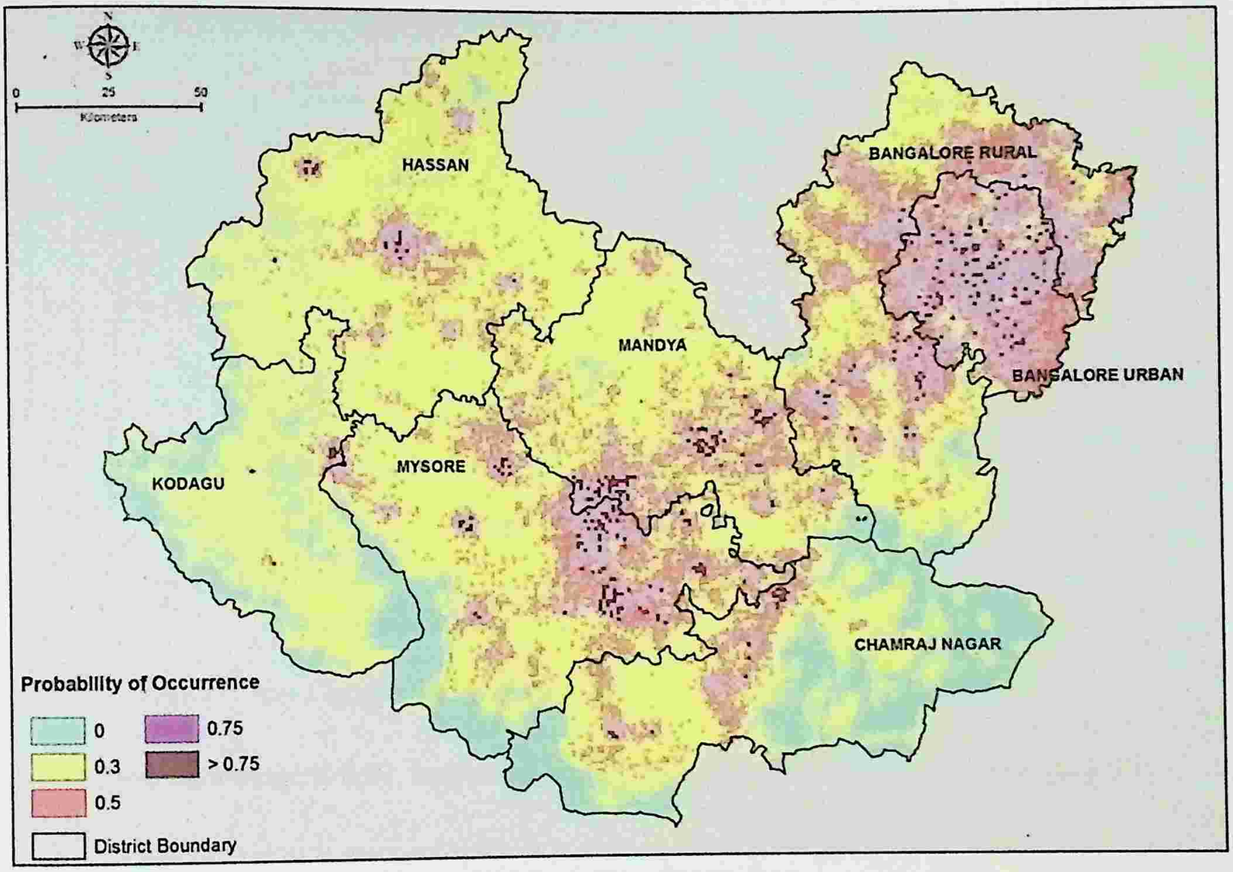


Fig. 12: General predicted model of potential roost locations for the Indian Flying fox, for the entire study area

The total extent of the study area was 31,881 sq.km, out of which 33.19% of the area is currently suitable for roosting habitat for *Pteropus giganteus* with probability of occurrence ranging from 0.5 to 0.75%. (Fig.12).

B) For modeling the specific suitability of to identify potential roost areas of the Indian Flying fox, already identified roost location data along with necessary variables including distance to orchard and water with 20 kms around the roost locations were used

The model was run with random selection of 75% roost presence location; remaining 25% were used as test data to evaluate model fit.

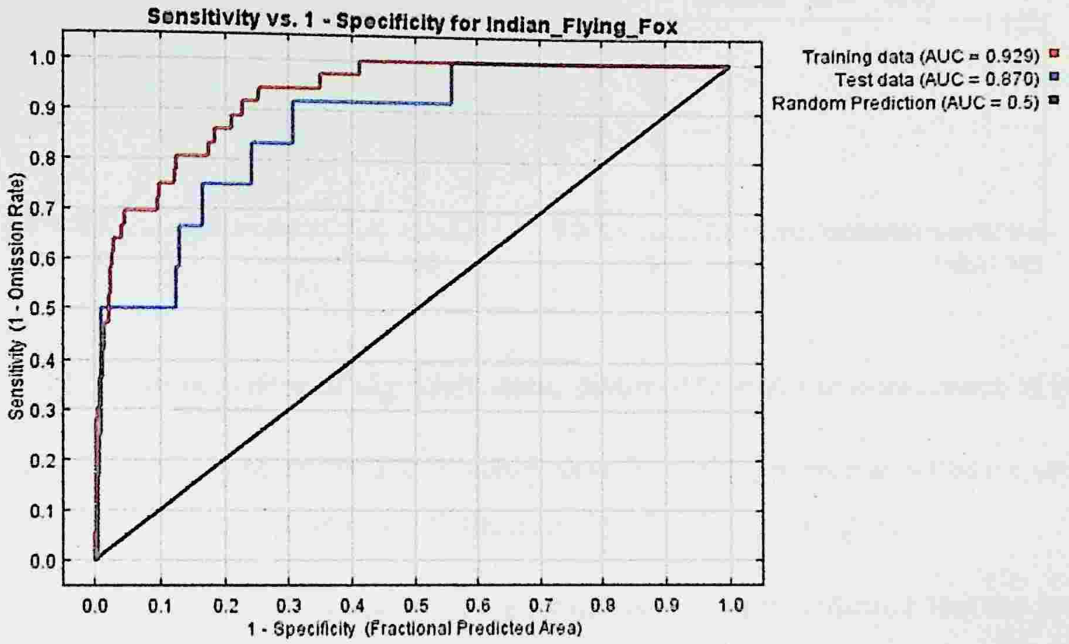


Fig. 13: Area under ROC curve (AUC)

The AUC test data value is 0.87, indicating a good fit with high predictive power. (Fig.13)

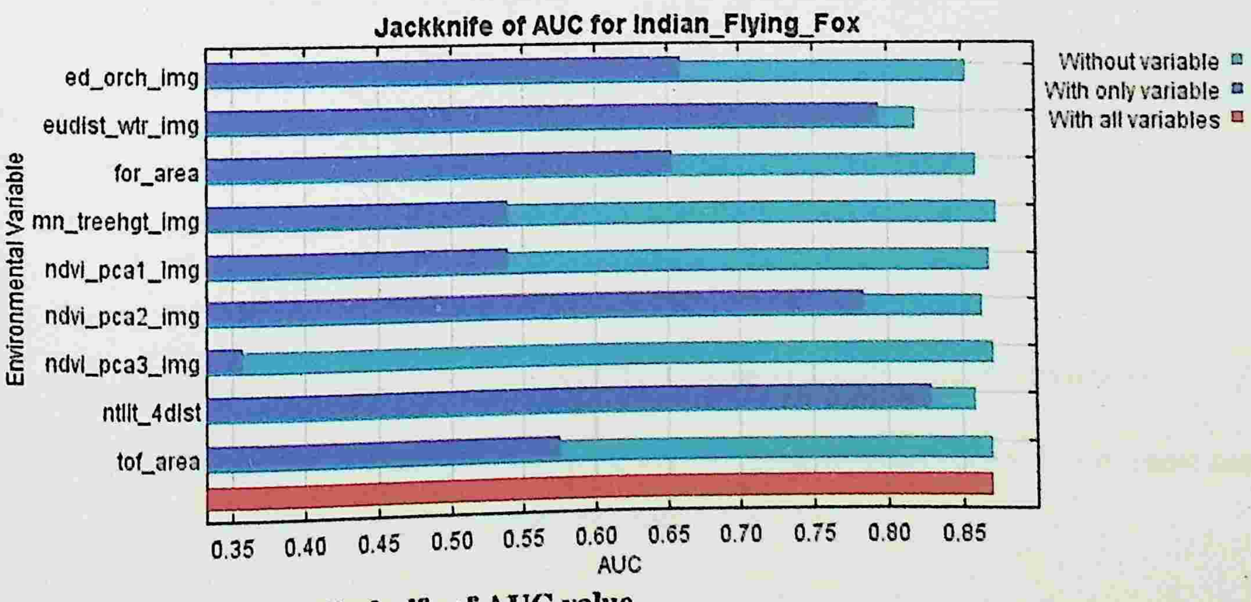


Fig. 14: Jacknife of AUC value

The AUC plot shows that the nightlight(ntlit_4dist) data is the most effective single variable for predicting the distribution of the occurrence of Indian Flying fox, followed by distance to water (eudist_wtr).(Fig. 14)

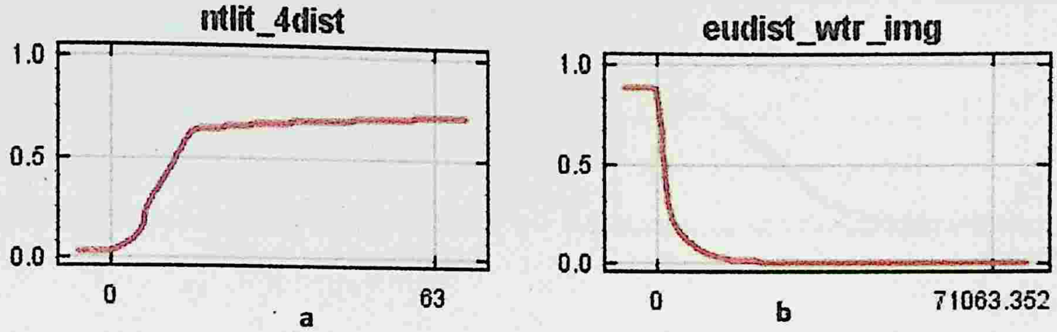


Fig. 15: Response curve of nightlight data, distance to water to occurrence of roosts.

a. Nightlight response curve: The response curve for nightlight indicates that the probability of occurrence of roosts increases with the intensity of nightlight. (Fig. 15)

b. Distance to water: The response curve for distance to water indicates that the probability of occurrence of roost sites decreases with the increase in distance to the water body. (Fig. 15)

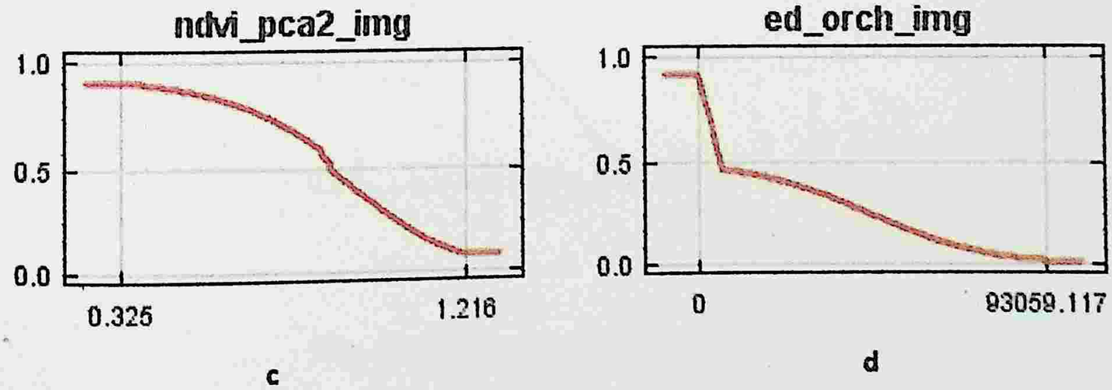


Fig. 16: Response curve of MODIS NDVI (Openness) and distance to orchards

c. MODIS NDVI: The response curve indicates that probability of occurrence of roost sites decreases with decrease in openness of vegetation. (Fig. 16)

d. Distance to orchards: The response curve indicates that the probability of occurrence of roost sites decreases with the increase in distance to the orchards. (Fig. 16)

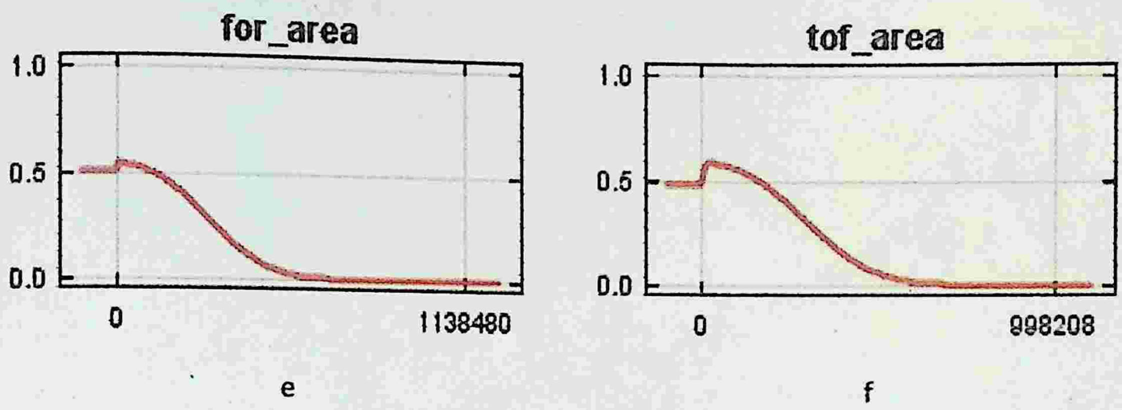


Fig. 17: Response curve of forest cover area and trees outside forest area

e. Forest cover: The response curve indicates that the probability of roost occurrence decreases with the increase in area under forest cover. (Fig. 17)

f. Trees outside forest: The response curve indicates that the probability of roost occurrence will decrease with decrease in area under trees outside forests. (Fig. 17)

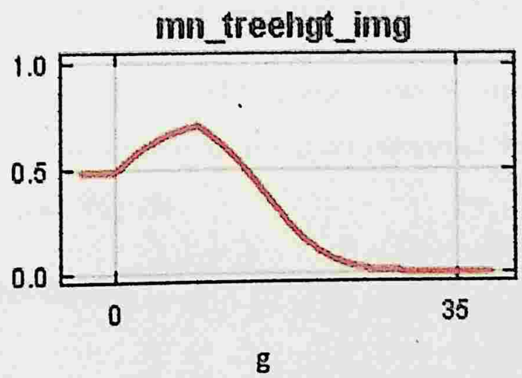


Fig. 18: Response curve of mean tree height

g, Mean tree height: The response curve indicates that the probability of occurrence of roosts will decrease with increase in tree height. Implying that the selection for roost trees are neither too tall or short.(Fig.18)

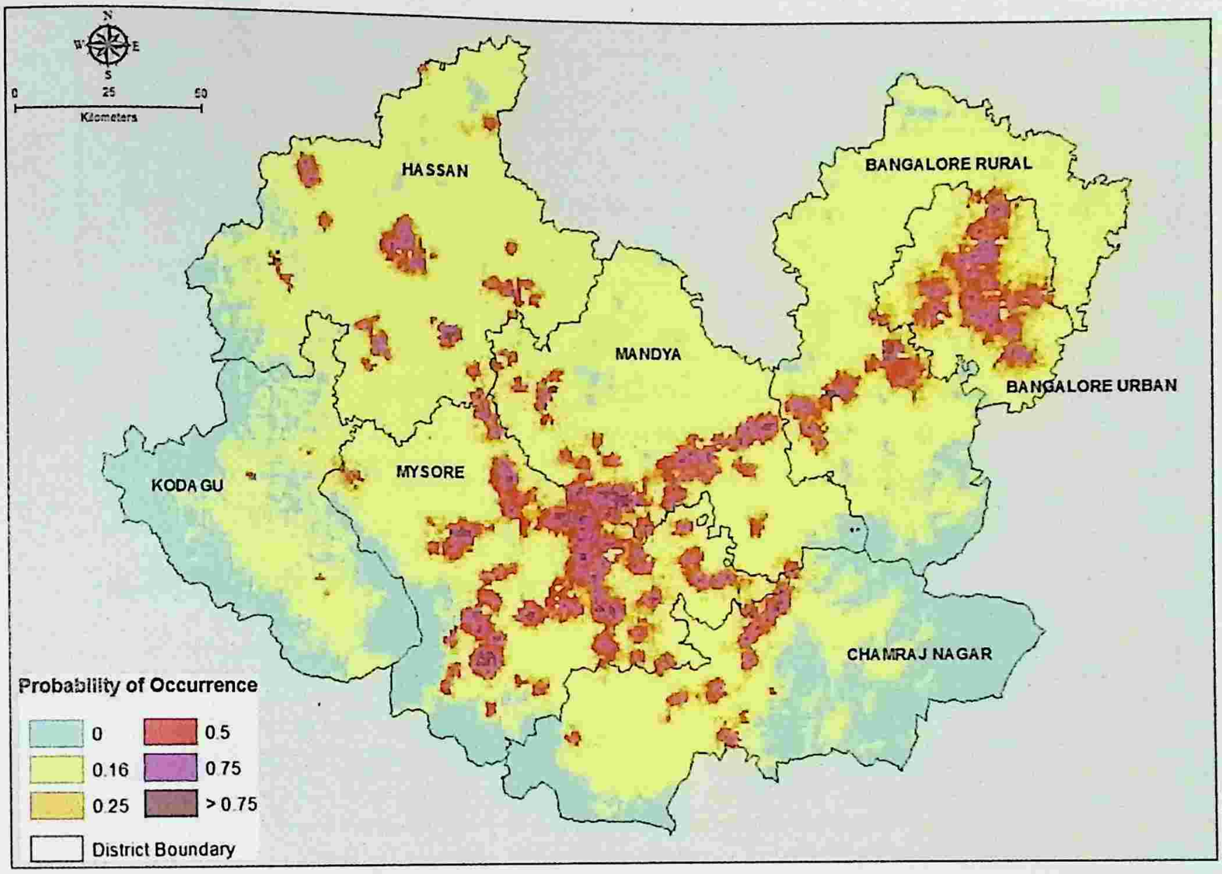


Fig. 19: Specific redicted model of potential roost locations for the Indian Flying fox.

The total extent of the study area was 31,881 sq.km, out of which 11.38% of the area is currently suitable for roosting habitat for *Pteropus giganteus* with probability of occurrence ranging from 0.5 to 0.75%. (Fig.19).

1 **b) Distance from water bodies.**

All water bodies around the roosts recorded were plotted on a bar graph which indicated that out of total 51 roosts located, maximum numbers of roosts 51% were located within 500 meters from the roost and 31% were located within 5 kilometers 3 and remaining 10% were beyond 5 kilometers. (Fig.20).The roost sites were negatively related with distance to the water. (Fig.21).

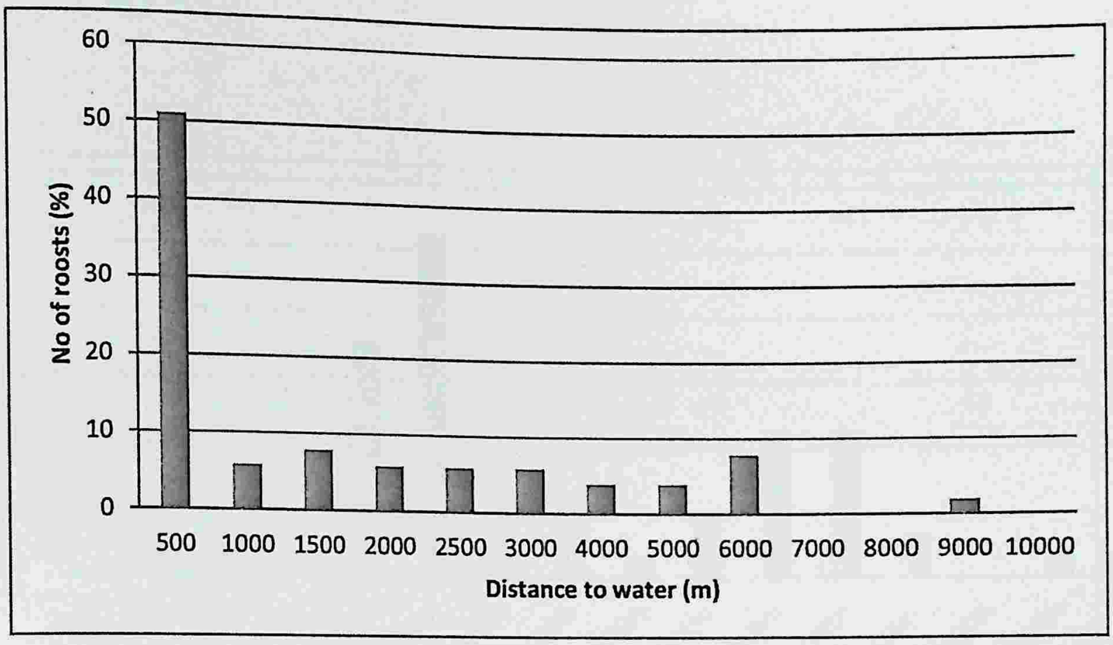


Fig.20: Relation between roosts with nearest water body

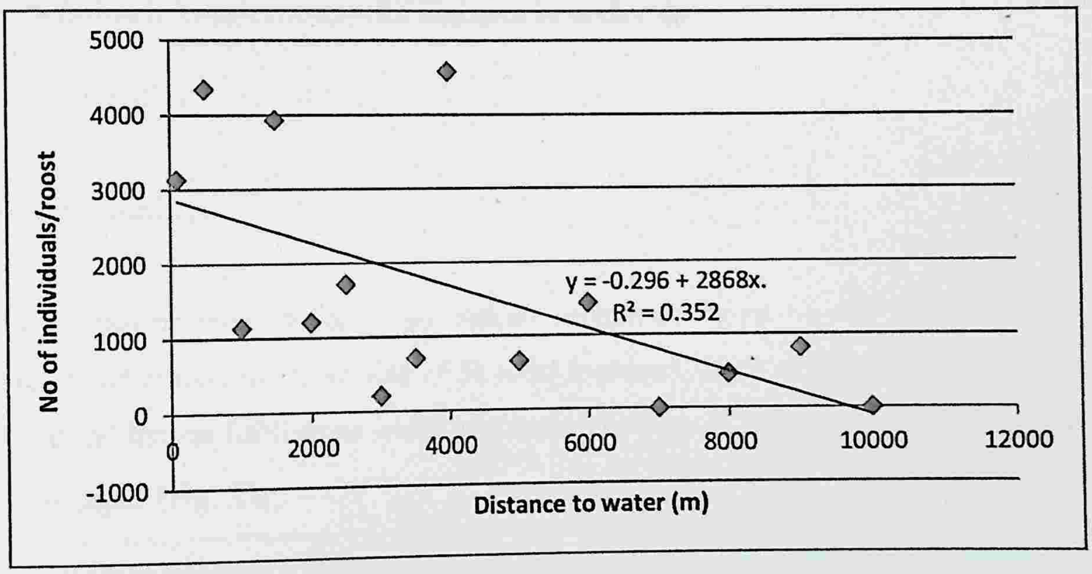


Fig.21: Linear relation between roost and distance to water source.

4.2.1 c) Distance to orchards

All the orchards found during location of roost sites were plotted on a bar graph which indicates that 27 % of the orchards were located 5 kilometers away from the roost. The indicates that 27 % of the orchards were located 5 kilometers away from the roost. The nearest orchards to the roost were18%, located 2.5 kilometers away from the roost and the farthest orchard recorded was located at 30 kilometers which was 2%.(Fig.22)

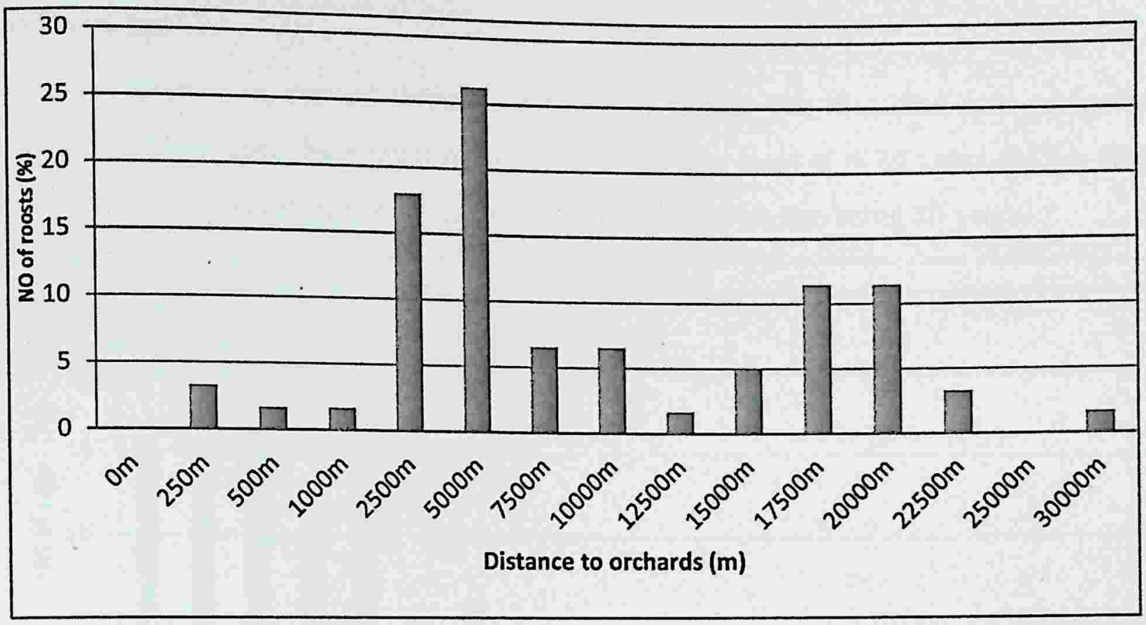


Fig. 22: Relation between roosts with distance to orchards

.2 Roost characteristics

4.2.2 a) Roost surroundings

Each roost locations were divided into various categories based on the type of human habitations found around the roost. Out of 51 roost locations, 20 % of the roosts were found in areas with no human habitations while maximum numbers of roosts (25 %) were located inside the villages. (Fig. 23)

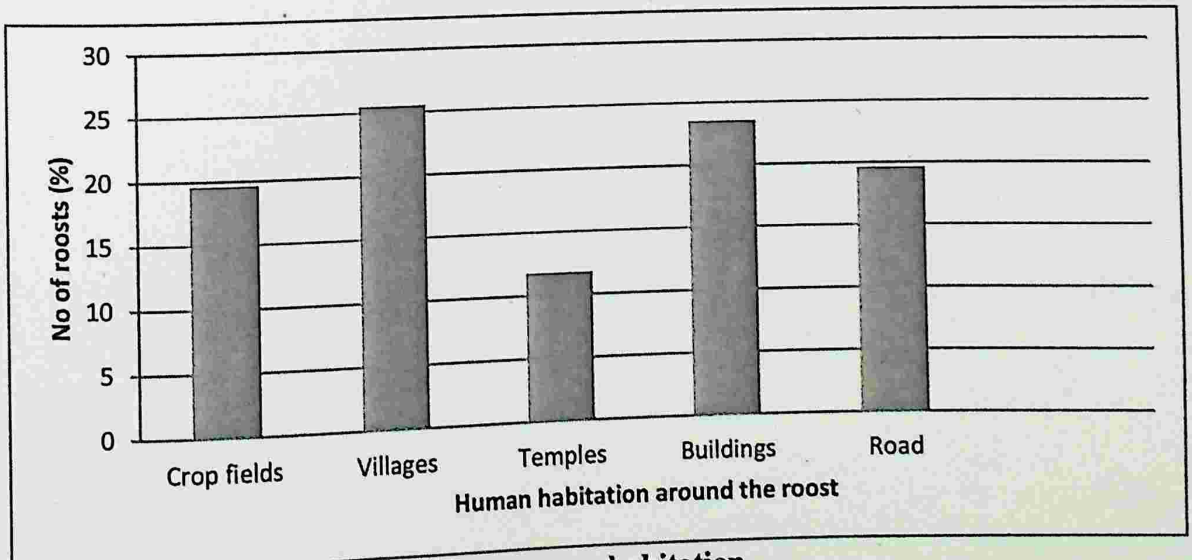


Fig. 23: Relation between roost and human habitation.

4.2.2. b) Roost age

Age of each roost derived through interview of people was classified into categories based on their age. Maximum roosts were in the age class of 0-25 years (84%). (Fig. 24). With the median age being 15 years and the maximum age being 80 years.

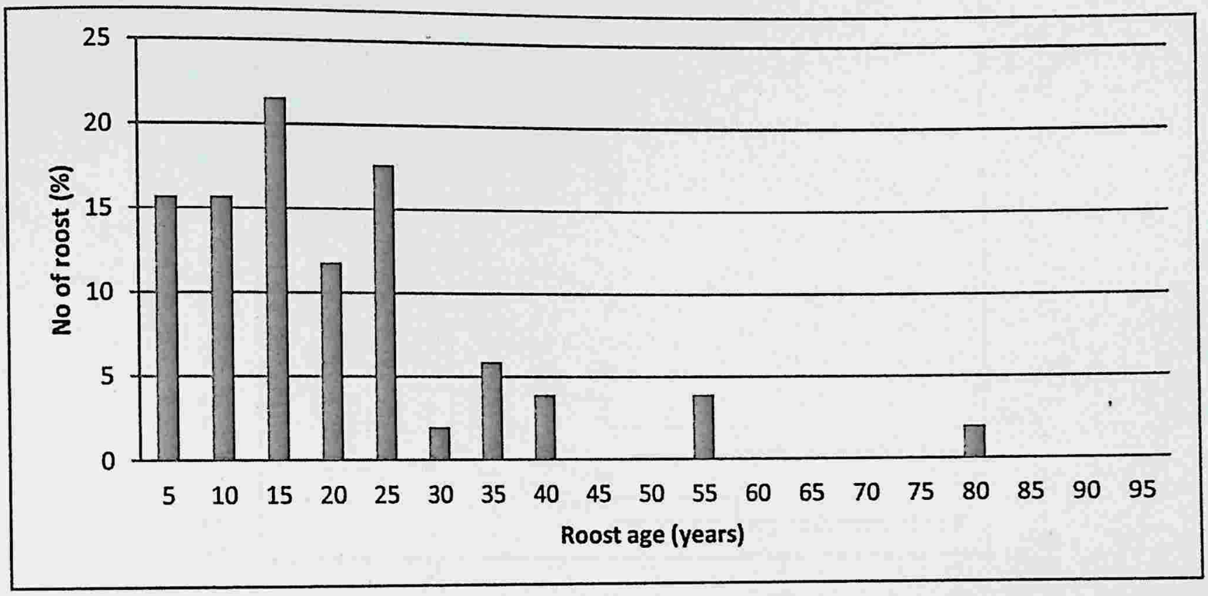


Fig. 24: Different age classes of roosts based on interview of local people

The plot of the Kaplan–Meier estimator shows a series of declining horizontal steps approaching the true survival function for that population, which indicates that the survivability of a roost drastically decreases beyond 20 years. (Fig. 25)

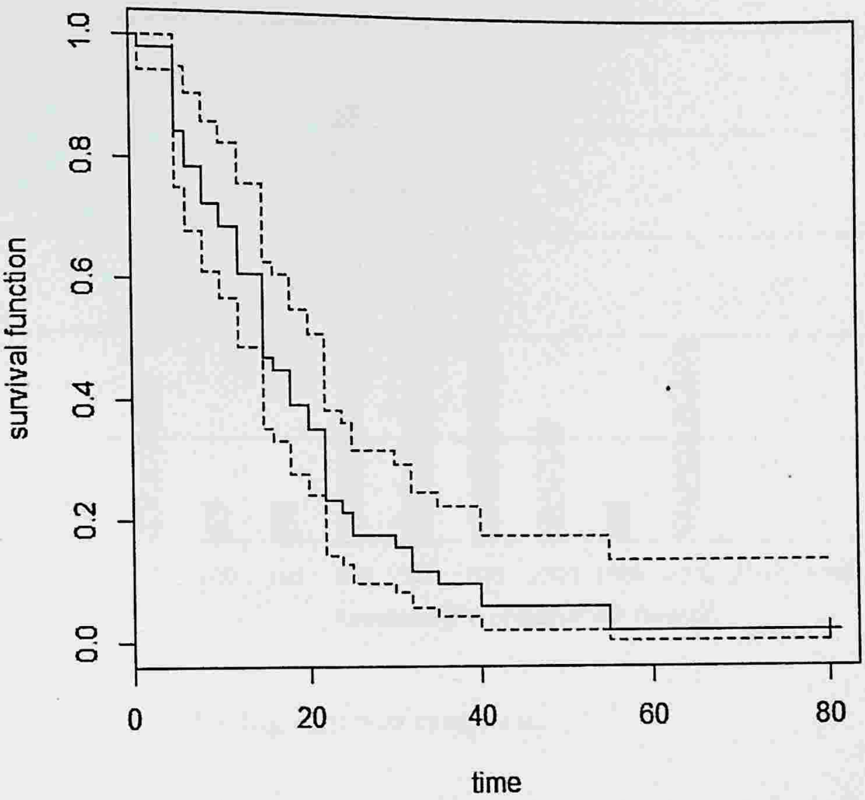


Fig 25: Kaplan Meier survivorship curve of *Pteropus giganteus* roosts

4.2.2. c) Roost size

Counts at each roosts revealing the number of flying foxes indicates, maximum number of roosts falling in the range of 500 – 800 individuals/roost (25%). The minimum size of the roost was found to be 39 individuals and maximum was 5504 individuals. (Fig. 26)

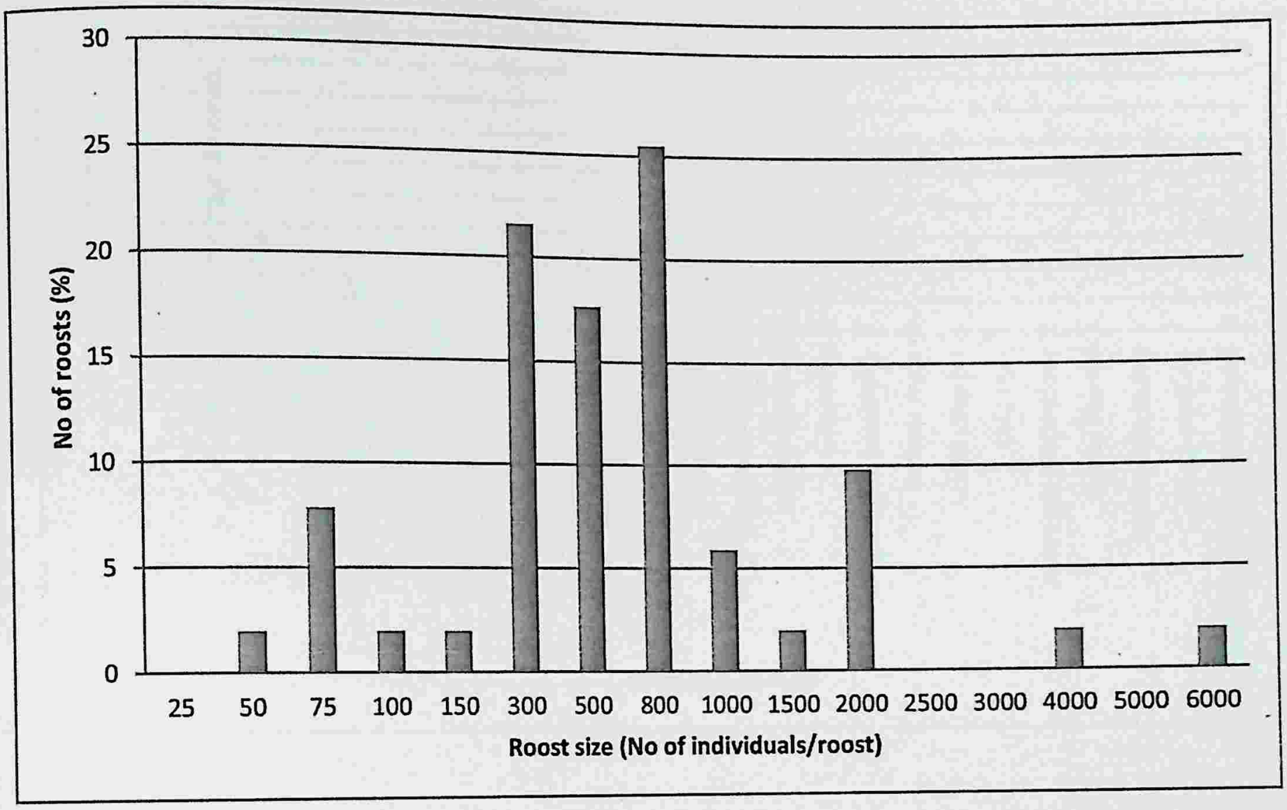


Fig. 26: Percent of roosts having different camp size.

4.2.2. d) Tree characters

The variables recorded for each roost tree and non-roost trees included tree species, tree GBH, tree height, canopy width, canopy cover and canopy height.

i) Tree species (Roost and Non-roost)

An array of roosting tree species were recorded, out of which *Eucalyptus* sp was the most commonly used (38%) followed by *Ficus* sp. (14%). The least used species recorded was *Cocos nucifera, Spathodea campanulata* and *Azadirachta indica* (0.3% each). (Fig. 27)

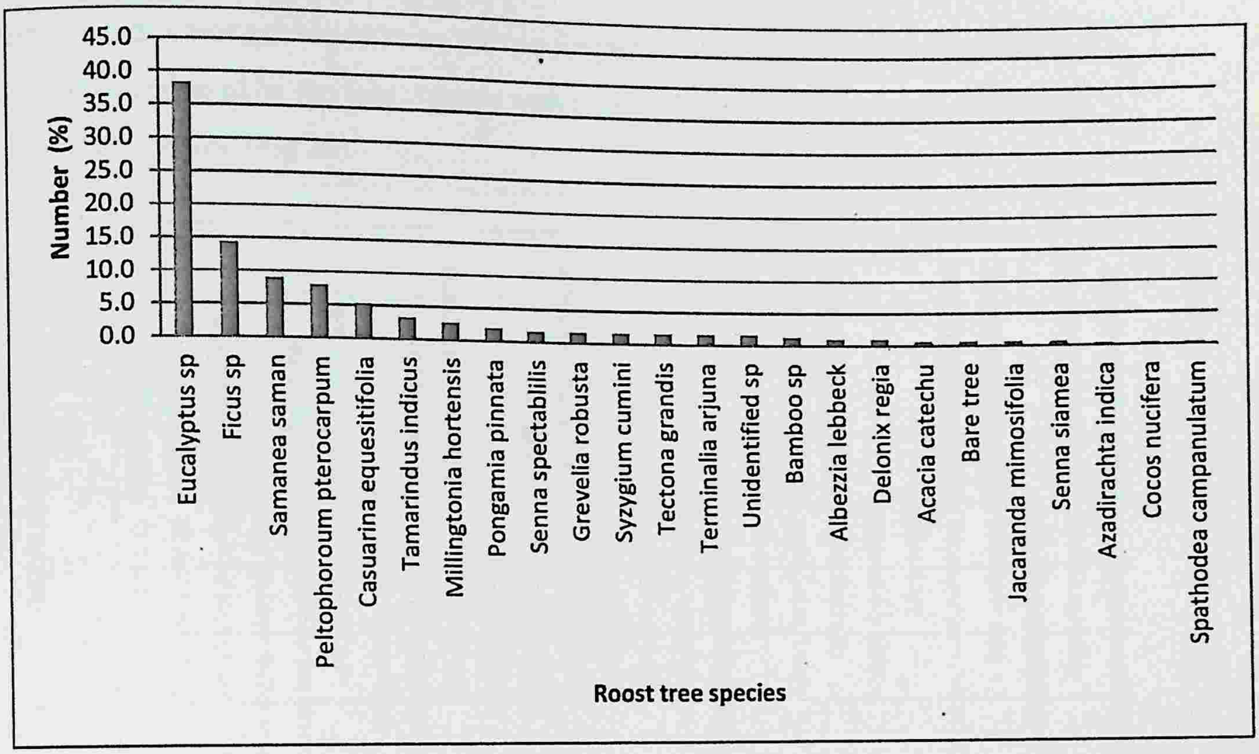


Fig. 27: Roost tree species used by the Indian flying fox.

The non-roost tree species, available around the roosts were *Cocos nucifera* (22%) followed by *Eucalyptus sp* (18%). (Fig. 28)

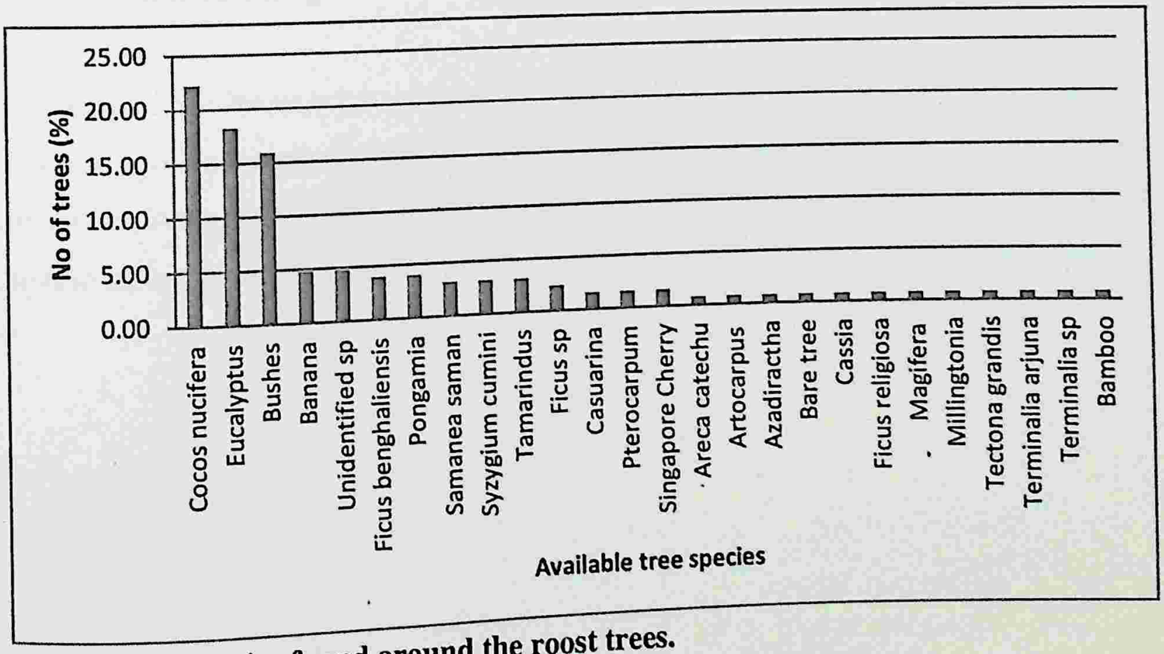


Fig. 28: Tree species found around the roost trees.

Ivlev's index was calculated using relative frequency of occurrence of tree species that is available and used by the bats. Species with positive index values are used more than available species. (Fig 29).

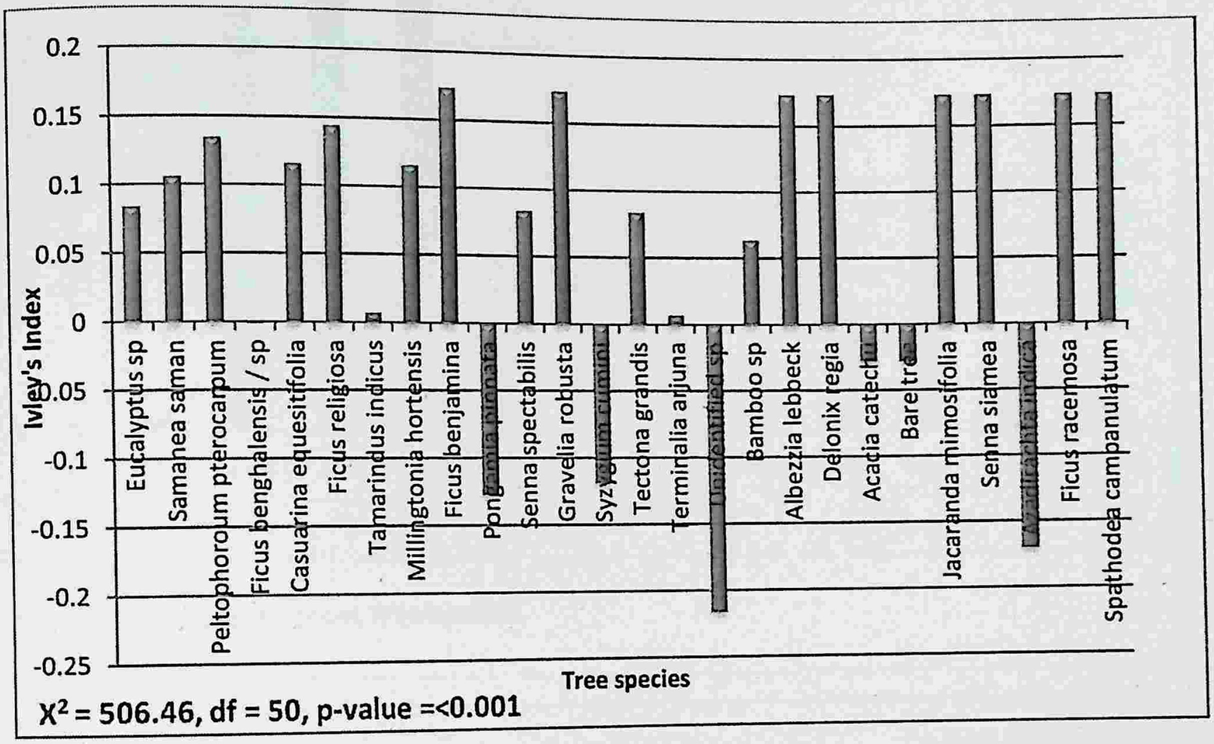


Fig 29: Ivlevs index of used and available trees species.

i) **Tree girth at breast height**

The mean girth at breast height of roost tree was 3.12 meters. The girth at breast height of the roost tree species recorded ranged from 0.6 meter to 12. 5 meter; whereas for the available roost tree species recorded ranged from 0.6 meter to 12. 5 meter; whereas for the available tree species it ranged from 0.5 to 7 meters (Fig 30). Maximum numbers of roosts trees were found to be in the range of 1 to 2.5 meters (56%).

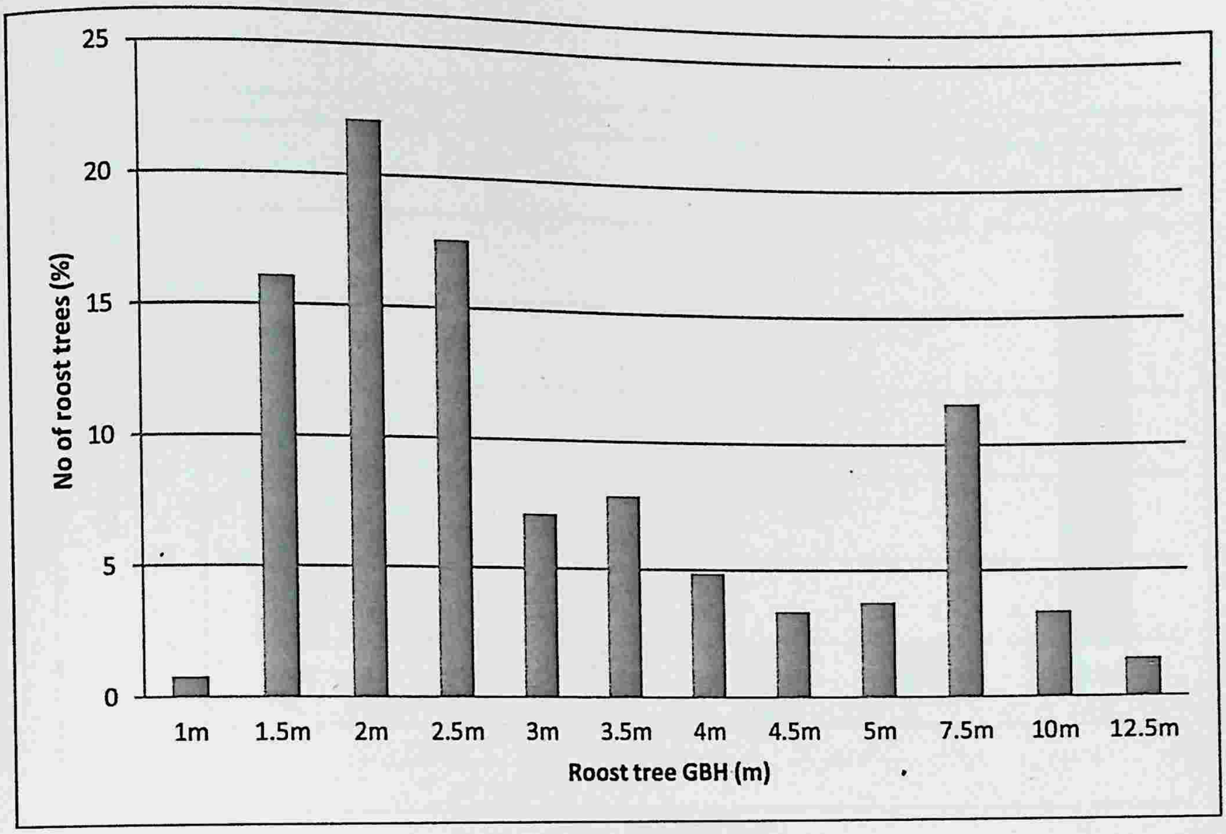


Fig 30: GBH (m) of roost tree species.

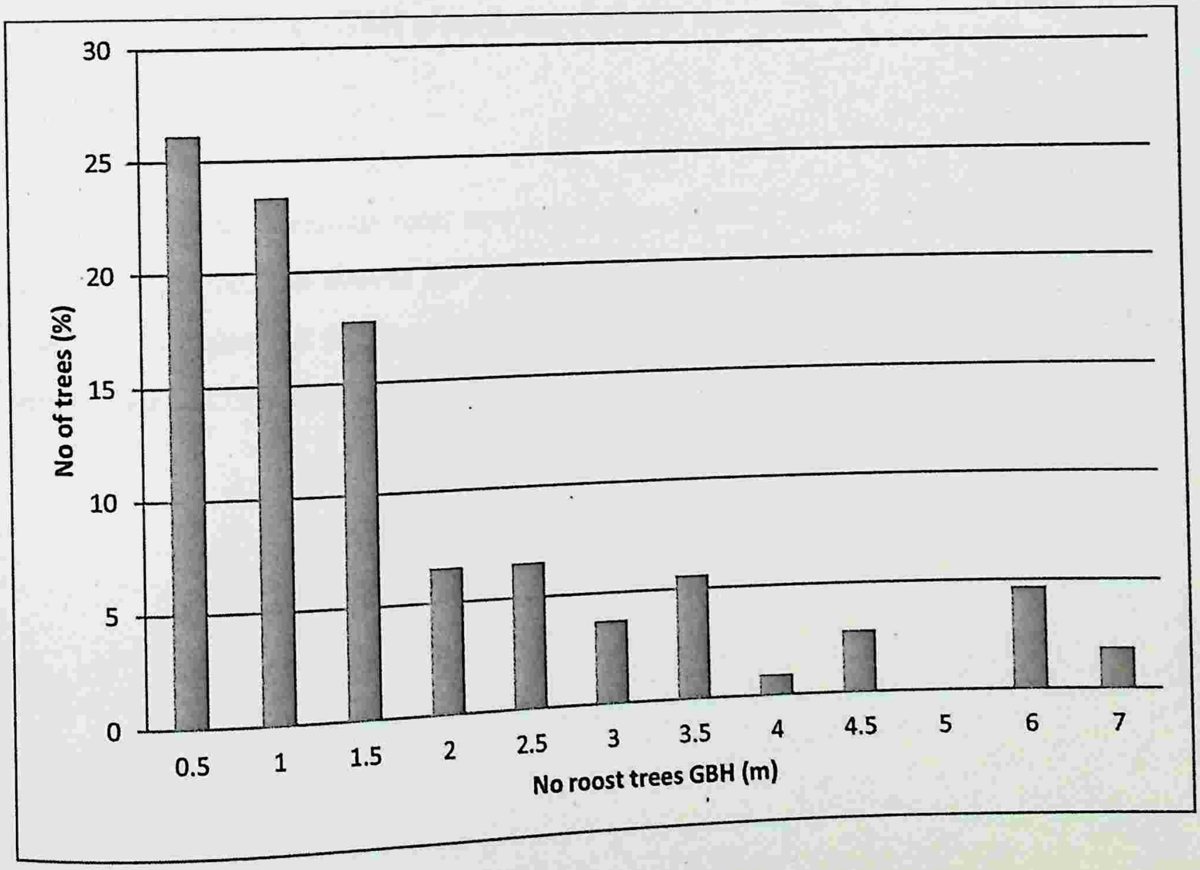


Fig 31: GBH (m) of non- roost tree species

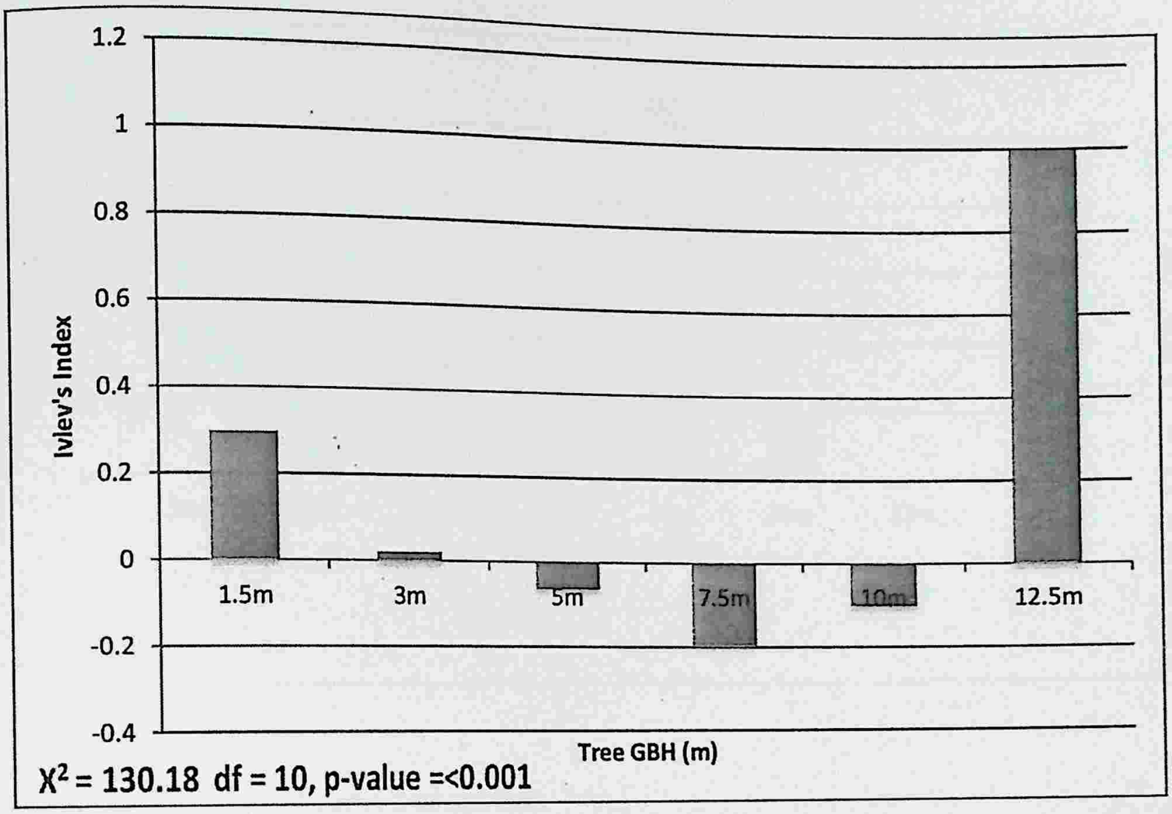


Fig 32: Ivlevs index – GBH of used and available tree species

iii) Tree height

The mean height of various roost tree species was 20.03.(Fig 33) And recorded range for height of roost tree was 8.64 to 30.7 meters tall, while the non-roost tree species ranged from 5.58 to 27.4 meters tall (Fig 34). Maximum numbers of roost trees were found to be ranging between 10 to 25 meters of height (88% of trees).

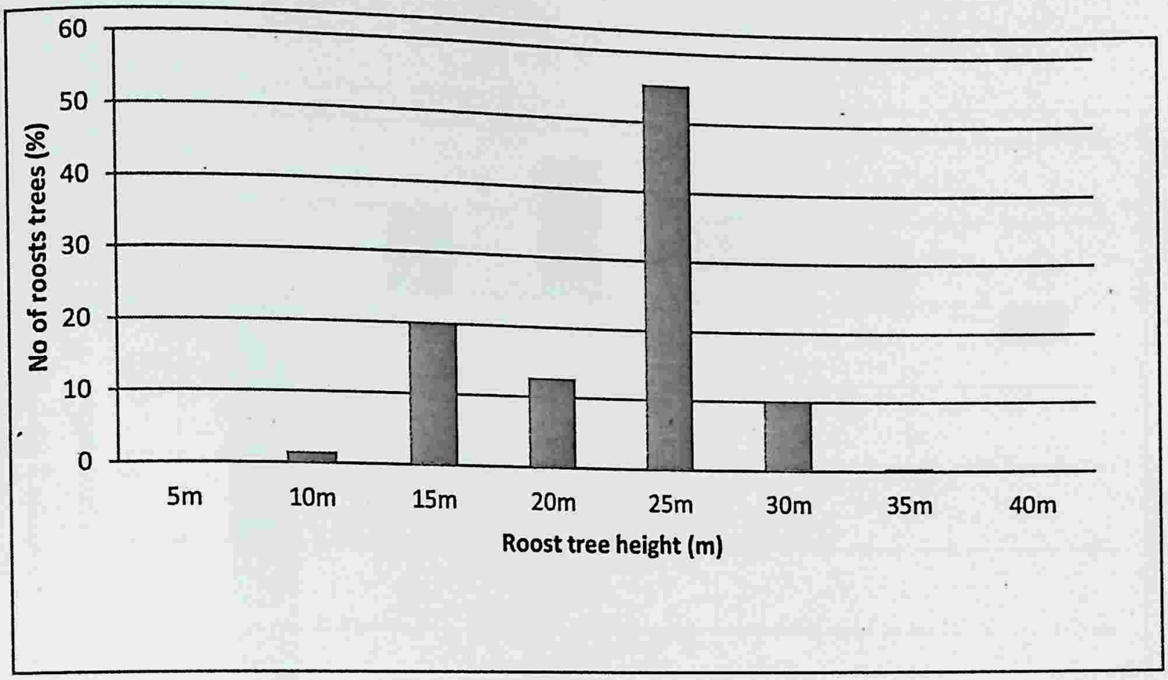


Fig 33: Height (m) of roost tree species.

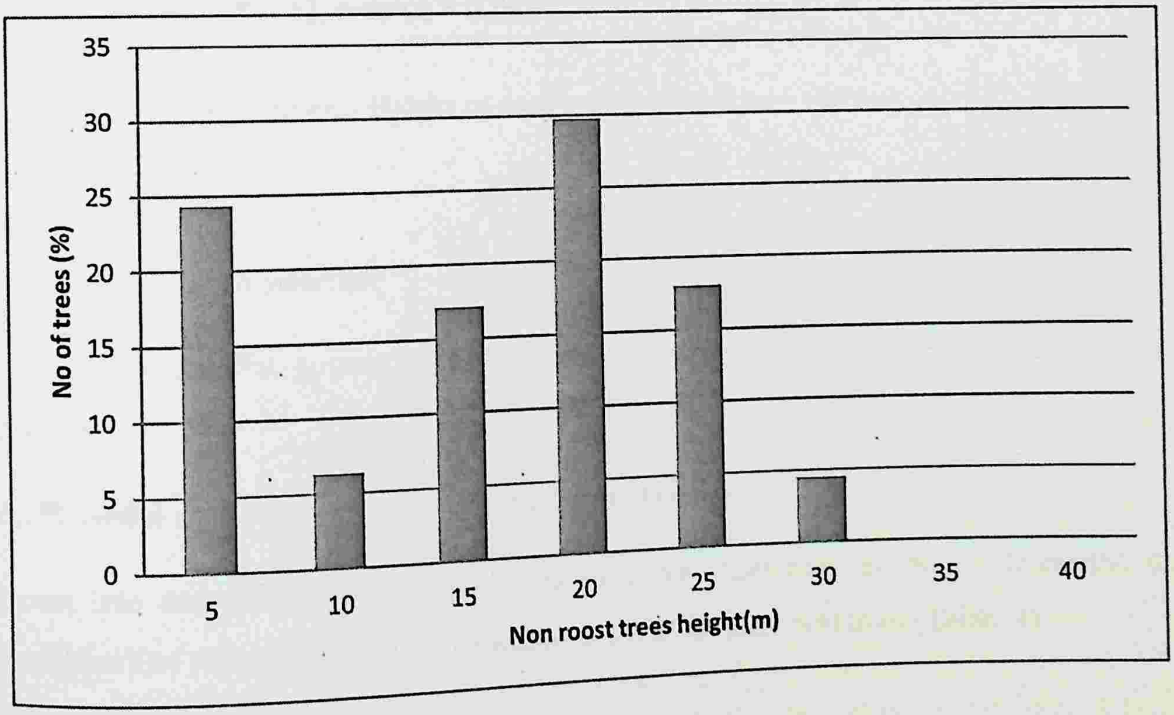


Fig. 34: Height (m) of non-roost tree species.

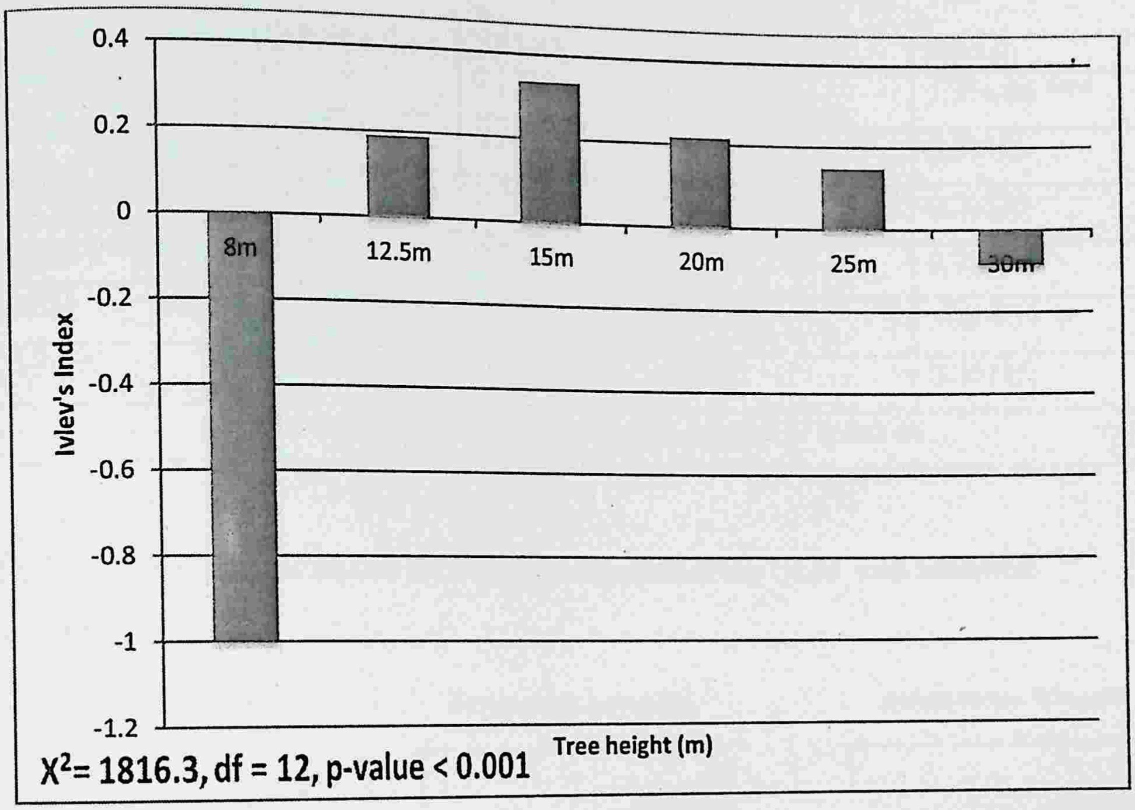


Fig. 35: Ivlev's index – Height of used and available tree species.

4.2.2. i) Micro-site selection

Tree characters that govern roost site selection were regressed using generalized linear models.

A. Presence or absence of bats and tree characteristics

Roost tree data (binary) were tested with each tree characters variable to determine the variables that influence presence or absence of roost and non-roost trees.(Table. 4)

	Estimate Std	Std Error	Z value	Pr(>|z|)
(Intercept)	0.57579	0.12391	4.647	3.37e-06 ***
Canopy cover	-0.09569	0.20072	-0.477	0.63356
Canopy height	0.37475	0.33505	1.119	0.26335
Canopy width	0.27995	0.28656	0.977	0.32859
GBH	0.59257	0.22548	2.628	0.00859 **
Height	0.60696	0.33156	1.831	0.06715
Residual deviance: 433.73 on 426 degrees of freedom				

Table 4: Parameter estimates for roost site selection using GLM with binomial function.

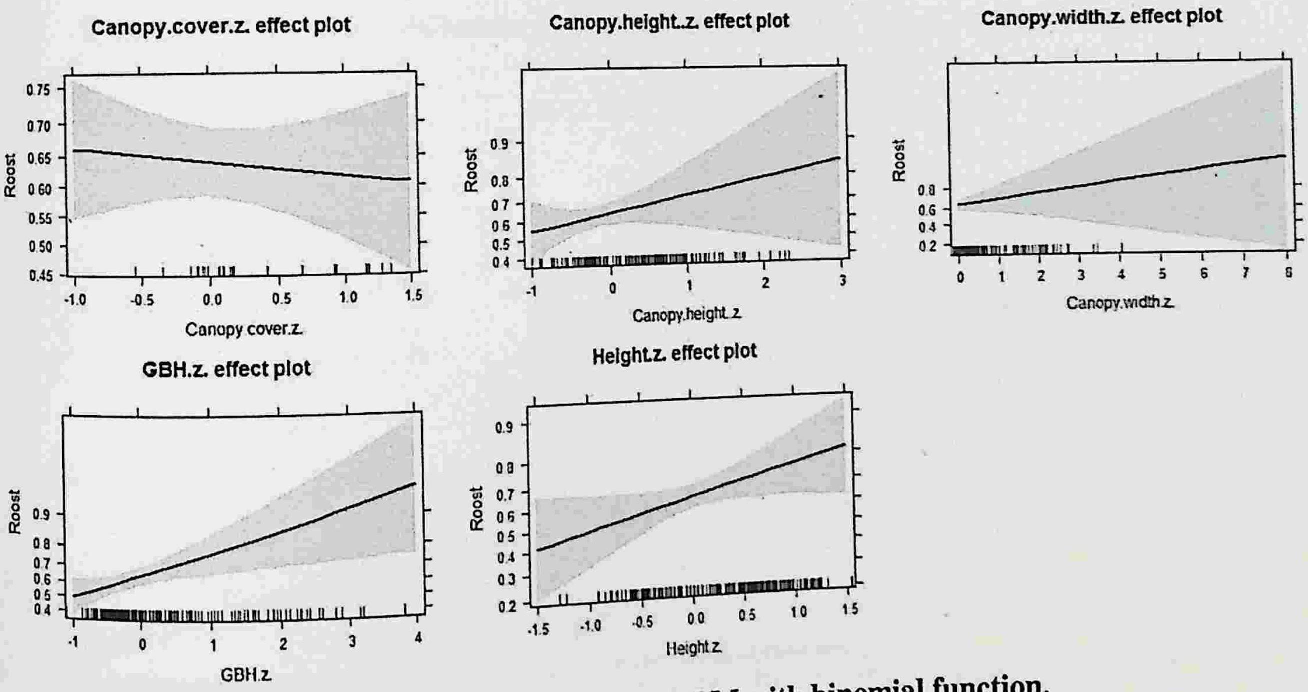


Fig. 36: Effect plots for roost site selection using GLM with binomial function.

B. Abundance of bats and roost characteristics

i) Count data was tested with the tree attributes that influence roost site selection to determine influence of tree attributes on abundance. (Table 5).

Since the count data was over dispersed, it was transformed to ordinal dataset.

	Estimate Std	Std Error	Z value	Pr(>|z|)
(Intercept)	0.14970	0.04834	3.097	0.001957 **
Canopy cover	0.04528	0.05955	0.760	0.447047
Canopy height	0.13662	0.10518	1.299	0.193977
Canopy width	-0.00455	0.04943	-0.092	0.926667
GBH	0.18167	0.05441	3.339	0.000841 ***
Height	0.31347	0.11931	2.627	0.008604 **
Residual deviance: 487.9 on 426 degrees of freedom				

Table 5: Parameter estimates for roost site selection using GLM with Poisson regression

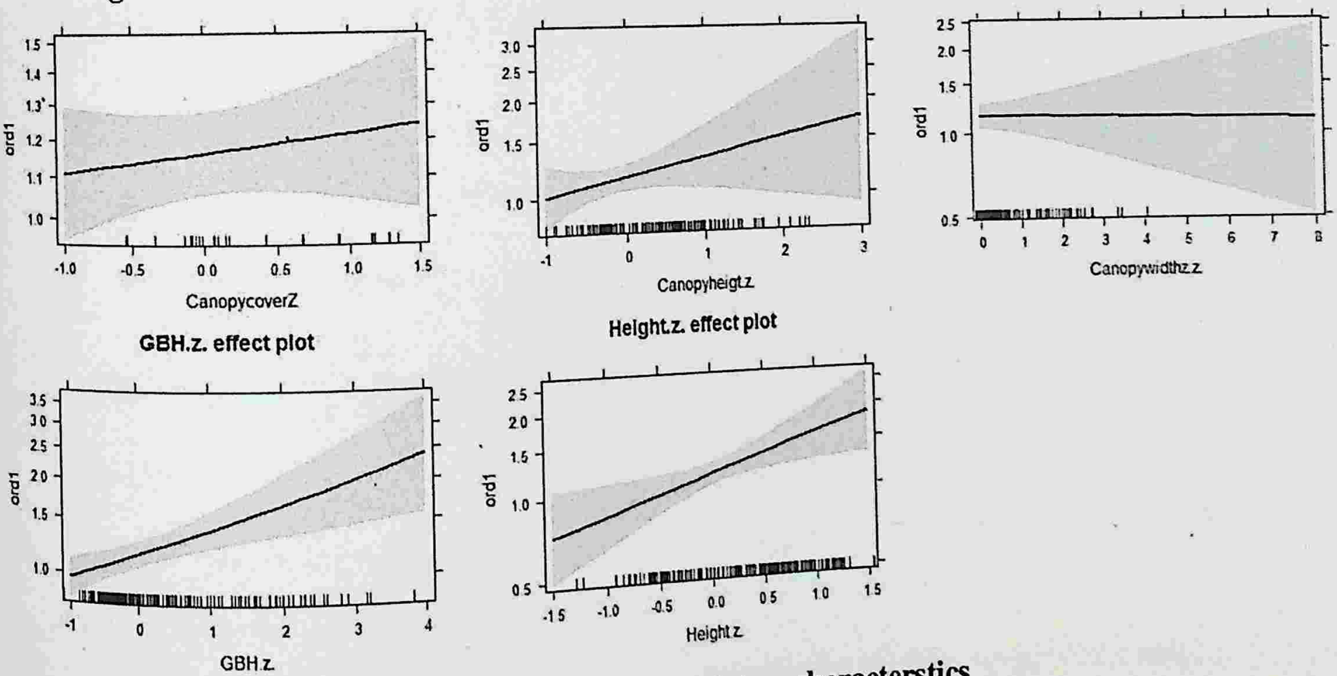


Fig. 37: Effect plot of influence of count data with tree characterstics

ii) Count data was tested with the tree attributes that influence roost site selection to determine interaction between trees attributes and hence affecting abundance.

	Estimate Std	Std Error	Z value	Pr(>|z|)
(Intercept)	0.34509	0.05386	6.407	1.49e-10 ***
Height	0.26405	0.07637	3.457	0.000546 ***
GBH	0.33330	0.05280	6.313	2.74e-10 ***
Canopy width	0.38256	0.06977	5.483	4.17e-08 ***
Canopy cover	0.13681	0.06002	2.279	0.022652 *
Height*GBH	-0.31393	0.06240	-5.031	4.87e-07 ***
Cover*width	-0.27957	0.04809	-5.813	6.13e-09 ***
Residual deviance: 413.22 on 426 degrees of freedom				

Table.6: Parameter estimates for roost site selection using GLM with Poisson regression

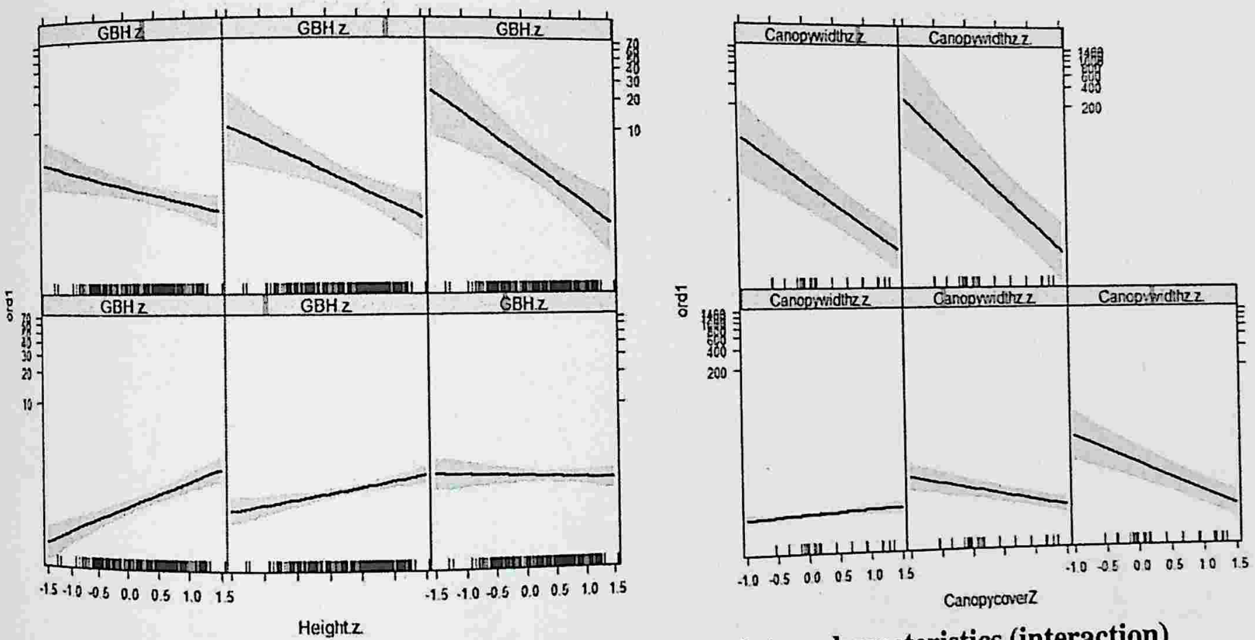


Fig 38: Effect plot of influence of count data with tree characteristics (interaction)

C. CART

CART yielded the output of basic statistical analyses performed for all the parameters and the results are represented in Fig. 40

The count data was compared with the tree attributes (height, GBH, canopy cover and canopy height and canopy width). The regression tree indicates that when the roost tree height is less than 6.1 meters the number of roosts with more than 200 individuals in less than 10% .

When the tree height is more than 6.1 meters and the GBH is less than 1.1 m the number of roosts with more than 200 individuals is 10%.

If the GBH is more than 1.1 meters but less than 2.2 meters the number roost with more than 50 but less than 200 bats is 40%

When the GBH is greater than 2.2meters and the height is less than 23.49 meters, the density of more than 200 bats using trees with these attributes is nearly 40%. And when tree height is greater than 23.49 it will be 70%.

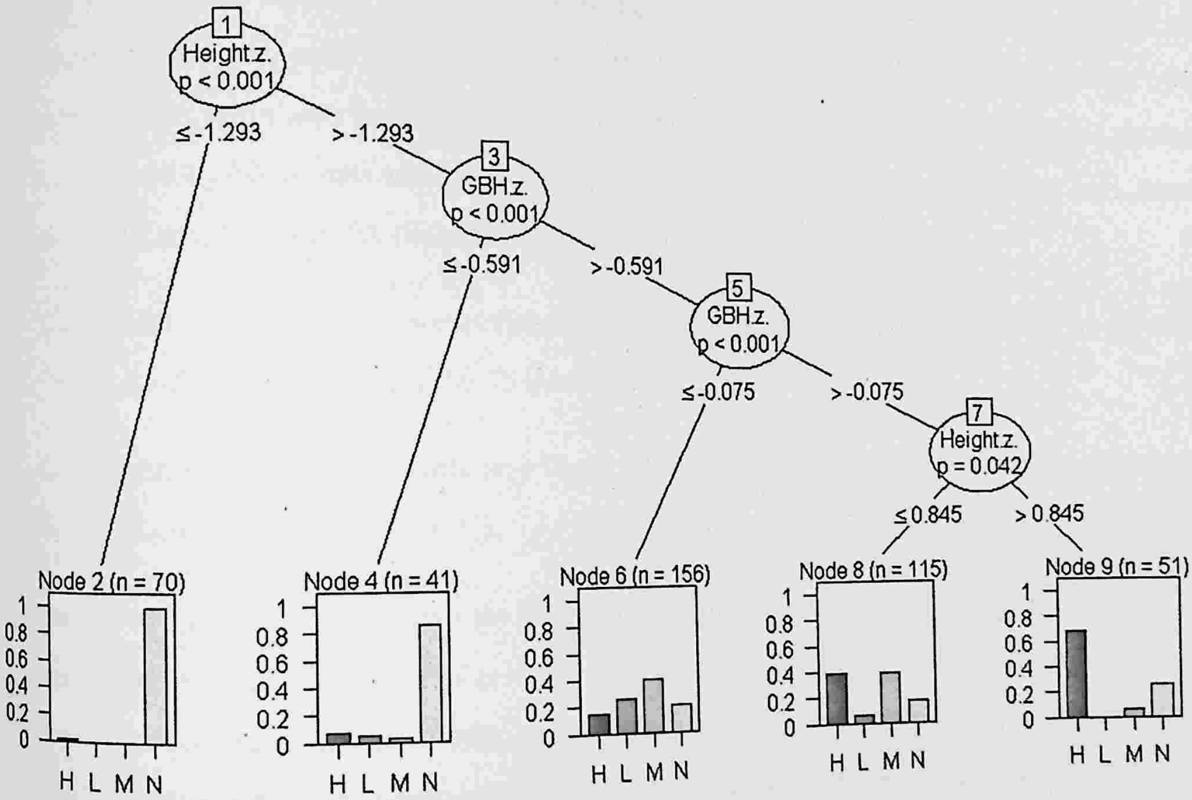


Fig 39: Regression tree of relation between tree attributes and roost presence.

4.3 Assessment of fruit damage

A total of 25 orchards were visited for assessment of fruit damage and extent of loss. The orchards experiencing high levels (56%) of fruit damage due to flying foxes were orchards that practiced mixed cropping (64%) and cultivated Guava, Mango and Sapota (24%), Guava, Sapota (36%). The orchards practicing mono cropping (36%) that cultivated only Mango experienced low levels (12%) of fruit damage due to flying foxes.

A whole range of factors were responsible for fruit damage in these orchards; fruit damage due to diseases was the lowest (16%), while natural calamities and pest was (24%) and natural calamities, pests and diseases, was the highest (64%). Besides the flying fox, other animal pests were also reported to cause fruit damage in these orchards, maximum damage was caused by birds, bats and monkeys (48%) followed by birds and bats (20%), bats, bears, birds and monkeys (16%), birds and monkeys (4%) and bears, birds (4%).

The extent of loss orchards experienced due to these animal pests ranged up to 25 kilos (28%), 25-50 kilos (64%) and 50-75 kilos (8%).

The extent of losses in orchards was found to be dependent on the type of fruits cultivated. (X^2=130.49, df=4, p-value=0.001).

Owing to the extent of damage the flying foxes cause in the orchards, they were constantly persecuted by a large number of orchardists, who adopted various control measures to reduce the extent of fruit damage, while some did not take up any control measures. Numerous methods of control were employed to reduce the extent of losses due to damage of fruits. (Fig 40)

Eighty four percent of the orchardists practiced various control measures to control fruit damage by flying foxes and 16% of the orchardists took up no control.

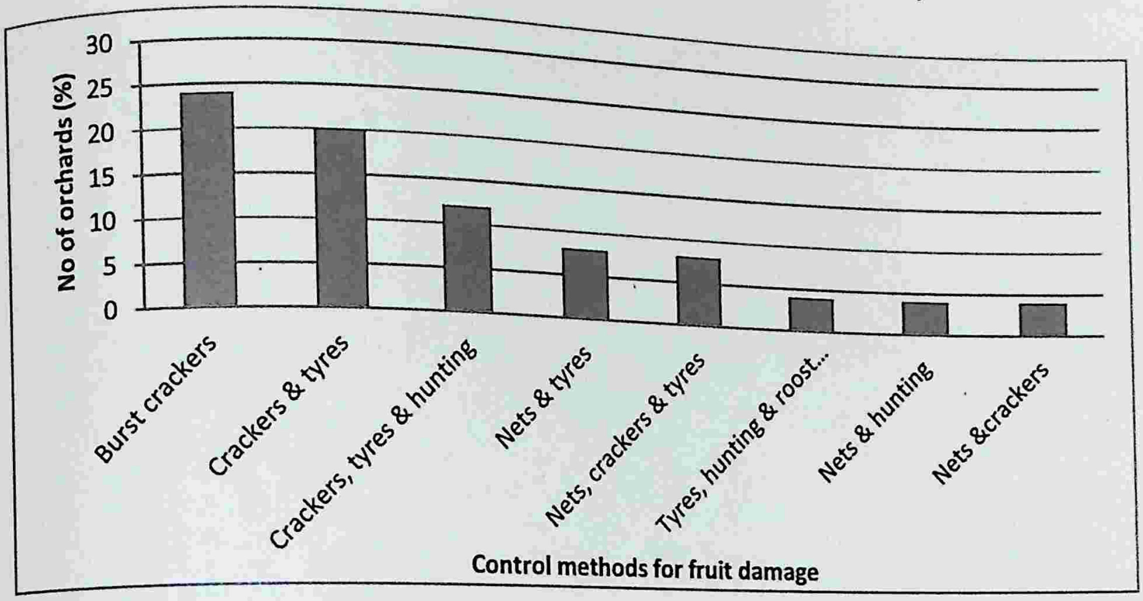


Fig: 40. Various control measures adopted to reduce extent of loss due to fruit damage.

Plate 5: Nets spread across the entire Sapota orchard to control fruit damage by birds and flying foxes.

Plate 6: ***Pteropus giganteus* trapped in the net set up to control fruit loss.**

5. DISCUSSION

Population estimation

Methods suitable for censusing flying foxes vary depending on the relative number of individuals present, roost tree attributes, location of the roost and accessibility (Mitchell – jones, 1987; Kunz *et al.*, 1996). Historically, the methods used for censusing bats were, roost counts, evening emergence counts, dispersal counts and disturbance counts (Kunz *et al.*, 1996). Since the Indian Flying fox is a highly gregarious species, censusing required coordinated efforts of multiple individuals and sophisticated imaging devices (O'Shea *et al.*, 2003). Therefore, this study utilized four methods to estimate the number of flying foxes, of which three were previously described.

The flying foxes were counted directly in the roost, by multiple observers using binoculars and tally counter with a reasonable amount of time and effort. Results from this method were not very accurate, since the bats can get hidden in the foliage and hence their number is likely to be underestimated. (Kunz, 1998; Nicoll & Racey, 1981; Wiles, 1987). The visibility bias here was accounted for by comparing the results with the counts from branch estimates and photographic count.

The multiple observer count was compared for bias with photographic count method. There was, on an average 94% detection probability and hence 6% under detection was corrected for counts. The branch versus observer count method gave 74% detection (i.e. there was 26% under detection). It was found that the branch estimation method overestimated the population size and hence observer count with photographic count correction is the best approach for population estimation.

Counts from the evening dispersal method yielded erroneous figures when compared with direct visual counts. This was due to many factors, first being the chance of doing double counts on account of the bats flying around the roost many times before they actually fly out to forage. And the second, the fading light in the sky made it harder to count the accurate number of bats flying out.

Comparisons of the present population estimates with the previous study reported a decline in population at certain roost sites. Interviews of the locals revealed that this decline has been consistent over the years majorly due to destruction of roosting trees for road expansion or fire wood, construction activities, fire and occasional hunting by outsider nomads for meat and traditional medicines. (Dey *et al.*, 2012)

Anthropogenic disturbances around the globe have been reported to have a negative influence on roosting flying foxes and most often the irreversible consequences have been reported as their numbers decrease (Fujita, 1991; Mildenstein, 2005; Mistry, 1995) which is consistent with the present findings.

Roost site selection

The study examined roost site selection of *Pteropus giganteus* at two scales (macro and micro). At the landscape level (macro), roost selection was greatly influenced by the proximity to water (Gulraiz *et al.*, 2010). Majority of the roosts were found to be close to water bodies, reason for this, could be that the flying foxes swoop down to drink water, which before they leave to the foraging grounds and also dip their bellies into the water for thermo regulation (Flying fox, Australian wildife.net, 2010). It was also found that the roosts were located in proximity to human dominated landscapes. (Krystufek, 2009; Chakravarthy *et al.*, 2008). One reason for this could be the availability of variety of fruit bearing trees in parks, home gardens and also the avenue trees planted in the urban habitats (Hahn *et al.*, 2014) also the availability of large man made water bodies.

Pteropus giganteus lives within trees, in large aggregations that range from tens to thousands (Marshall, 1983; Pierson and Rainey, 1992). The observations made in this study revealed that the colony/camp size varied from minimum of 40 individuals and maximum of 5504 individuals at the roost sites. (Senthil & Marimuthu, 2012). Among the 51 roosts that were identified, majority (84%) of the roosts were occupied for 10 -80 years. This finding is consistent with observations that megachiropterans exhibit high roost fidelity (Marshall 1983; Pierson & Rainey, 1992).

At the micro scale, this study showed that moderately tall trees, with moderately wide girth were preferred as roost trees by *Pteropus giganteus*, this could be because they need room for free-fall during take-off, also for better protection against unfavorable environment (Pierson & Rainey, 1992). It was found that *Pteropus giganteus* roosted in a wide range of tree species. More widely used trees were *Eucalyptus sp, Ficus sp* and *Samanea saman*. Other studies also suggest that the flying foxes roost only in a subset of roost trees. (Pierson & Rainey, 1992; Vardon *et al*., 2001).Several of the non roost tree species that were found around the roosts and not used for roosting have been reported as roost and food species elsewhere (Chakravarthy & Girish, 2003; Stier & Mildenstein 2005).

Fruit damage

Crop damage by *Pteropus giganteus* was one of many risks people reported to experience in their orchards (Garentt, 1999). And there has been conflict between the orchardists and the flyig foxes for many years now (Tidemann *et al*, 1997). In this study the flying foxes were reported to be second in rank, causing maximum fruit damage and loss, only after birds. (Chakravarthy & Girish, 2003). Fruit damage was claimed to be higher in the fruiting period, which suggests that orchardists practicing mixed cropping are more prone to loss due to fruit damage depending on the fruiting seasons of the orchards. In this case, the orchardists cultivating Guava, Sapota and Mango experienced more fruit damage due to the availability of fruit throughout the year. (Chakravarthy *& Girish,* 2003). Beside fruit damage by the flying foxes, bad weather, diseases and insect pests also were believed to negatively impact the orchardist's livelihoods (Webber, 2104). Loss due to fruit damage is higher due to poor environmental factors like physiological stress, diseases and natural calamities like rain or drought which affects fruit set and development, than losses due to animal pests. (Pedro, 1987). Orchardists considered crop damage by flying foxes and other animal pests to be a more significant risk than other factors which implies that they are less tolerant towards fruit damage by them (Webber, 2014). This conflict demands implementation of control measures to decrease the extent of fruit damage. The growing conflict between fruit growers and flying foxes has resulted in adoption of various control measures to deter flying foxes from damaging fruits. (Chakravarthy & Girish, 2003, Garnett, 1999). This study reported usage of nets as the least destructive method which served as a better crop protection measure than the other highly destructive method of control (Korine *et al*., 1998).

Besides being persecuted for being agricultural pests in orchards, Pteropid bats are threatened throughout their range primarily due to habitat loss (roost destruction) and hunting (Fujita 1991; Epstein et al. 2009). And this conflict between fruit growers and flying foxes due to habitat loss will continue to grow and threaten *Pteropus giganteus* unless protection policies are amended. In addition to this, the reputation of the *Pteropus* giganteus as a reservoir of a deadly virus highlights the perceived conflict between public health and conservation (Breed et al. 2006).

6. CONCLUSION

In summary, this study used three existing methods of population estimation for flying foxes and tested their efficacy. And also devised a new method to estimate the flying fox populations using 360 degree photographs clicked from the base of the tree. Hence, a combination of traditional census methods (direct visual counts and branch estimates) and the photographic method developed in this study offer great promises in estimation of camp sizes of the Indian flying fox.

With respect to roost site selection at the landscape level 11.38% of the entire study area (31,881 sq km, 7 districts) was found suitable as roosting habitat for *Pteropus giganteus* using distance to water and orchards, intensity of urbanization and low tree cover as primary criteria. . Nearness of the water body was also a crucial factor for presence and absence of roosts. At individual roosts, it was found that *Pteropus giganteus* showed preferences for roost and habitat in term of tree species and tree characters; in particular, tree girth at breast height and tree height. *Pteropus giganteus* was also known to exhibit high degree of roost fidelity at traditional roost sites.

In commercial orchards, *Pteropus giganteus* was known to cause significant fruit damage and losses in orchards cultivating Guava, Mango and Sapota. This was due to availability of fruits throughout the year. The extent of damage they were reported to cause was ranked second, only after birds. For this reason, the Indian flying foxes were persecuted, by means of roost destruction, setting up nets and hunting, leading to indiscriminate killing of the flying foxes.

With increase in intensity of urbanization, deforestation leading to habitat loss has also increased. This in turn causes escalation of conflict between fruit growers and flying foxes. Thus, leading to persecution of the flying foxes. But, unless quantitative assessment of the damage inflicted is carried out, the role of *Pteropus giganteus* as a severe agricultural pest in commercial orchards, should be re –examined.

Over the years, there has been a decline in the populations of the Indian flying fox; majorly due to anthropogenic activities (roost destruction and hunting). Despite their beneficial role as crucial pollinators and forest regenerators, they are hunted indiscriminately for meat and traditional medicine and are also persecuted for being pests in orchards. The Indian Wildlife (Protection) Act does not have a provision for protection of this species and has listed it under Schedule V (Vermin). And since the flying fox is a mammal with low reproduction rate, the decline in their numbers will have a cascading effect of the ecosystem due to break down of pollinator, seed disperser relationship with native plants. This in turn will have serious ecological consequences and economic disadvantages.

More recently, the role of *Pteropus giganteus* in zoonosis has also gained importance. Since, *Pteropus giganteus* are found roosting in human dominated landscapes, the interface between human and them is constantly growing, thus, increasing the emergence of zoonotic disease endangering all life forms. Hence, it is important for us to improve our understanding about the habitat requirements of this species of flying fox, so that we can conserve the keystone species and also avert a spill over event in the future.

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APPENDIX - I

Plate. 1: *Pteropus giganteus* roosting in *Terminalia arjuna*

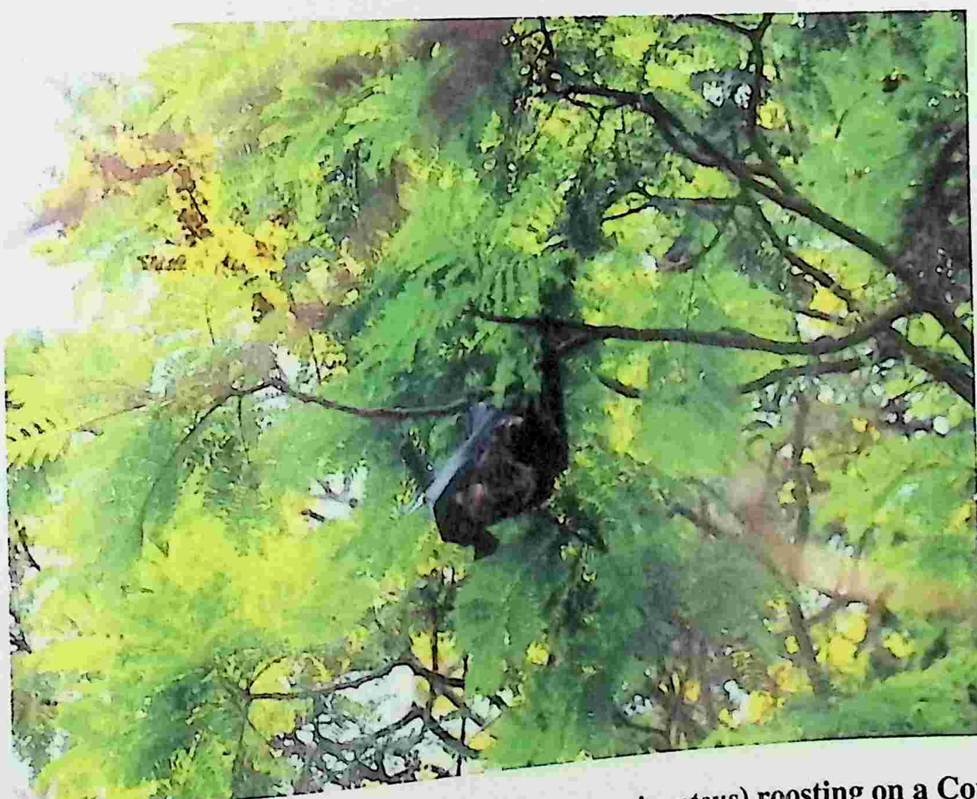

Plate 2: Mother and 4 weeks old pup (*Pteropus giganteus*) roosting on a Copper pod tree (*Peltophoroum pterocarpum*)

Plate 3 : ***Pteropus giganteus*** **electrocuted on electricity lines.**

APPENDIX – II

COLONY COUNT DATA SHEET

Observer name:	Weather:	Start time:	Roost location:
Date:		Stop time :	

Roost age:	Roosts: Solitary / clumped	Counting method used:
	Roosting: Clumped / Satellites	Direct / Branch /Photographic /Emergence

Tree ID	Branch ID	Tree sp.	Count trial			Total	Remarks
			1	2	3		

Signs of human access to the roost:	Type of access to the roost and frequency:

COLONY COUNT DATA SHEET

<table>
<tr><td colspan="2">Observer name:</td><td rowspan="2">Weather:</td><td>Start time:</td><td rowspan="2">Roost location:</td></tr>
<tr><td colspan="2">Date:</td><td>Stop time :</td></tr>
<tr><td rowspan="2">Roost age:</td><td>Roosts: Solitary / clumped</td><td colspan="3" rowspan="2">Counting method used:

Direct / Branch /Photographic /Emergence</td></tr>
<tr><td>Roosting: Clumped / Satellites</td></tr>
<tr><td colspan="2">Photograph ID:</td><td colspan="3">Emergence video ID:</td></tr>
<tr><td colspan="2" rowspan="2"></td><td>Start time</td><td>Stop time</td><td>Count</td></tr>
<tr><td colspan="2">Total</td><td></td></tr>
<tr><td colspan="2"></td><td colspan="3">Direction of flight:</td></tr>
</table>

QUESTIONNAIRE SHEET - ROOST SITE FIDELITY

Interviewer name:

Date:

Interviewee name:

Location:

1. Are you from around here?

2. For how many years have you been living here?

3. Do you know what these animals are?

4. Is this the first time you are seeing the Indian flying fox here?

5. When was the first time you saw them here?

6. Have you seen the Indian flying fox else at any other location?

7. If you have seen them before, has there been an increase or decrease in their numbers?

8. What are your opinions of the Indian flying fox, roosting here?

9. If the numbers are decreasing, what are the reasons for their decline?

QUESTINNIOARE SHEET – PERCIEVED CROP LOSS

Interviewer name: Date:

Interviewee name: Location:

1. What fruit crops do you grow?

2. In which season are these fruit crops being cultivated?

3. What is the area under cultivation for these fruit crops?

4. What are the investments/ season for cultivation?

5. What is the yield/tree/acre/season for the fruits?

6. What is the price/kg/crate of ripe fruits in the market?

7. What are the various risks that are encountered in cultivation and selling of these fruits?

8. What is the extent of losses that are incurred due to loss of trees/fruits to natural calamities, diseases and pests?

9. List the animals that cause harm to the tree/fruits.

10. What is the extent of damage caused by these animals and birds?

11. If fruit bats cause damage, how do they cause it?

ROOST CHARACTERISTICS DATA SHEET

Observer name:	Date:	Time:	Roost location:
Roost tree species:		Data loggers :	

Tree architecture

Tree GBH (m)	Tree height				No. of branches			Canopy cover (%)					
	Distance	Percent		Total	Type	Total	Roosting	Direction	I	II	III	IV	Mean
		Tip	Base										
					Primary								
					Secondary								
					Tertiary								

Canopy width (m)					Canopy height							Roost height (m)			
CW 1	CW 2	CW 3	CW 4	Mean	Left			Centre	Right			Left		Right	
					1	2	3		1	2	3	Lowest	Highest	Lowest	Highest
Calculation:					Calculation:							Calculation:			

Roost aspect (w.r.t. tree)	Data logger					
	Roost tree			Control		
	Lux	RH	Tempr	Lux	RH	Tempr

Remarks:

ROOST CHARACTERISTICS DATA SHEET

PCQ Method: Pick the closest trees to the roost tree in all four cardinal directions

Inter tree distance (m) with bat roost								
I	II	III	IV	V	VI	VII	VIII	Mean

Note:

Tree architecture

Direction	Tree species	Tree height(m)				Tree GBH (m)	No of branch		Canopy width(m)					Canopy height (m)						
		Distance	Percent		Total				I	II	III	IV	Mean	Left				Right		
			Tip	Base										I	II	III	C	I	II	III
N							1													
							2													
							3													

Canopy cover (%)					
Direction	I	II	III	IV	Mean

Remarks

Calculations

Direction	Tree species	Tree height(m)				Tree GBH (m)	No of branch		Canopy width(m)					Canopy height (m)							Canopy cover (%)					
		Distance	Percent		Total				I	II	III	IV	M	Left				Right			Direction	I	II	III	IV	Mean
			Tip	Base										I	II	III	C	I	II	III						
S							1																			
							2																			
							3																			
Remarks																										

Direction	Tree species	Tree height(m)				Tree GBH (m)	No of branch		Canopy width(m)					Canopy height (m)							Canopy cover (%)					
		Distance	Percent		Total				I	II	III	IV	M	Left				Right			Direction	I	II	III	IV	Mean
			Tip	Base										I	II	III	C	I	II	III						
E							1																			
							2																			
							3																			
Remarks																										

Direction	Tree species	Tree height(m)				Tree GBH (m)	No of branch		Canopy width(m)					Canopy height (m)							Canopy cover (%)					
		Distance	Percent		Total				I	II	III	IV	M	Left				Right			Direction	I	II	III	IV	Mean
			Tip	Base										I	II	III	C	I	II	III						
W							1																			
							2																			
							3																			
Remarks																										