Status and Ecology of House Sparrow *Passer domesticus* along an urban to rural gradient in Coimbatore, India

A thesis submitted to the Bharathiar University

in partial fulfillment of the requirements for the award of degree of

DOCTOR OF PHILOSOPHY

IN

Environmental Sciences

By

R Dhanya

Division of Environmental Impact Assessment

Sálim Ali Centre for Ornithology and Natural History

COIMBATORE, INDIA

2011

Dedicated to,

Jayadevan , Radhamani and Jayaprasad

CERTIFICATE

This is to certify that the thesis, entitled "Status and Ecology of House Sparrow *Passer domesticus* along an urban to rural gradient in Coimbatore, India" submitted to the Bharathiar University, in Partial fulfillment of the requirements for the award of the Degree of **Doctor of Philosophy** in **Environmental Sciences** is a record of original work done by **Mrs. R Dhanya** during the period September 2005 – December 2011 of her study in the Department of Environmental Impact Assessment at Sálim Ali Centre for Ornithology and Natural History, under my supervision and guidance and the thesis has not formed the basis for the award of any Degree / Diploma / Associateship / Fellowship or other similar title to any candidate of any University.

Signature of the Guide

Head of the Department

Director

DECLARATION

I, **R Dhanya** hereby declare that the thesis, entitled "Status and Ecology of House Sparrow *Passer domesticus* along an urban to rural gradient in Coimbatore, India" submitted to the Bharathiar University, in partial fulfillment of the requirements for the award of the Degree of **Doctor of Philosophy** in **Environmental Sciences**, is a record of original and independent research work done by me during September 2005 – December 2011 under the Supervision and guidance of **Dr. P A Azeez,** Director and Senior Principal Scientist, Department of Environmental Impact Assessment, Sálim Ali Centre for Ornithology and Natural History, Coimbatore and it has not formed the basis for the award of any Degree / Diploma / Associateship / Fellowship or other similar title to any candidate in any University.

Signature of the Candidate

The journey involved in doing a PhD was remarkable. Many people were responsible for showing the correct way. The journey was filled with many excitements, entertainments, constrains, hardships and ups and downs. There were times when I was unaccompanied in this pursuit; however with many people around me to guide, support, debate and to discuss. It was hardly possible for me to thrive in my doctoral work without the precious support of these personalities. I thank them all for not just greatly broadening my knowledge and sharpening my thinking, but also for providing friendship and emotional support. Here is a humble mark of respect to all those people.

First of all, I wish to thank my supervisor Dr. P A Azeez for his valuable guidance, cheerful enthusiasm and ever-friendly nature throughout the programme. I give him my most heartfelt thanks for the time he openhandedly made accessible. I would like to thank both Drs. Rvisankaran, S Bhoopathy and P.R Arun for their expert advice on my analyses, stimulating discussions and highly valuable comments on drafts of this thesis. I am extremely grateful to them both for their support and encouragement throughout.

I am grateful to Dr. V.S. Vijayan, founder Director of SACON for his support and encouragements, and providing me the opportunity to work in this programme. Dr. Ravi Sankaran had been always encouraging and inspiring in research as well as in life. As with many of my colleagues, to me he was a fatherly friend, philosopher and mentor.

All scientific and administrative communities at SACON extended their support. I would like to thank Drs. Lalitha Vijayan, Ravi Sankaran, P. Pramod, S. Bhupathy, S.N. Prasad, P. Balasubramaniam, S. Muralidharan, P.R Arun, Shomita Mukherjee, Shirish Manchi, Anjan Kumar Prusty, G. Gladwin, S. Mathew, H.N Kumara and B. Mahendrian for their support in various ways. I consider it as my privilege to have them at hand for discussion and guidance on any topics irrespective of their field of interests.

This study was supported in part by small grants from the Department of Science and Technology and United Nations Environment Programme- Eco-Peace leadership Centre. I wish to express my gratitude to Dr. Sashi Ahuja and the Department of Science and Technology (Rajath Jayanthi Science communication Award) program for providing the financial support for this work. United Nations Environment Programme's- Eco-Peace leadership Centre gave me the opportunity to attend the 4th and 5th Asia Pacific Environment Forum at Kangwaon National University, South Korea during 2009 and 2010. This enabled me to have fruitful discussions and interactions with several young researchers across the globe. My special gratitude to Prof. (Dr). Hoo Zoo Lea (Kangwon National University, South Korea) for performing commendable improvement in the study structure. I also take this opportunity to express my special gratitude towards Dr. Yeong (UNEP-EPLC) for helping me out with grants and their hospitality in South Korea. This supported the study immensely and kept the continuity of the work.

Drs. P. Pramod, S.N. Prasad, G Gladwin, S Mathew, H N Kumara and P. Balasubramaniam helped me to substantially improve the thesis. Drs. T.V. Sajeev, Ajith Kumar, Nagarajan, Kunjhikrishnan and Suhel Quader offered crucial advice during field work. The support and constructive criticism of have greatly strengthened this dissertation and made my time at SACON much more enjoyable and educational than it could otherwise have been.

My senior colleagues at SACON, Drs. P.R. Arun, R. Mohanraj, Seedikkoya, B. Maheshwaran, Maya Arun, Anoop Das, Manchi Shirish, Anjan Kumar, Rachna Chandra Rajamamannan, Sreenivas and A.M.A. Nixon offered their time and thoughts during the study. I gratefully acknowledge them.

I am obliged to Dr. Kunnhikannan, for helping with plant identification and sharing their field experiences. I would like to thank Dr. Shomita Mukherjee for clear comments and suggestion, and for the skill and knowledge shared in the field of ecological research. Dr. Shomita and Dr. Kunjhikannan have been very gratifying with their warming hospitality. I appreciate the inputs rendered by Dr. Ajith Kumar with valuable comments on the thesis. Special thanks to Drs Suhel Quader, Balakrishnan, Seethikkoya and K.M. Jayahari for much needed suggestions and discussion on studying nest-site selection. Statistical counsel from Dr. Nagarajan, A.V.C College was important in the development of the thesis, apart from his crucial comments on the thesis draft.

I thank Mr. M. Manoharan and Ms. Santhi for their support of the SACON library. Mr. M. Manoharan was very kind enough to provide some of the rare and the latest references in the field. I received invaluable help from the librarian and staff at the Bombay Natural History Society, Kangwon National University and Bharathiar University.

I am privileged for having Drs. Mukherjee, Manchi Shirish, Abdul Riyas, Joya Thapa, Raja Mamannan, Prasanth Narayanan and Nikhil Raj and, Eswaran as my colleagues who have provided great corporation during all those years in SACON. Especially, the assistance of Ranjini, Ezhil and Anbarassi in sorting out data sets was more than precious. I also must mention the valuable support that I received from Nikhil Raj and Nehru. Sreeninvas was of great support in the development of this work. I am so grateful to Nishadh K.A for his timely assistance, which has made this thesis in this form. Drs. Balakrishnan, K Seedikkoya and P. R Arun has made a commendable investment in the form of reviewing my thesis. The scientific discussions with Ranjini at the field and SACON were always productive. Together they have given me the skills and confidence to conduct important and thought provoking research. I thank Sreenivasan for helping with formatting and other assistance whenever required.

I must thank all my former departmental and lab mates who, well, provided me with many amusing memories and for their support and advice of course, which was sometimes very superior. I am thankful to all my vibrant colleagues of SACON, particularly Drs. Jayakumar, Uma J Vinod, Somasundaram, Manjula, Dhananjayan, Selvam, Gunasekaran, Bhoj, Basundara, Sheeba, Gomathi, Santhi, Anjan, Jisha, Venkitachalam, Anitha, Santhosh, Mathivanan, Sreenivasan, Balaji, Manjari, Roopa, Senthil, Selvakumar, Santhanaraj, Prithi, Jayanthi, Vinny, Aruna, Ezhil, Zaibin, Jayakumar Jr., Devanayaki Murugesh, Arthi, Ganeshan, Bharathi, Joseph, and Alaguraj for their fun and assistance whenever required. The technical assistants at SACON, especially Patturajan, Ramakrishanan, Muthukumar, Ravi, Geetha, and Joseph were extremely supportive.

I convey my gratefulness to my graduate college teachers: Drs. N Parthasarathy, Priya Davidar, Vikram Reddy and CBSR Sharma have shown me the path of scientific investigations. My friends at Pondicherry University Anuty, Leishma, Anna, Preji, Unni, Madhavan, Varrier,Jaykumar, Dinup, Teyjo, Subbu, vijay, Swamy and Valli were very supportive throughout my interaction with them. Dinesh assisted me in the fieldwork.

Ashish bhayya, Bipin, Vysakh, Reshma, Rajesh, Abhijith, Avinash, Agnivesh, Adarsh, Deepu, Arsha, Akshara, Hridya and Vihan were very considerate. Shylaja, Surendran, Neena, Vineeth, Aswin, Vipi, and Varsha were compassionate in many ways. I am obliged to members of my home for their never-ending supports. I thank Hariharan for his constant inspirations. I must also thank Dr. Aparna, Soumya, Kuruvila, Vichu, Abie, Lisho, Renjith, Gilljith, Shaji, Sreeni and Shamseer for their support and encouragement.

I am very much obliged to my in laws Sakthidas, Savithri and sister Neenadas for facilitating everything and for their patience and support. Love and support received from my parents- Chachan and Manikutty and my Brother Jayaprasad and sister in law Prisily were consistent. I wish to thank my parents for their constant support and encouragement in all my professional endeavours.

I would love to thank Dr. Anoop Das, for listening to my endless rants about my data without falling asleep, too often. He had since generously contributed to all aspects of my work, from ideas to logistics to merciless editing. I've learned an enormous amount from him, and gained one good friend which in turn converted into a life partner. I express my gratitude to our daughter Neeharika for her cooperation. Especially, the time she spared without my presence during the last phase of the thesis.

Thank you for one and all for everything.

R Dhanya

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Chapter I

Introduction, study area and thesis organisation

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1.1 General introduction

1.1.1 Urbanisation

In due course of the evolution of human civilisation, from their nomadic to the resident lifestyle, they were industrious agents of change. Their behaviours changed ecological processes in agglomerates of residences and trades, in cities and as well as in other areas (Vitousek et al. 1997). As the human population rise, infrastructure grows up; urbanisation spreads and increasingly affects biodiversity (Blair 2004). Human activities in the form of land use changes, urbanisation and infrastructure developments are considered major threats to biodiversity (Gontier 2008). This in turn results in the loss and fragmentation of natural habitats, thereby threatening populations of local species and ultimately biodiversity (Saunders et al. 1991). Urban development produces the greatest local extinction rates and eliminates the majority of the species (Vale and Vale 1976, Marzluff 2001, Czech et al. 2000). This replacement brings in the process of biotic Homogenisation that threatens to reduce the biological uniqueness of local ecosystems (Blair 2001). The loss and fragmentation of valuable habitats influences the long-term viability of species populations, which may ultimately become extinct at the local or regional scale (Opdam et al. 2001).

Worldwide urbanisation and agriculture are the most important threats to biodiversity (Ricketts and Imhoff 2003). However, urbanisation is likely to top agriculture as the dominating agent of habitat fragmentation because of the increasingly urbanising human population. Today, half of the world's population lives in urban areas and by 2030 the overall urban population is projected to be five billion (United Nation's World Urbanisation Prospectus 2003). For a long time urban ecology has been a neglected research area which now is becoming highly topical, manifested in an increasing number of publications and conferences focussing on urban flora and fauna (Blair 1996, McKinney 2002, Chace and Walsh 2006). However, it still remains a relatively neglected research area compared to the amount of research conducted in forest and agricultural ecosystems (Figure 1.1).

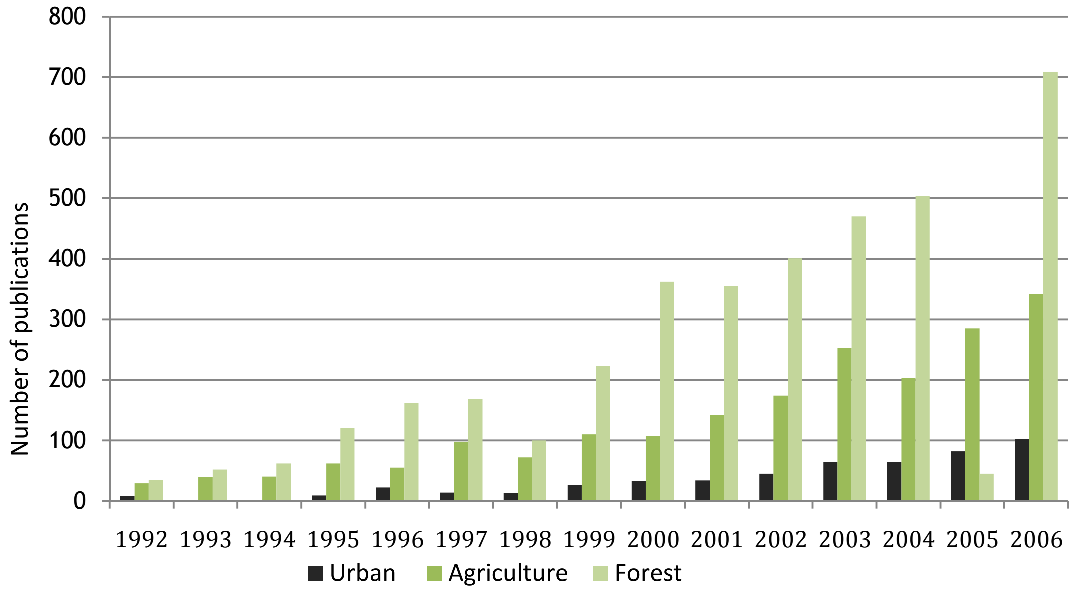


Figure 1.1 Published articles on biodiversity in urban, agricultural and forest areas. Data from the ISI Web of Knowledge database (Heldblom 2007)

The process of urbanisation can generate a different ecological pattern along an urban to rural gradient. Species vary in their ability to adapt to the often drastic physical changes along the gradient (Gilbert 1989, Pennignton and Blair 2009, Blair 1996, Savard et al. 2000, Fernandez-Juricic and Jokimaki 2001, Melles et al. 2003, Lim and Sodhi 2004). Species richness of many flora and fauna declines along the gradient, with the lowest richness found in the urban core. Much of the reduction in species richness is obviously caused by the loss of vegetation as over 80 percent of most central urban areas are covered by pavement and buildings (Blair and Launer 1997). The area covered by vegetation is potentially a good predictor of species richness of birds (Goldstein et al. 1986), mammals, amphibians, and reptiles (Dickman 1987), and insects (McIntyre 2000). Human population density, road density, pollution, heat island effect, average annual rainfall and soil compaction can be explicit urban indicators. All these pave the way for the loss of natural habitat and the natural habitat is replaced by four types of altered habitat that become progressively expanding. According to McKinney (2002) the four types of habitat that replace the original are listed below;

1. Built habitat: buildings and sealed surfaces, such as roads
2. Managed vegetation: residential, commercial, and other regularly maintained green spaces
3. Ruderal vegetation: empty lots, abandoned farmland, and other green space that is cleared but not managed

4. Natural remnant vegetation: remaining islands of original vegetation

Although ecologists now recognize the scale at which humans influence the global ecology, many have largely ignored the human component in ecological systems research and instead focused on natural or pristine systems without considering the human factor (Gallagher and Carpenter 1997, Liu 2001). The consequence of ignoring the human component is that ecologists' understanding of how humans interact and influence different ecosystems is still in its infancy (Redman 1999). The increasing recognition of human impacts on surrounding environment and on the lives of ours as well as other species has triggered attempts to have a better understanding to analyse and remediate the consequent problems.

1.1.2 Urban ecosystem

Urban population expansion contributes to the conversion of natural ecosystems into agricultural and urbanised areas (Vitousek et al. 1997) which leads to the loss of natural habitat and native biodiversity (Czech et al. 2000, McKinney 2002) mainly due to continued growth of roads and buildings to meet the demands from an increasing number of citizens (Niemela 1999). Due to the drastic developmental activities urban areas accommodate fewer native species (Emlen 1974) and comparatively higher amount of disturbed habitats (Niemela 1999).

A functional network of green space is vital to maintain the ecology of a sustainable urban landscape (Sandstrom et al. 2006). Urban parks, avenues, greenways and other semi-natural habitats will offer a suitable habitat for a variety of species found in cities and suburbs (Tomiałojc 1998, Savard et al. 2000). Such green spaces may also function as dispersal corridors for several organisms (Bolger et al. 2001). Most of the studies conducted in urban parks found such areas to be an important variable in explaining bird diversity and richness (Tilghman 1987, Jokimaki 1999, Fernandez-Juricic 2000, Cornelis and Hermy 2004). These sites are often found to be very rich in invertebrates and plants (Mason 2006, Muratet et al. 2007). Hence the adequate quantity of green space of relevant quality in cities may help the presence of wild species in urban landscapes (Sandstroma et al. 2006, Gilbert 1989, Hadidian et al. 1997, Rottenborn 1999).

1.1.3 Urban Birds

Urbanisation has direct and indirect impacts on native flora and fauna. However, in the urban landscapes birds are relatively more studied groups (Lepczyk et al. 2008). There are several special characters of urban ecosystems such as mosaic phenomena, specific disturbance regimes, and the 'heat islands' which are expected to influence the population dynamics and structure of bird populations in the urban ecosystem (Fernandez-Juricic and Jokimaki 2001). Several studies supported that the bird species diversity in urban landscapes is associated with habitat complexity (Lancaster and Rees 1979, Tilghman 1987, Clergeau et al. 1998, Fernandez-Juricic 2000), and the bird community patterns are explained well by the differences in the structural diversity and species richness of the associated plant communities (Clergeau et al. 2001). According to Schwartz et al. (2007) bird richness was negatively correlated with lawn cover and was positively correlated with the richness of woody plants. Similarly some of the studies in urban areas suggested the presence of grass, nettles and weedy patches to be linked to increased bird diversity (Chamberlain et al. 2005). It clearly suggested that tidy gardens with high proportion of paving are less suitable habitat for foraging birds. According to Marzluff et al. (1997) with respect to birds settlement can change ecosystem processes, habitat, food, predators and competitors, and disease. This will cause significant changes in the population biology of birds in urban areas with resulting effects on the structure and composition of bird communities (Marzluff 2001).

1.1.4 House Sparrow

Historically the House Sparrow has a commensal relationship with humans and has become one of the most widely distributed land birds in the world (Summers-Smith 1988, Vincent 2005). Drastic decline of the species has been reported from different parts of the world. The decline has been reported in many urban areas of different countries such as the United Kingdom (Crick et al. 2002, Hole et al. 2002, Summers-Smith 2003) Central Europe (Bohner and Witt 2007), Spain and Dublin (Prowse 2002, Balmori and Hallberg 2007) and Western Europe (Crick et al. 2002), and cities such as Berlin (Balmori and Hallberg 2007), Brussels (Balmori and Hallberg 2007). The urban areas in India also have experienced the decline of the species (Daniels 2008, Rajashekhar and Venkatesha 2008). According to Summers-Smith (1988) in the United Kingdom the trend in decline of Sparrows in built up areas is much more complex with a gradual decline up to about 1990, followed by a massive decrease that has resulted in the almost complete extinction of the species in certain urban centres. Laet and Summers-Smith (2007) suggests that while dealing with the Sparrow decline in Europe, two separate subpopulations has to be dealt separately; one associated with farmland and the other associated with built up areas. Distribution of House Sparrows within urban areas is often very patchy, and recent evidence suggests that human socioeconomic status may offer a partial explanation for this (Shaw et al. 2008).

1.1.5 Factors responsible for the decline of species

House Sparrow, being a synanthropic bird several hypotheses had been put forth regarding the decline of its population and a compilation of same is provided in the Table 1.1. Severe reduction in productivity can be solid reasons for species extinction. Summers-Smith (1988) reasoned the decline of urban House Sparrow as due to; increased predation, competition for food with other urban species, Feral Pigeons (*Columba livia*) loss of potential breeding sites, decline of spill over from the farmland, diseases and increased traffic. Summers-Smith (2003) considers the timing of population decline and the local re-distribution of nesting Sparrows to be consistent with an impact of vehicle exhaust emissions on House Sparrows possibly via their invertebrate prey. Peach et al. (2008) suggested low ambient temperatures, extremes of rainfall, high vegetable content in the diet, low aphid densities and high air pollution from traffic as some of the factors associated with reduced reproductive output included.

Reproductive failure due to inadequate invertebrate availability accounts for the decline in urban–suburban House Sparrow populations (Peach et al. 2008, Summers-Smith 1988). Peach et al. (2008) suggested that maintenance of key invertebrate densities should be an objective of conservation management aimed at urban–suburban House Sparrows. A small scale study conducted in Hamburg, Germany suggests that the declining suburban House Sparrow population might have been caused by lack of aphids (Aphidoidea) and ants (Formicidae) as chick food close to nests (Peach et al. 2008).

Loss of suitable nesting sites in modern buildings or in buildings after renovation is considered as an important reason for the decline of the species in urban areas, as modern roofs are likely to provide fewer cavities than older ones or those in poor condition (Summers-Smith 2003, Vincent 2005). Use of plastics instead of wood and cast iron for the buildings have reduced the nesting sites for the species as the plastic would not rot or degrade to provide nesting holes (Shaw et al. 2008). It is also reported that though the nesting sites are available Sparrow population may decline still. This is explained as the birds are loose/partially colonial nesters; a decrease in the size of a colony may inhibit breeding in the remaining individuals. This could lead to the loss of the colony altogether (Summers-Smith 2003). Adult Sparrows show a very restricted movement once settled (Vincent 2005), they have restricted movement between populations (Hole et al. 2002), which suggests that rural House Sparrows are unlikely to be a source of recruitment to the urban breeding population.

Changes in habitat could influence House Sparrow populations by affecting nesting success, foraging and predation risk (Shaw et al. 2008). Planting exotic ornamental shrubs are likely to reduce the habitat available to House Sparrows. This can be related to the high developmental activities and habitat alterations in the highly economical areas of the urban centres (Shaw et al. 2008). Tidy and well maintained gardens are not conducive for adult House Sparrows during the breeding season, when insect food is required for nestlings (Shaw et al. 2008). Studies on urban arthropods (Vincent 2005) suggests that House Sparrow fledging success was higher in areas where insect abundance was high, and chicks were less likely to starve when fed with a high proportion of insectivorous as opposed to vegetable food. Whittingham and Evans (2004) suggest that a mosaic of short and long grass may provide the optimal habitat to maximise foraging efficiency. Replacement of native shrubs with paving or concrete areas (London Assembly 2005) could cause the habitat structure to become more homogeneous, thereby increasing predation risk and less insect food for birds.

Table 1.1 Some studies on factors responsible for the decline of House Sparrow

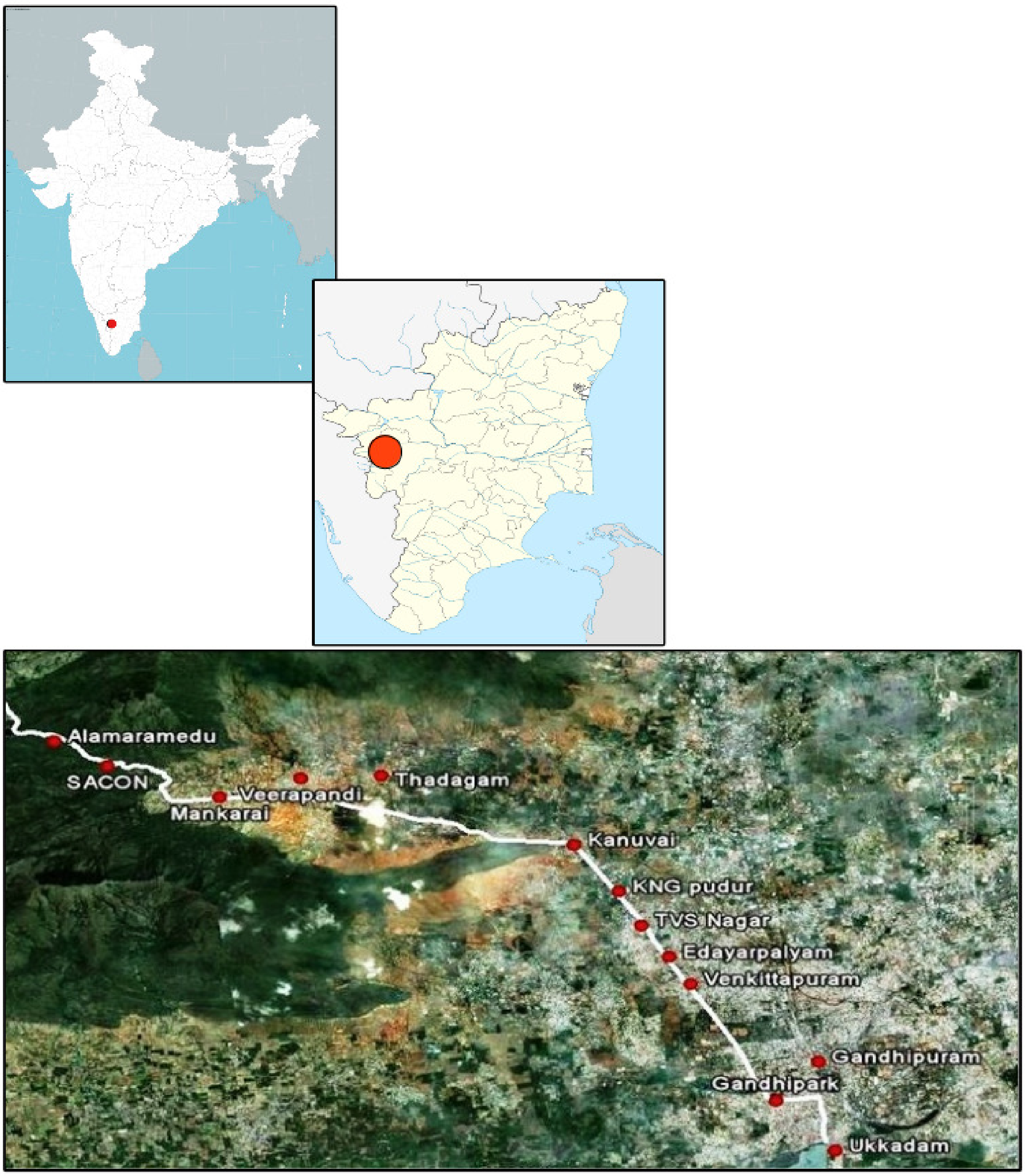
Sl No	Factor	Source	Year
1	Changes in farming practices	Fuller et al.	1995
		Siriwardena et al.	2002
		Hole et al.	2002
		Summers-Smith	2003
		Vincent	2005
2	Lack of nest site, nest failure	Witt	2000
		Wotton et al.	2002
		Crick	2002
		Summers-Smith	2003
		Witt	2005
		Mason	2006
		Anderson	2006
		Peach et al.	2008
3	Reduced survival rate	Siriwardena et al.	2000
		Crick et al.	2002
		Vincent	2005
		Klok et al.	2006
4	Habitat change	McIntyre	2000
	a) Lack of green space	Whittingham and Evans	2004
	and native flora	Vincent	2005
	b) Garden/park	Pauleit et al.	2005
	management	Bokotey and Gorban	2005
		Wilkinson	2006
		Chamberlain et al. (a)	2007
5	Starvation	Summers-Smith	1999
		Garnet	1981
		Magrath	1991
		McIntyre	2000
		Hole et al.	2002
		Summers-Smith	2003
		Vincent	2005
		Bokotey and Gorban	2005
		Anderson	2006
6	Predation	Swaddle and Lockwood	1998
		Woods et al.	2003
		Summers-Smith	2003
		Whittingham and Evans	2004
		Baker et al.	2005

		Anderson	2006
7	Disease	Summers-Smith	2003
		Vincent	2005
		Dandapat et al.	2010
8	**Urbanisation**	Pauleit et al.	2005
	Increase of flats and allotments	Bokotey and Gorban	2005
		Raven and Noble	2006
		Chamberlain et al.	2007
		Bohner and Witt	2007
9	Higher socioeconomic status	Bland	1998
		Witt	2000
		Siriwardena et al.	2002
		Noble et al.	2004
		Robinson et al.	2005
		Witt	2005
		Pauleit et al.	2005
		Shaw et al.	2008
10	Allee effect	Summers-Smith	2003
11	Electromagnetic radiation	Balmori and Hallberg	2007
		Everaert and Bauwens	2007
12	Pollution and heavy traffic	Summers-Smith	2003
		Bokotey and Gorban	2005
		Anderson	2006
		Peach et al.	2008

1.2 The study area

Coimbatore (11°0′45″N 76°58′17″E) known as 'the Manchester of South India' is the third largest city in Tamil Nadu (Figure 1). The city is famous for textile mills, small scale engineering works and in recent years as an educational hub. Industrialization was set out in the area in 1888 and continued into the 20th century. The city experienced a textile boom in 1920s and 1930s due to the decline of Cotton industry in Mumbai. The British made the city well connected with roads and rails and helped in industrialization. As of now, the total extent of the Coimbatore city is 105.60 sq. Km (Coimbatore City Development Plan 2006). This is divided into 72 wards grouped under four zonal ward Committees. The city is a part of Coimbatore-Tiruppur-Erode industrial corridor. Also, the municipal towns of Mettupalyam, Pollachi and Tiruppur are within a radius of 40 km from the city (Coimbatore city development plan 2006). From the city seven roads (Thadagam, Metupalayam, Sathy, Avinashi, Trichy, Cochin and Perur roads) radiates connecting with other important places and most developmental activities here are concentrated around these arterial roads.

The study was conducted along an urban to rural gradient, along the Thadagam road. The Thadagam road linking Kerala, radiates from the centre of the city and connects Anaikatty, 28 km away from the city centre (Figure 1.2) which borders with Kerala state



Source: www.GoogleEarth.com Accessed on March 6, 2010

Figure 1.2 Map showing the study area

1.2.1 Climate

In general, climate of the Coimbatore is pleasant and moderate for most of the year. Summer (March to May) is relatively dry and warm. This area receives precipitation from both Southwest (May to August) and Northeast (September to November) monsoons (Figure 1.3). The Northeast monsoon supply major portion of the total annual rainfall and the average precipitation during past 10 years was 668 mm. During this study, the highest rainfall was observed in October and the lowest in January. The mean of monthly minimum and maximum rainfall was 0.41 and 8.53 cm in January and October respectively. The mean maximum (34.8°C) and minimum (18.2°C) temperature was recorded during April and January respectively (Figure 1.3). The number of rainy days was highest in October and lowest in January (Figure 1.3).

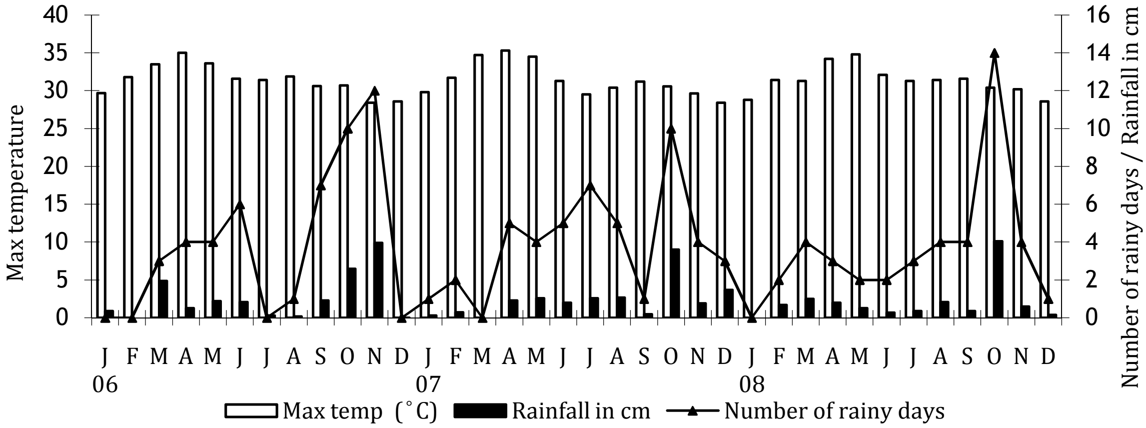


Figure 1.3 Ombothermic diagram of the study area during 2006-2008

1.3 Objectives of the study

Urbanisation leaves a clear signature on the distribution patterns of birds, it affects and alters the heterogeneity of the landscape and, consequently, the distribution, abundance, and resources upon which the birds depend. The House Sparrows being, the natural symbionts of humans, respond to the intensity of urbanisation in differing manners. They show tolerance to certain level of environmental transition entailing to tackle more than one limiting factors. Very little work has been done in order to foretell the influence of urban expansion on wildlife and to develop management strategies aimed at diminishing these impact.

Being a synanthropic bird to an extent, House Sparrows reflect the state of urban ecosystem. The major hypothesis relating disappearing species to the physical urban growth is regarding the habitat loss. The phenomenon of change in species in cities is widely visible in India as elsewhere in other countries; but the records here are only anecdotal. Not much scientific works have come out on any such particular decline of synanthropic species and it makes a scientific investigation on the issue timely. This proposed study aims to look at the impact of urbanisation on House Sparrow population, an almost ubiquitous species. This study was undertaken with the objectives given below:

To study the

- Land use land cover change in the study area and overview the urbanisation trend in Coimbatore
- Document status, distribution and habitat use of House Sparrow

- Examine breeding performance and the factors affecting along an urban to rural gradient
- Examine the pre roost, roost activities, nocturnal roost population and roost site characteristics, and
- Identify major plausible threats to the population

1.3.1 The study species

The House Sparrow is a brown bird about 15 cm long and very common in human-made habitats. It is a rather large headed, heavy billed passerine. The sexes are dimorphic with the male being boldly patterned. The male House Sparrow has a grey crown, chestnut brown nape, dull white cheeks, dark brown and black streaked back, grey under parts and rump, black eye stripe and bib. The beak is a yellow-brown to black. The female is paler and lacks the grey crown, white cheeks, black bib and eye stripe, and chestnut brown nape.

1.3.2 Habitat

The House Sparrow is found in nearly every habitat except dense forests. It prefers human associated or human altered habitats such as agricultural land, villages and urban areas (Vincent 2005). The optimum habitat for House Sparrows in temperate regions is a combination of buildings with holes under tiles or eaves to providing suitable nesting sites and sufficient green areas providing insect food for the young (Summers-Smith 1988).

1.3.3 Behaviour

House Sparrows are normally found in flocks that associate in many activities, varying from communal roosting to feeding, dust and water bathing and 'social singing' when the birds collect in bushes/trees and call together. This usually happens at the roost sites prior to searching for food (Summers-Smith 1988). House Sparrows are aggressive and social, both of which increases their ability to compete with many native birds. Adult Sparrows generally do not migrate. They stay within a radius of 2 km during the nesting period. Exceptions occur when flocks of juveniles and non-breeding adults moving long distance from nesting sites to seasonal feeding areas.

1.3.4 Diet

House Sparrows are primarily granivorous (Summers-Smith 1988, Vincent 2005). Plant materials (grain, fruit, seeds and garden plants) make up the majority of the adult diet. The remainder consists of insects and other animal matter. Garbage, and refuse from restaurants can support Sparrow populations in urban habitats. Birds living in built up areas, supplement their diet of natural vegetable matter with a variety of household scraps, such as cooked rice, bread and peanuts deliberately put out by humans (Summers-Smith 1988). Nestlings are fed mostly with animal matter (both their larval and adult form). The most consumed taxa are aphids (Aphidoidea), spiders (Arachnida), beetles (Coleoptera), weevils (Curculionidae), grasshoppers (Orthoptera) and caterpillars (Lepidoptera) (Seel 1968, Gavett and Wakely 1986). The vegetable matters are supplemented more in course of the development of young ones.

1.3.5 Breeding

House Sparrow is generally regarded as monogamous despite extra pair paternity can vary from population to population (Summers-Smith 1988, Vincent 2005). Males usually occupy the nest site and control a territory around it. A wide variety of nest sites are being used, ranging from holes and crevices in man-made structures, trees, in earth banks, nest-boxes and even on the top of electricity poles (Summers-Smith 1988). House Sparrows use a broad range of materials for nest building including feathers, grass, inflorescences, stalks and roots of plants, bark, threads, string and even pieces of paper. Indykiewicz (1990) analysed the frequently used position of urban Sparrow nest and found that it is three to four meters high. According to Summers-Smith (1988), the breeding season starts in April and runs through August, allowing pairs to produce up to four clutches over the summer. The clutch size normally ranges from two to five eggs with four being the model number in the United Kingdom. The interval between the laying of each egg is approximately 24 hours and both sexes took part in incubation (Seel 1968).

1.4 Chapter organisation

Keeping the objectives above the thesis is organised as follows;

- Subsequent to the introductory chapter, the next one (chapter II) presents the urbanisation trend and land use land cover changes in the study area. The trend of urbanisation is reviewed looking at the human population changes and developmental activities of the City, Coimbatore.
- In the chapter III a detailed discussion of the status, distribution and habitat utilisation of House Sparrows is reported.

- Reproductive success is fundamental to study the population changes of the species. The factors affecting the breeding performance and productivity of House Sparrow along an urban to rural gradient is analysed in chapter IV. Nest substrate, nesting material, nest site selection, chick diet and habitat utilisation are also examined.
- The nocturnal roosting behaviour of the species was studied as the behaviour can be considered as the result of social development. Proper roosting sites are diminishing due to extreme developmental activities. The characteristics of nocturnal roosts of House Sparrows in relation to environmental variables are discussed in chapter-V.
- In the next chapter (VI) the plausible threats to the House Sparrow population such as urban heat Island, Homogenisation , competition and cultural festivities are discussed.
- In the last chapter (VII) an overall synthesis of the thesis with future perspectives on the conservation of the House Sparrow is discussed.

Chapter II

The urbanisation trend and land use land cover changes in the study area

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2.1 Introduction

2.2 Methodology

2.3 Results

2.3.1 The causes and status of urbanisation in Coimbatore

2.3.1.1 Industrialization and economic growth

2.3.1.2 Population, migration and settlements

2.3.1.3 Connectivity

2.3.1.4 Land use and land cover change in the study area

2.3.2 Discussion

2.3.2.1 Industrialisation and economic growth

2.3.2.2 Population, migration and settlements

2.3.2.3 Connectivity

2.3.2.4 Land use and land cover change in the study area

2.3.3 Summary

Chapter II

The urbanisation trend and land use land cover changes in the study area

2.1 Introduction

Urbanisation is a leading cause of demographic change and a vital component of global land transformation (Pickett 2001). With the increase in population and economic development worldwide, urbanisation is progressing at a rapid pace. The population growth happening worldwide, in the next thirty years it is expected to concentrate in the urban areas (United Nations World urbanisation prospectus 2003). The urban human population reached one billion in 1960, two billion in 1985, and three billion in 2002. Economic growth involves large scale conversion of rural land to urban uses (residential, commercial and industrial) as the regional economies transition from an agrarian-based economy to an urban economy based on industry and services (Irwin 2010). Similarly on a global scale, changes in information, production and transportation technologies have had the profound impetus for on urbanization.

According to the 2001 census, Tamil Nadu has emerged as the state with the highest level of urbanisation (43.86%) in the country. Coimbatore, the study area, is the third largest city in the state of Tamil Nadu. Coimbatore in 1865 became the capital of the newly formed Coimbatore district. In 1866 it was accorded with the municipality status. Industrialisation has begun in the area in 1888 and continued into the 20th century. Currently the city's most important industries are engineering and textiles. Conversion of land from wild and agricultural uses to urban and suburban areas happened at a faster rate than the population in urban areas. Gradually the geomorphology of the city changed from a compact one to a sprawl in more or less spider-like configurations. The growth extended from the urban centre along the sides of the roads spreading the suburban sprawl (City development plan-Coimbatore 2006).

Land use and land cover change (*hereafter referred to as* LULC) is recognized as an important driver of environmental change in all spatial and temporal scales (Zhang et al. 2008). The LULC pattern of a region is an outcome of natural and socio – economic factors and their utilisation by man in time and space (Opeyemi 2008). It has become one of the major issues of environmental change monitoring and natural resource management. LULC, as the basic spatial element of the landscape, plays an important role in the study of landscape ecology. Most major metropolitan areas face the growing problems of urban sprawl, loss of natural vegetation and open space, and a general decline in the extent and connectivity of wetlands and wildlife habitat. Land is becoming a scarce resource due to immense demographic and commercial pressures and associated needs. Hence, gather information on LULC is so essential for management and implication of land mass for increasing demands for basic human needs and welfare. Such information also helps in monitoring the dynamics of land use resulting out of changing demands of increasing population (Opeyemi 2008). In the current chapter the trend of urbanisation in the city is examined along with and land use land cover analysis of the area with the aid of remote sensing and GIS.

2.2 Objectives:

1. Examine the causes and status of urbanisation in Coimbatore
2. Evaluate the land use land cover change in the study area

2.3 Methodology

The cause and status of urbanisation in Coimbatore were reviewed based on available literature. For this related paper appeared in journals, reports, thesis and online sources were used. The satellite imagery of the study area Landsat TM (Thematic Mapper) for the year 1989 and Landsat ETM+ (Enhanced Thematic Mapper+) for the years 1999 and 2004 were obtained from the Global Land Cover Facility (GLCF www.landcover.org), Institute for Advanced Computer Studies, University of Maryland, United States of America. The satellite imageries obtained from GLCF were used to quantify the land use of Coimbatore (11°0′45″N 76°58′17″E) and classified city broadly into four classes *viz*., vegetation, urban, lake and bare land. The multi-spectral data from Landsat TM 1989, ETM+ 1999 and 2004 were analysed using ERDAS Imagine 9.2 (ERDAS 2001). The image analyses included false colour composite (FCC) generation, registration and classification (Sudhira and Ramachandra 2007). The false colour composites were generated using: green, red and near-infrared bands. The next step involved registration of the imagery on to the toposheet of Coimbatore and then the classification of the multi-spectral remote sensing data, which was carried out through a two-stage classification process; unsupervised and supervised. In the unsupervised classification the number of clusters for classification was identified through the number of distinct peaks obtained from the histogram. For the supervised classification the signatures were derived from the training data obtained from land use features obtained from unsupervised classification. The signatures were generated for each of the land use types and were verified with the composite image. Based on these signatures, corresponding to various land features, supervised image classification was done using Gaussian Maximum Likelihood Classifier. The classified images were further reclassified to note the expansion of built up area and reduction of non built up area during 1989 and 1999.

2.4 Results

2.4.1 The causes and status of urbanisation in Coimbatore

2.4.1.1 Industrialisation and economic growth

Coimbatore is a part of Coimbatore-Tiruppur-Erode industrial corridor. Coimbatore has made its own signature in the fields of foundry castings, rubber, machine tools, cutting tools, electric motor pumps, wet grinders, textile machinery, plastic spares, washing machines, domestic vessels, domestic electrical appliances, transformers, illuminations, waste cotton units, automobile spares, education, tourism and health care (Table 2.1). The major industrial estates are situated at Peelamedu, Kurichi, Singanallur and Uppilipalayam. The engineering units, both light and heavy, are mainly located along Mettupalayam and Avinashi road. Industries related to food products are clustered mainly along the Mettupalayam road and the major textile mills are located along Trichy road and Avinashi road. There are ten commissioned Special Economic Zone (SEZ) in Coimbatore. Of these SEZs two are completed, four are proposed and four are under construction.

a) Textile

The city experienced a textile boom in the 1920s and 1930s due to the constrains in the cotton industry in Mumbai. The dry belt of the Coimbatore is rich with black cotton soil and is best for cotton cultivation. This resulted in the extensive growth of textile mills. This belt has around 2,000 textile mills, both large and small industries. It made for a substantial increase in auxiliary industries, workers migrating from different parts. Currently the city has around 210 dyeing and bleaching units. Textile export in Coimbatore accounts for a hundreds of million US Dollars per year.

b) Information technology (IT) and Business process outsourcing (BPO) companies

Private sector initiatives and a multitude of educational institutions have attracted several industries to Coimbatore, predominantly the IT sector. Coimbatore is an important educational hub with seven universities, two medical colleges, 18 polytechnics, 54 engineering colleges and 70 arts and science colleges. Yearly these educational institutes produce around one lack arts graduate and 50000 engineering graduates. Thus it holds an excellent human resource pool and this makes the city an alluring destination for the IT and BPO companies to establish their offices. The city is the second largest software producer in Tamil Nadu. The IT software export from Coimbatore is close to 150 Crores.

c) Engineering clusters

The engineering clusters in Coimbatore are producing a variety of engineering products and components, accessories to supplement the needs of the country. During 2010 the exports of engineering products from Coimbatore was worth Rs. 3,377 Crores.

Wet grinders

There are about 700 wet grinder units in Coimbatore and are located within a radius of about 25 kms from the center of Coimbatore. Monthly around 75,000 wet grinders are manufactured in Coimbatore. The industry is offering 20,000 employments directly.

Pump manufacturing units

The textile boom during the 1920s and 1930s gave impetus farmers to improve irrigation methods to increase the cotton production and this paved the way for setting up pump industry, foundries and electric motor manufacturing units. The growth of the motor and pump industry started during the 1920's and was at the peak during 1991-1992 to 1995-1996 due to the immense industrialization. At present about 40 percent of the country's requirement of motor pump sets is catered by the industries in Coimbatore.

Foundry

The development of textile and pump-set industry paved the way for the foundry units in Coimbatore. During 1980, Coimbatore became one of the five major foundry clusters of the country with more than 500 foundries and the value of items produced costs around 45 crores per month. The foundry cluster is mainly to supply to the industries like motor pumps, machineries and which has recently started catering auto components sector too. These foundry units generated about one lakh direct and indirect employment in and around Coimbatore.

Table 2.1 Number of industrial units and approximate workers *(Source: City development plan-Coimbatore 2006)*

Industries	**No. of Units**	**Approximate number of manpower**
Textile sector	4642	232110
Foundry sector	1310	013012`
Electrical manufacturing sector and small scale sector	0680	6332

d) Jewellery business

The city resides a number of jewellery, major diamond cutting and gold casting units in

South India. The Emerald Jewel Industry India, one of the largest manufacturers of jewellery in SAARC countries also well established in Coimbatore. Coimbatore has over 3,000 jewellery manufacturers with about 40,000 goldsmiths.

2.4.1.2 Population, migration and settlements

The population of Coimbatore has reached more than a million (10.36 lakhs) by the end of 2005. The urban population in the district now reached around 75.83 percent (out of 34.72 lakh) as against 70.70 percent in 2001. The rural population has decreased by 1.76 percent in the last 10 years and the same time the urban population has increased by 27.69 percent. The industrial growth due to the availability of raw materials and power supply caused nearly a 52 percent increase in population between 1941 and 1951. The population of Coimbatore is spread over an area of 105.60 Sq. Km with a density of 8815 persons /Sq. Km. The density has increased from 7727 persons /Sq. Km in 1991 to 8815 persons /Sq. Km in 2001 (Figure 2.2). The city is divided into four zones ie, north, east, south and west zone (Table 2.3). The east zone being, large has lesser density. Other than the east zone the rest has a density of nearly 9200 persons /Sq. Km. The Coimbatore city population was 9,30,882 as per 2001 census and the urban agglomeration is 21,51,466 as per 2001 census. The population has grown from 0.47 lakhs in 1911 to 12.5 lakhs by the year 2001 (Figure 2.1 and 2.2) with an average annual growth rate of 2.7 percent.

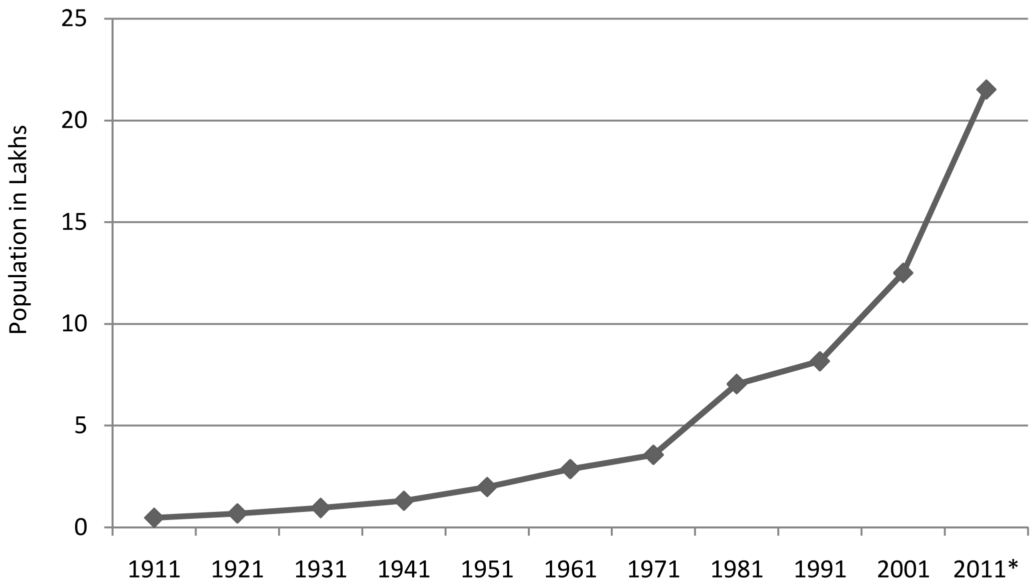

Figure 2.1 Population growth in Coimbatore City Corporation (*Source: Elangovan 2005*) **Projected*

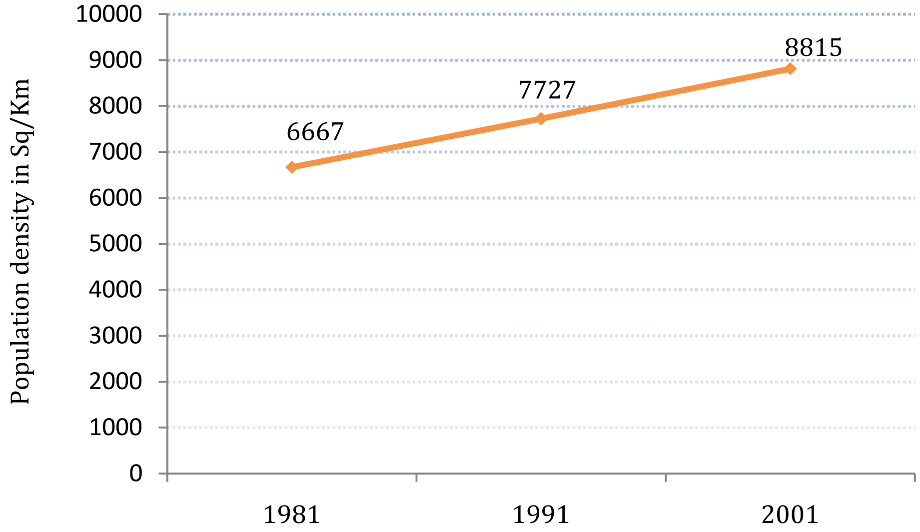

Figure 2.2 Population density in Coimbatore *(Source: http://censusindia.gov.in)*

Owing to the rapid industrialisation, large influx of the migrants happened to the city. Every year nearly 20,000 people immigrate to Coimbatore. Job opportunities draw people from the villages and towns to move in. For e.g. in the jewellery sector about 10 percent of the goldsmiths and workers are from West Bengal. Hence such migration process resulted in the formation of slums. In Coimbatore Corporation limits there are 195 slums located at 23 locations. It is estimated that 2,90,970 lived in the slums in 2002; the population which has reached 3,52,219 during 2006.

Table 2.3 Population density at different zones *(Source: City development plan- Coimbatore 2006)*

Zone	Area (Sq. Km)	Population	Density (Persons/ Sq. Km)
North Zone	28.1	2,56,434	9115
East Zone	33.0	2,61,889	7945
South Zone	21.5	2,02,021	9383
West Zone	22.8	2,10,538	9235

Compared to the various districts of the Tamil Nadu state the city of Coimbatore (73.43%) has the highest proportion of residential houses of permanent nature. The Nilgiris (3.79%), Coimbatore (5.39%) and Chennai (5.66%) have shown low percentage of temporary houses. The second and third highest ratios in the state are registered in Coimbatore for permanent houses (73.45%) followed by The Nilgiris (70.22%) district. The census showed that within the corporation limit, the buildings with tiled and concrete roof dominated (Table 2.4).

Table 2.4 Distribution of houses by roof type *(Source: City development plan- Coimbatore 2006)*

Roof	Number	Percentage
Grass, thatch, bamboo, wood, mud etc.	1880	0.75
Plastic, polythene	525	0.21
Tiles	1,18,429	47.13
Slate	166	0.07
Metal, asbestos	14,020	5.58
Brick	1816	0.72
Stone	243	0.10
Concrete	1,13,544	45.19
Others	643	0.26

2.4.1.3 Connectivity

The road connectivity of the place is a very significant cause for rapid urbanization. The British made the Coimbatore well connected with roads and rails and helped to trigger the industrialisation in the area. With the establishment of mills, technical and educational institutions, the city is mainly growing towards North, East and South directions. The Coimbatore city is connected with seven radial roads namely Thadagam, Metupalayam, Sathy, Avinashi, Trichy, Cochin and Perur roads (Figure 2.3). The city corporation alone maintains a road network of 635.52 kms. Of the total road length 83.6% are black topped roads, 10.4% are concrete roads, and the balance 6% include earthen and other roads. The city is connected with main industrial cities such as Chennai and Bangalore, which are about 500 and 350 km respectively. The city has good road, rail and air links with industrial cities. The railway network was established in 1862, passing through Podanur to Cochin for quicker transit of raw materials. Currently the district is well connected with railways and has 20 railway stations. The adjacent seaports are Cochin and Tuticorin which are about 200 km and 300 km away, is also catering to the needs of the exporters. Coimbatore is known for the production of vegetables and flowers. For marketing of such goods it is very essential to have well connected interstate roads. Almost all the leading transport carriers of India have their offices in the city to facilitate this requirement. A detailed portrait of the roads connecting Coimbatore is given in Table 2.5.

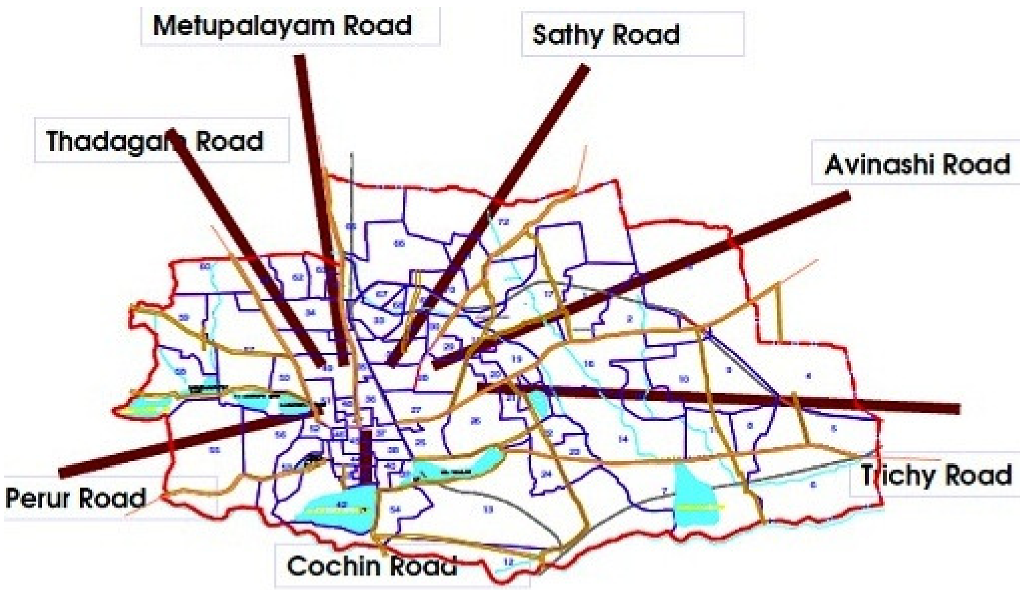

Figure 2.3 Connectivity of Coimbatore by different roads (*Source: City development plan- Coimbatore 2006*)

Table 2.5 Road connection in Coimbatore district (Annual Employment Report 2007-2008)

Sl.No	Road	Length (km)
1	National Highways	269.40
2	State Highways	4058.22
3	Corporation and Municipalities road	1190.44
4	Panchayat Union and Panchayat road	6133.76
5	Town Panchayat and Township road	1857.27
6	Others (Forest Roads)	226.24

2.4.2 LULC in the study area

The False Colour Composite imagery and classified images for land use in 1989, 1999 and 2004 are given in Figure 2.4, 2.5, 2.6, 2.7, 2.8 and 2.9 the classification statistics are shown in the Table 2.6. Considering the variations in image acquisition during different time periods and scope of the study on urban expansion, the different classes of classified imageries were stacked together as build up and non build up area. Within a span of fifteen years (1989-2004) the extent of the urban area has shown a 58.2 percent growth.

Table 2.6 Classification statistics of land use change in the area

Category	1989	1999	2004
Built up area (Sq. Km)	22.25	35.02	44.72
Non built up area (Sq. Km)	276.37	263.59	253.89
Percentage increase in built up area	-	36.5	21.7

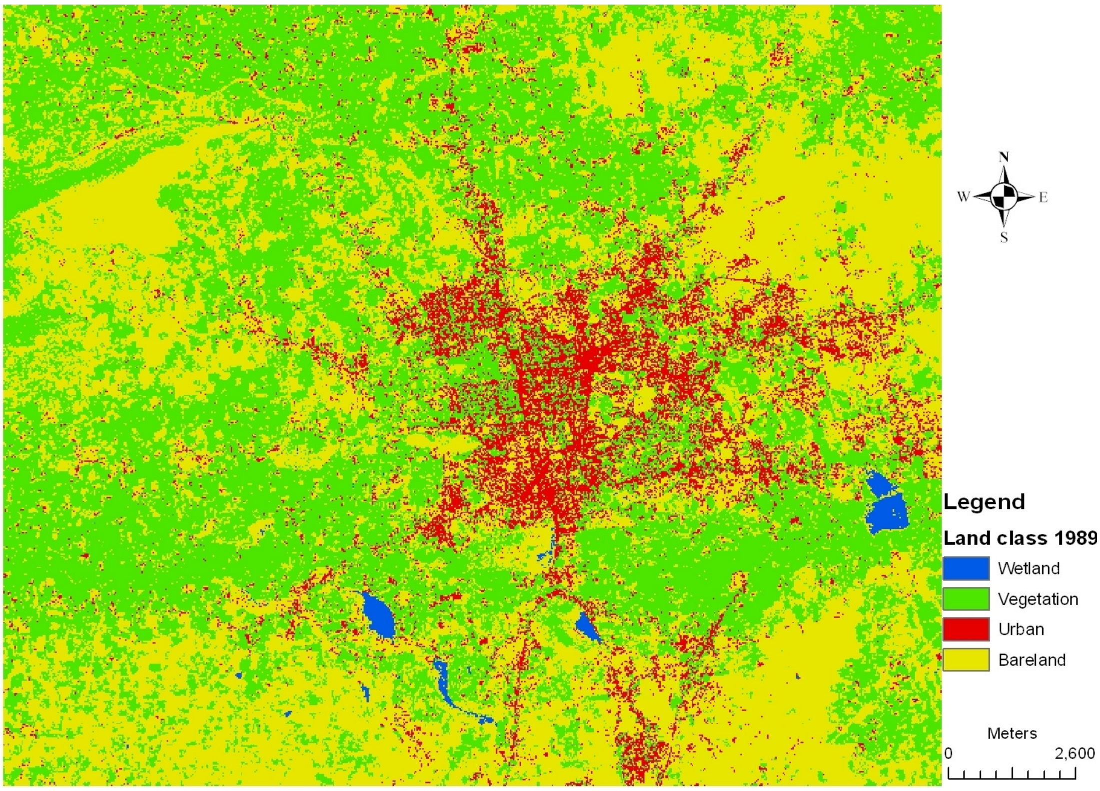

Figure 2.4 Land use classification for the study area, Coimbatore -1989 based on Landsat TM data

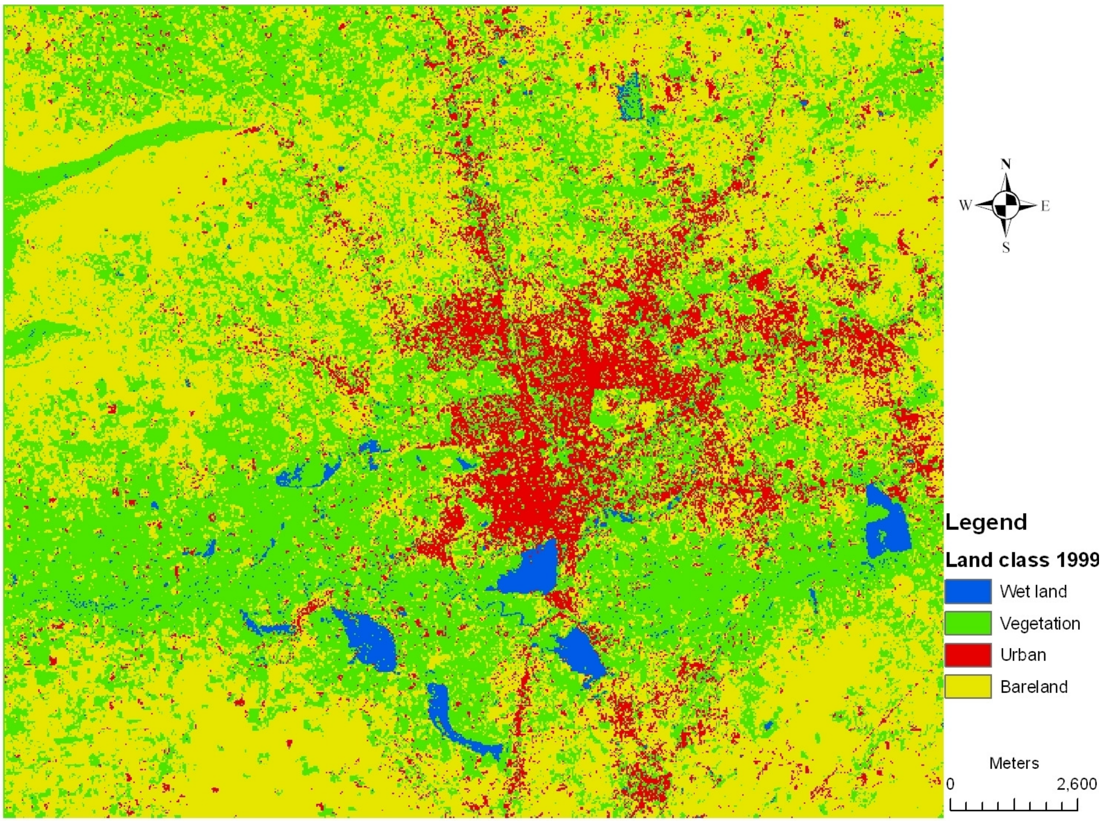

Figure 2.5 Land use classification for the study area, Coimbatore -1999 based on Landsat ETM+ data

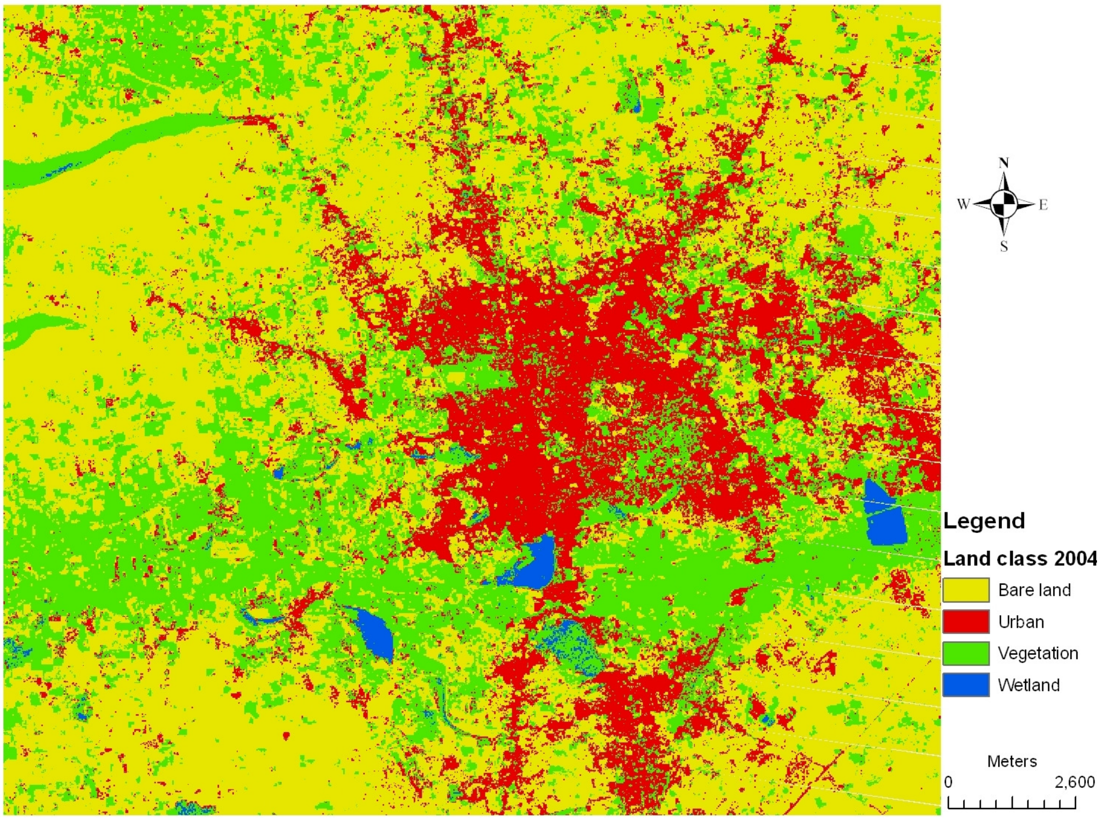

Figure 2.6 Land use classification for the study area, Coimbatore -2004 based on Landsat ETM+ data

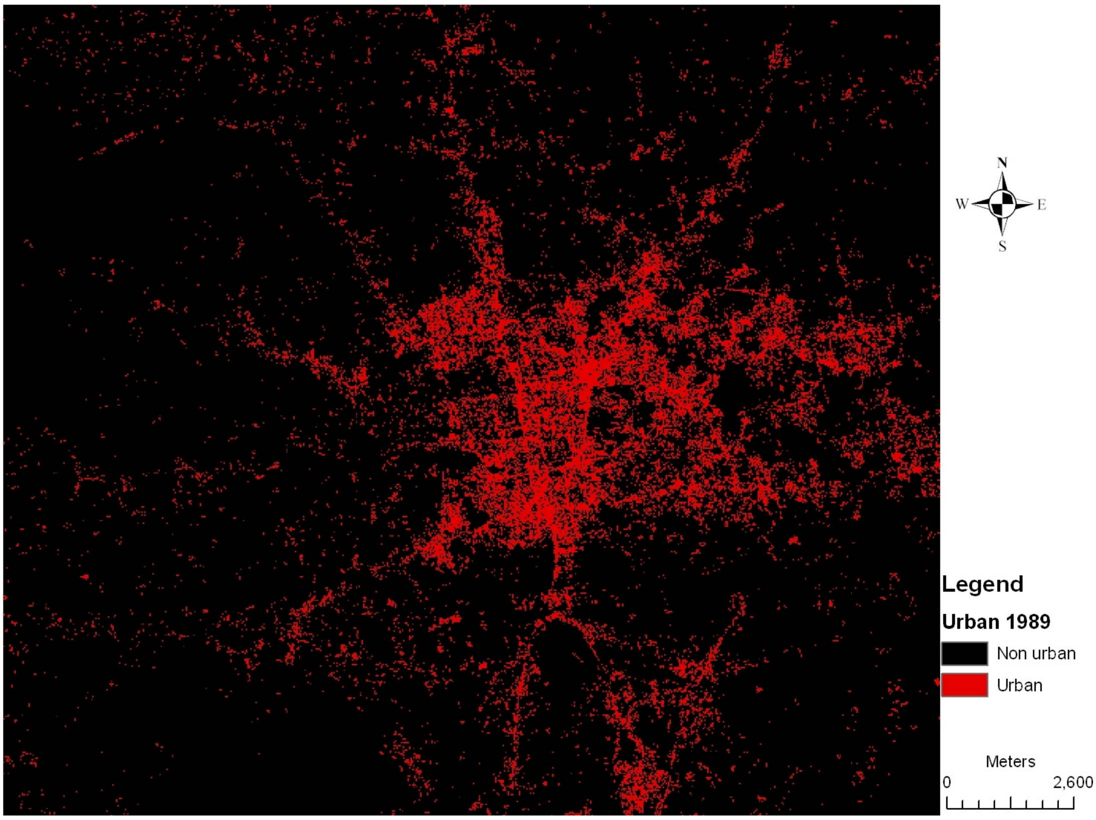

Figure 2.7 Urban expansion – 1989

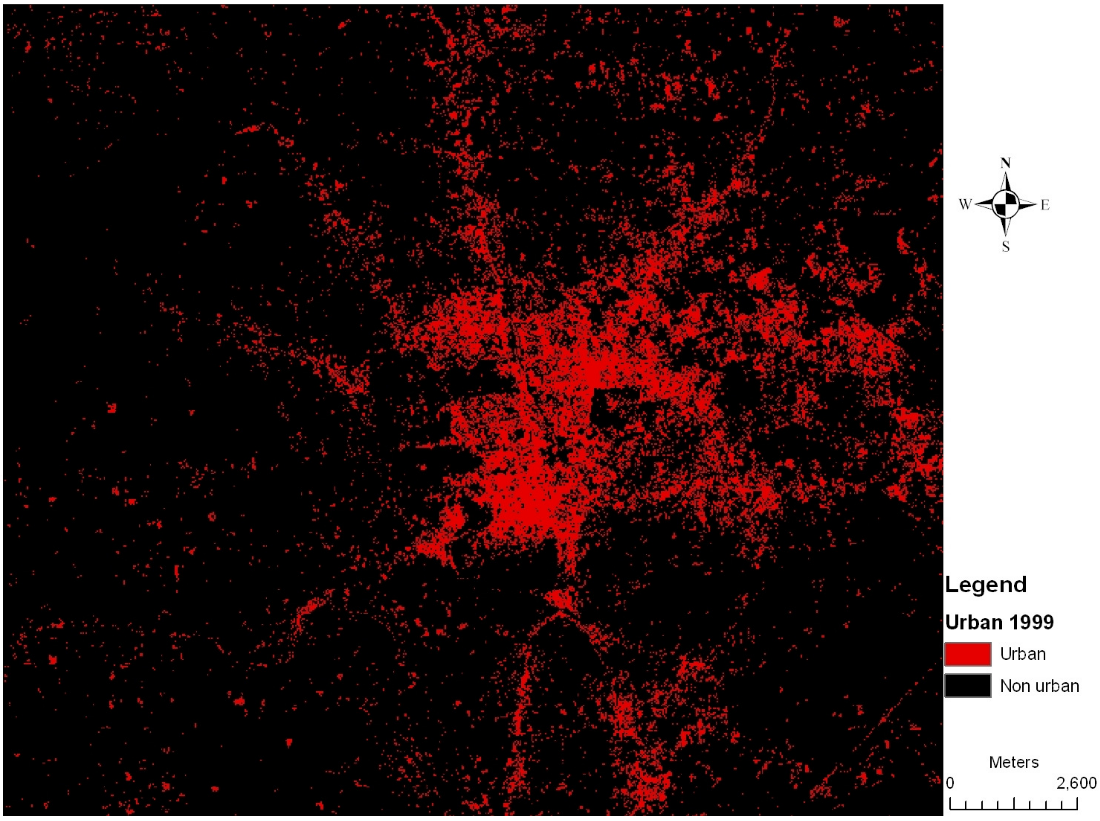

Figure 2.8 Urban expansion – 1999

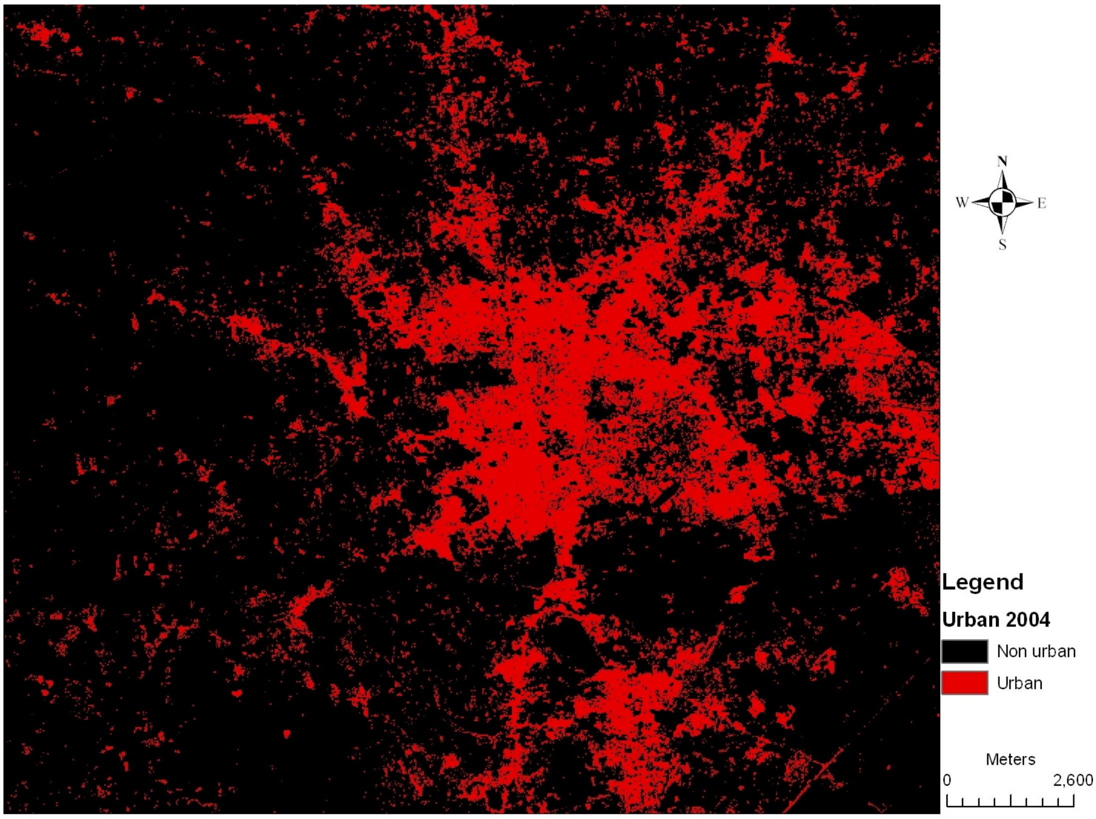

Figure 2.9 Urban expansion - 2004

2.5 Discussion

2.5.1 Industrialisation and economic growth

Industrialisation is one of the main factors which increases migration and triggers urbanisation (Schmidt and Kedir 2009). The economic growth depends on growth and survival of the industries (Simons 2003). Coimbatore is the largest growing industrial area after Chennai. The set up of industrial clusters and excellent human resources helped the city to be recognized as an industrial city of South India. Other than the engineering and textile industry Coimbatore also has units of Power loom, Hosiery, Agricultural implements (Diagnostic survey report 2009). Recently IT and BPO companies are well established in the city. The aggressive growth of the industries paved the way for setting up of the SEZs like TIDEL Park and Coimbatore Hi-Tech Infrastructure (CHIL) also eight more SEZs are in the pipeline (Coimbatore residential real estate view 2010). Ultimately the faster economic and industrial growth enhances the urbanisation in Coimbatore.

Urbanisation is closely linked to the economic activities in a particular area. In the case of Coimbatore the stimulus for faster industrialisation and economic growth came mainly from the emphasis on development of agriculture sector and the support of the industrial sector during the successive five year plans. The setting up of textile mills and engineering units led to the shift in most workers from the primary to the secondary sector; thus a large number of farmers changed their profession. From Coimbatore alone industries like foundry and IT software export yields around 45 crores and 150 crore (per month) respectively. Likewise in the textile industry a hike in export is expected from 2,70,000 crore to 4,95,000 crore by 2012. Hence the cities' industrial growth and the extent of urbanisation will boost in the future years.

2.5.2 Population, migration and settlements

In third world cities natural population growth is one of the major contributors to the expansion of the city. Migration is also an important factor (Masika et al. 1997), which sometimes can overwhelm the natural growth. Urban areas are characterized by higher population density than its surroundings. Coimbatore being an industrialised city, the migration is high due to the surplus job opportunities (Preetha 2010). Significant factors driving the rapid urbanisation are the migration of people towards the urban area in search of job, food security, water supply, shelter, sanitation and education. Urbanisation requires labour mobility (Schmidt and Kedir 2009). However, rapid urbanisation, particularly the growth of large cities, and the associated problems of unemployment, poverty, inadequate health, poor sanitation, urban slums and environmental degradation cause a difficult challenge.

Coimbatore being a growing industrial area provides a good number of skilled and unskilled job opportunities. According to Alaci (2010) to some extent urbanisation is capable of enhancing access to adequate shelter in a built environment and enables communities to have infrastructure access, employment opportunities and security. The economy of the workforce can be a reason for the highest permanent settlements (73.43%) in Coimbatore compared to the various districts of the Tamil Nadu state (City development plan-Coimbatore 2006). It is also reported that the urban agglomeration growth rate of Coimbatore during 1981 – 1991 was 19.6; while 1991-2001 it increased to 31.4 (Bhagat 2005). Due to the industrialisation and migration of the people to the city, it has become an emerging real estate business destination. Coimbatore is all set to scale new heights by the investment for corporates to expand their business combined with entrepreneurial spirit and efficient manpower. Hence the city may experience a lack of residential area in the future. Aiming these already ten key residential developers initiated their projects in the city premises (JLLM 2011).

2.5.3 Connectivity

The urbanisation triggers the connectivity of a place. As the transportation is very essential for the developments of the industries and is a must criterion for the developments.

Transport- Energy -Communications facilities are extremely essential for smooth and accelerated industrial growth.

2.5.4 LULC change in the study area

Major pressure on landscape changes are mainly the result of human settlements and have been progressing in concert with urbanisation. In Coimbatore the pressure on land mass was high during 1989-2004 and the urban expansion recorded was 58.2 percent. The increase of built up area during 1989-1999 was notable. This could be due to the industrial growth and migration. During 1971 the population was just 3.5 lakhs in city, while during 1991 it has reached to 8.16 lakhs and in 2001 it was 12.5 lakhs. The population statistics showed a considerable growth of population during 1980-90's. During this time the open areas were largely converted to settlements (City development plan-Coimbatore 2006). Similarly the workforce participation from all the sectors were high from 1981-2001. All these factors could have increased the extent of urbanisation to a faster rate.

The consequent chapters will deal with the impact of urbanization on sparrows' status and ecology along an urbanisation gradient. The chapter that follows will discuss the House Sparrow Structure and composition of the various habitat types discussed above and would attempt to decipher the influence of the urbanization in structuring the House Sparrow population.

SUMMARY

- Coimbatore is a part of Coimbatore-Tiruppur-Erode industrial corridor. The major industrial estates are situated at Peelamedu, Kurichi, Singanallur and Uppilipalayam.
- There are nine commissioned Special Economic Zone (SEZ) in Coimbatore.
- Coimbatore is famous in the fields of IT and BPO, Textile, Engineering clusters and Jewellery business.
- The rural population has decreased by 1.76 percent in the last 10 years and the same time the urban population has increased by 27.69 percent .
- The industrial growth due to the availability of raw materials and power supply is a significant factor resulting nearly 52 percent increase in population between 1941 and 1951.
- The Coimbatore city population was 9,30,882 as per 2001 census and the urban agglomeration is 21,51,466 as per 2011 census.
- Rapid industrialisation invited large influx of the migrants to the city and yearly around 20,000 people immigrate to Coimbatore. The migration process resulted in

the formation of 195 slums in Corporation limits and the population during 2006 was 3,52,219.

- In Tamil Nadu state the city of Coimbatore (73.43%) has the highest proportion of residential houses of permanent nature.
- The Coimbatore city is connected with seven radial roads namely Thadagam, Metupalayam, Sathy, Avinashi, Trichy, Cochin and Perur roads.
- The road connectivity of the place is a very significant cause for rapid urbanization.
- The city Corporation alone maintains a road network of 635.52 kms. Of the total road length 83.6% are black topped roads, 10.4% are concrete roads, and the balance 6% include earthen and other roads.
- The city is connected with main industrial cities such as Chennai and Bangalore, which are about 500 and 350 km respectively.
- Within a span of fifteen years (1989-2004) the extent of the urban area has shown a 58.2 percent growth

Chapter III

The status and habitat utilisation of House Sparrow

3.1 Introduction

3.2 Objective

3.3 Methodology

- 3.3.1 Population monitoring
- 3.3.2 Habitat variables

3.4 Statistical analysis

3.5 Results

- 3.5.1 Population survey
- 3.5.2 Population in the intensive study area
- 3.5.3 Habitat utilisation of House Sparrow

3.6 Discussion

- 3.6.1 Population
- 3.6.2 Habitat utilisation
- 3.7 Summary

3.1 Introduction

The House Sparrows are present naturally in Northern Africa, Asia, and Europe (Khera et al. 2009). Owing to the introduction of House Sparrows to islands and continents, it has become one of the most widely distributed land birds in the world (Summers-Smith 1988). The bird is absent only in regions such as China, Indochina, Japan and areas of Siberia and Australia to the east and tropical Africa and northern areas of South America to the west (Summers-Smith 1988). Two subgroups of House Sparrows are recognised. The '*domesticus*' subgroup includes five subspecies with a natural range covering Siberia, Europe, North Africa and the Middle East. The other, '*indicus*' subgroup contains six subspecies confined to Asia (Summers-Smith 1988). The '*domesticus*' subgroup is typically larger, with grey cheeks and underparts whereas the '*indicus*' subgroup is relatively smaller, with smaller bill, white cheeks and underparts and a richer colour on the upperparts (Summers-Smith 1988).

The House Sparrow stays close by to humans inhabiting with farmyards, villages, and urban areas, where in buildings play a key role by offering small cavities, eaves and crevices as suitable nesting sites. World over, the decline of the species is in an alarming state (Vincent 2005, Anderson 2006, Hole et al. 2002). In Britain, Royal Society for Protection of Birds claimed 62 percent decline within 25 years (RSPB 2003), whilst the British Trust for Ornithology reported a 56 percent decline within last 40 years. The overall decrease of the species is evident not only in cities but also in rural areas. The House Sparrow has declined especially in the north-western parts of Europe, since the 1970s or even earlier. The House Sparrow decline in Germany has been reported from Hamburg, Cologne, Duesseldorf, Bielefeld (Laske et al. 1991) and Berlin (Bohner and Witt 2007). Similar decline was reported in cities in other countries like Warsaw (Węgrzynowicz 2006), Spain and Dublin (Prowse 2002, Balmor i and Hallberg 2007). The worldwide trend in House sparrow population is given in Table 3.1.

To set off conservation activities for the species, they were included in the Red Data Book published by IUCN (BirdLife International 2008). As urbanization progress the species would not be able to tolerate the rapidly changing habitat. There are many hypotheses explaining the disappearance of House Sparrows; which include the lack of nesting, feeding and roosting sites (Chamberlain et al. 2005,), electromagnetic radiations and the exhausts of automobiles running on unleaded petrol (Balmori and Hallberg 2007, Everaert and Bauwens 2007). Very little has been done that could predict the influence of urban expansion on wildlife and to develop management strategies aimed at reducing the possible causes.

Human disturbance may be considered as an environmental filter (Tonn et al. 1990) which may cause species to disperse in fragments according to levels of disturbance and species-specific tolerance to those disturbances. The tolerance levels of each species will vary and this will be reflected by disappearance of species, changes in species composition and Homogenisation of habitats (Marzluff 2001). Urbanization considerably affects the distribution patterns of birds, it alters the heterogeneity of the landscape and consequently, the distribution, abundance, and resources upon which birds depend. Synanthropic birds, the natural symbionts of humans, respond to the intensity of urbanization in differing manners (Marzluff 2001). They exhibit tolerance up to a certain level of environmental transition.

The House Sparrow is residential and sedentary bird, the majority living out their lives within a range of 1–2 km (Summers-Smith 1963). In India the House Sparrow survives in all areas from humid warm coastal regions to Kashmir and beyond cold Ladakh up to 15,000 feet above sea level (Dandapat et al. 2010). The Sparrow's population decline is reported from India, although the records are anecdotal (Daniels 2008). Moreover we do not have past authentic records on the species to compare the current population variations. Similarly we lack a continuous long-term observation of its population as conducted by BTO and RSPB. However a few short term studies (Khera et al.2009, Daniels 2008, Rajashekar and Venkatesha 2008, Dhanya and Azeez 2010, Dandapat et al. 2010) provides brief information which showed the population status and habitat utilisation of House Sparrow in India.

Table 3.1 A brief on House Sparrow population trends in cities

Decrease		
1	Biristol	Bland (1998)
2	Dublin	Prowse (2002)
3	Edinburgh	Dott and Brown (2000)
4	Hamburg	Summers-Smith (2003)
5	London	Sanderson (1996)
6	Moscow	Kostantinov and Kakhanov (2005)
7	Norwich	Paston (2000)
8	Prague	Stastny et al. (2005)
9	Rotterdam	Shaw et al (2008)
10	St Petersburg	Khrabryi (2005)
11	Glasgow	Summers-Smith (2003)
12	Edinburgh	Summers-Smith (2003)

13	Ghent	Summers-Smith (2003)
14	Lvov	Bokotey and Gorban 2005
15	Delhi	Khera et al. (2009)
16	Northern Ireland	Gibbons et al.(1993)
17	The Netherlands	Klok et al. (2006)
18	Valladolid	Balmori and Hallberg (2007)
19	Dutch urban centres	Balmori and Hallberg (2007)
20	Warsaw	Luniak (2005)
Stable		
21	Brussels	**Everaert and Bauwens (2007)**
22	Manchester	Prowse (2002)
23	Paris	McCarthy (2006)
24	Berlin	Witt (2000, 2005)
Increase		
25	Scotland and Wales	Summers-Smith (2003)
26	Lisbon	Geraldes and Costa (2005)

3.2 Objective

Examine the status and habitat use of House Sparrows along an urbanisation gradient in the study area.

3.3 Methodology

3.3.1 Population monitoring

The study points were taken from urban, suburban and village areas based on developmental activities (Pennington and Blair 2007) and the distance from the urban centre (Mcdonnell and Pickett 1990). For monitoring the population point count method (Bibby et al. 1998) was followed. A point count consisted of an observer standing at a location for 5 minutes and recording all birds seen within a radial distance of 50 m. A minimum of 100 m distance was maintained between the observation points. The counts were made from 06.30 AM to 11.00 AM when the birds are most active. Survey was conducted in the morning except on days with heavy rain or strong wind.

There are problems in surveying suburban/urban environment as the multi storied buildings and high traffic areas restrict the visibility to count the birds (Vincent 2005). Hence the sampling area was standardised as 50 m points for the bird count. In each study points the number of Sparrows, habitat characteristics and coordinates of these positions were recorded using Global Positioning System (Garmin E.Trex). According to the presence or absence of House Sparrows the study point was grouped into used and unused points. The unused sites were selected at least 100 m away from the used points and were confirmed as unused later by regular monitoring.

Total 227 points were randomly selected along the urbanization gradient to study the population distribution of the bird. These points were surveyed from 2006 to 2008 (two sampling efforts per year). The gradient was selected from Anaikatty (village) to Ukkadam (urban) and the intensive study points were spread along the Thadagam road (27 km). The village stretch measured about 16 km, with four km suburban stretch and six km and urban stretch. There was a considerable decrease in geographical area from village to urban area. Therefore 35 study points were taken accordingly along the gradient based on the area availability and accessibility. Of the 35 points, 20 were from village, eight from suburb and seven from urban area.

In the urban area the study points were dispersed from Ukkadam to Venkitapuram, where as in suburban area it was from Edayarpalayam to KNG pudur. In village the sites were dispersed from Kanuvai to Alamaramedu. Considering the developments and being an important junction connecting the city to the other areas I considered Gandhipuram as the centre of the city. The intensive sites were surveyed once in two months to assess the population changes. At each point the population of the species were grouped under class I if it numbered 1-10 individuals and under class II if the population is more than 10 individuals (Zhang et al. 2008). In addition to this the population count, the following habitat variables were also recorded from each point.

3.3.2 Habitat variables

Habitat variables determining the bird abundance and distribution were examined at the landscape scale by analysing the general habitat composition of the used and unused points. The following habitat variables were recorded from both used and unused points (Table 3.2).

Table 3.2 Habitat variables collected from the study area

Variables	**Specifications**
Distance (m) and characteristics of drainage	Open or closed
Number of waste dumps	Waste bins, pile of wastes near house/shop etc.
Number of water sources	Water supply pipe, small stagnant water sources
Number of hotels	Street vendors were also counted
Number of provision stores	Super markets were not included as the spillage of grains was nil

Number of weedy patches	An area which is noted by the presence of more than three weeds as a cluster
Number of trees	Recorded all types of trees from the point
Roof garden	Number was recorded
General landscape usage type of the study point	*a)* Commercial *area - Shops/market place* *b)* Residential area- *Mainly with houses* *c)* Open area- *Open land without any constructions/buildings, may or may not have vegetation* *d)* Open area + houses- *Open area interrupted with houses* *e)* Houses + shops- *Residential area with some shops* *f)* Open area + shops- *Open area with some shops* *g)* Office places- *Which are having buildings mainly for office use/storehouse/industries or abandoned/dilapidated structures or water tank etc.*
Roof type	Tiled/thatched/concrete
Road type	Tarred/concrete/gravel
Building characteristics	*Number of* *a)* Shutter hood *(sealed hood /open one)* b) Roof extension c) Sophisticated *(comparatively newer buildings with well plastered and painted walls)* and not sophisticated *(older /abandoned / partially abandoned buildings with no redevelopment or an incomplete)* buildings *d)* Ventilation *(open and covered with a net)*
Number of pedestrians	Passed in five minutes (in both directions)
Number of vehicles	Passed in five minutes (in both directions)

3.4 Statistical analysis

- Pearson rank correlation was performed with urbanization, habitat, food, building characters and human disturbance variables and the population of the House Sparrows.

- The Stepwise Discriminant Function Analysis (SDFA) was used to analyse the difference of habitat variables between Sparrow used and unused points. To predict main factors influencing the habitat use, classes I and classes II points were analysed separately.
- To monitor the distribution of House Sparrow at different habitat, the average value of the nine habitat variables which might be related to the distribution of House Sparrows were noted from each intensive point (presence or absence values were not included in the analysis). Following Zhang et al. (2008) the average variable values at each point were plotted against the average population at the respective points. The average number of House Sparrows from all study sites for one landscape usage type was used as the House Sparrow number for each land use type.
- Mann-Whitney U test was used to compare the habitat variables of used and unused points of House Sparrow.

  To determine the important habitat variable for Sparrow used site Principal Component Analysis (PCA) was performed. The first few components (with eigen values above one) explain most of the variation in the data set.
- Chi-square analysis was done to determine the population distribution among the sites.
- ANOVA was done to examine the population changes in the sampling sites and among different years.
- All analyses were performed using the SPSS software version 16 (Norusis Inc. 2005).
- Significance levels were set at $p < 0.05$ for all analyses.
- Percentage data were arcsine-transformed to meet the assumptions of normality and the counts were log transformed.

3.5 Results

3.5.1 Population survey

Of the 227 points surveyed 120 points were used by the Sparrow. The Sparrow population showed significant difference among years ($F=3.199$, $df=5$, $p<0.05$). The birds were not evenly distributed in village, suburban and urban areas ($\chi^2=2.12$, $p<0.05$). Over three years, in village and urban areas the population was evenly distributed ($\chi^2=1.681$, $p>0.05$ and $\chi^2=1.273$, $p>0.05$), the population was unevenly distributed in suburbs ($\chi^2=10.768$, $p<0.05$).

3.5.2 Population in the intensive study area

The survey was conducted once in two months for the intensive sites from 2006 to 2008. During 2006 to 2008 the total individuals encountered was 4613; out of this 3237 were from village, 603 were from suburb and 773 were from urban area. In 2006 a total of 1610 individuals were observed followed by 1575 during 2007 and 1428 during 2008 from the sites respectively. During 2008 the population showed a decreasing tendency in urban and suburban area (Figure 3.2 and 3.3). During 2007 the population in the village showed a slight increasing tendency (Figure 3.1). Of the 20 points in the village, seven showed a decreasing tendency in population (Table 3.3).

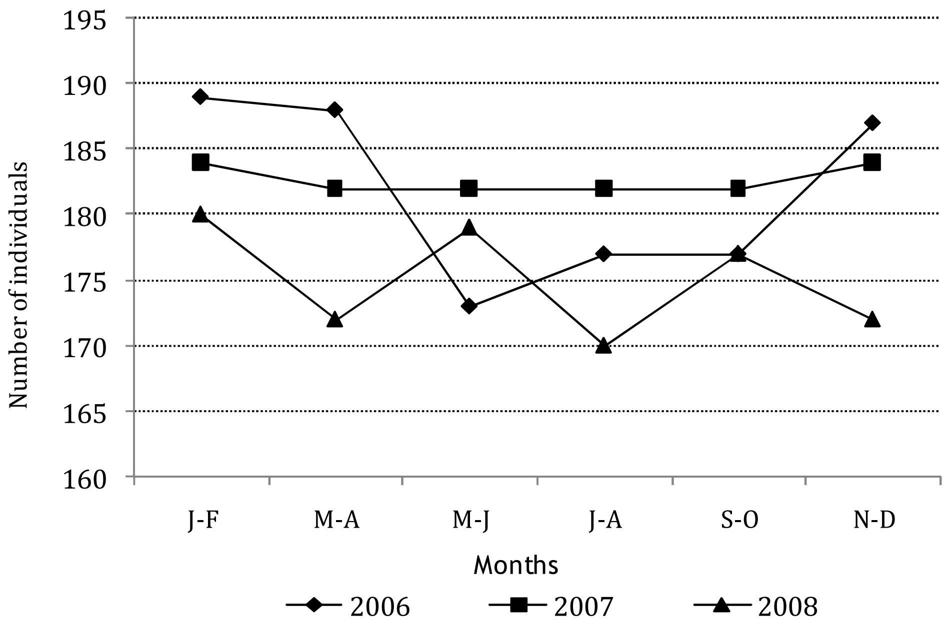

Figure 3.1 House Sparrow populations in village area (2006-2008)

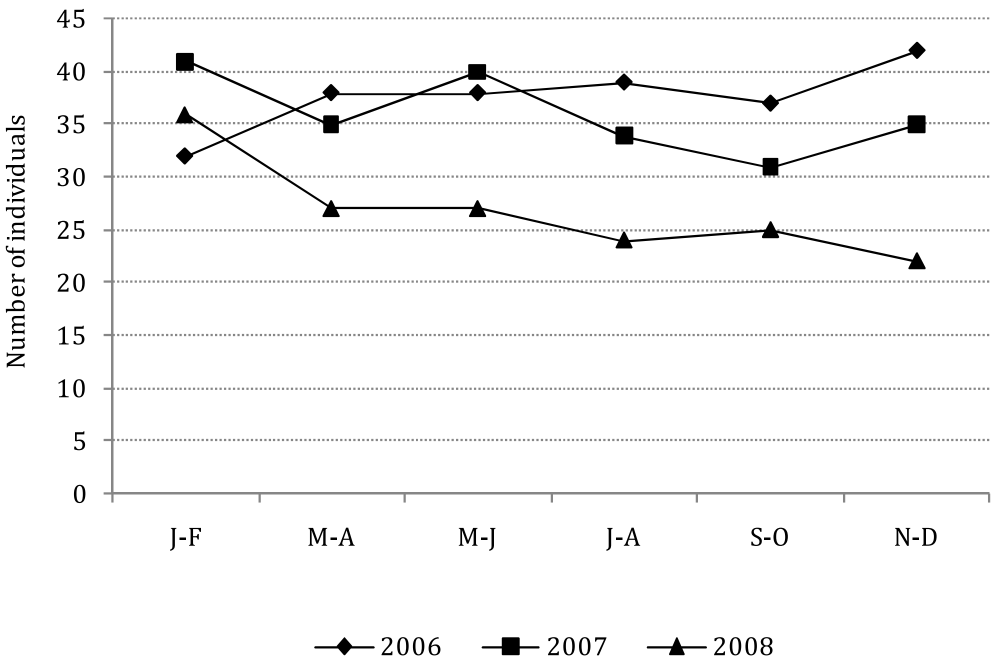

Figure 3.2 House Sparrow populations at suburban area (2006-2008)

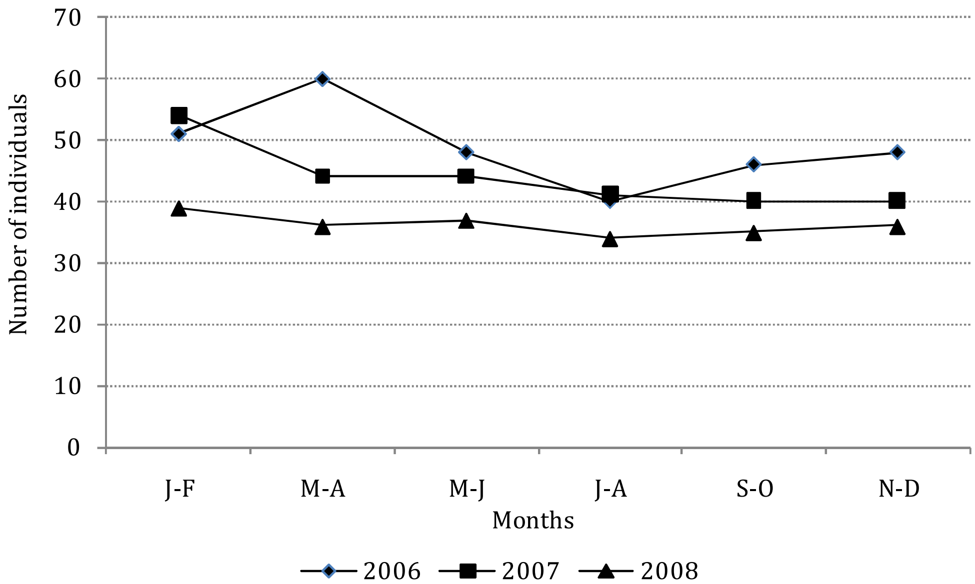

Figure 3.3 House Sparrow populations at urban area (2006-2008)

The total population of Sparrow was fluctuating among years (χ^2 =12.131, d*f*=2, p<0.05). Similarly it was not evenly distributed among villages, suburban and urban (χ =2. 826, d*f*=2, p<0.05). the population was not evenly distributed across the three years in urban (χ^2 =11.374, d*f*=2, p<0.05) and suburban (χ^2 =12.189, d*f*=2, p<0.05) area as well. The population was evenly distributed only in village (χ^2 =1.181, d*f*=2, p>0.05).

Table 3.3 Population of House Sparrow during 2006 to 2007 at the intensive study points (n=35)

Location	**Points**	**Population**			**Total population** (2006-2008)	**Percentage of birds**
		2006 (Mean±SE)	**2007 (Mean±SE)**	**2008 (Mean±SE)**		
Village	1	10.50±0.99	0.50±0.50	0	66	1.43
	2	02.83±0.87	09.83±1.01	13.17±0.90	155	3.36
	3	00.00±0.00	02.00±0.44	02.00±0.44	65	1.41
	4	00.00±0.00	01.83±0.40	03.33±0.42		
	5	00.00±0.00	0.50±0.34	01.17±0.54		
	6	13.83±0.60	15.00±0.81	14.17±0.30	1176	25.49
	7	10.83±0.54	11.67±0.76	11.83±0.60		
	8	10.67±0.49	11.50±0.42	11.33±0.49		
	9	19.17±0.87	15.67±0.91	13.67±0.42		
	10	06.50±0.42	07.50±0.88	08.50±0.84		
	11	03.67±0.33	05.00±0.25	05.50±0.50		
	12	19.17±2.12	20.50±0.92	13.67±1.11	544	11.79
	13	13.17±0.30	12.33±0.33	11.83±0.48		
	14	02.33±0.21	02.83±0.30	03.67±0.33	229	4.96
	15	11.67±0.42	10.17±0.30	07.50±0.42		
	16	07.83±0.30	09.17±0.60	09.00±0.73	1002	21.72
	17	05.00±0.37	04.17±0.74	06.67±0.33		
	18	10.83±0.30	10.00±0.44	09.33±0.49		
	19	33.67±0.49	32.33±0.33	28.67±0.33		
	20	00.17±0.17	00.17±0.17	00.00±0.00		
Suburb	21	02.00±0.26	04.50±0.42	04.00±0.45	219	4.74
	22	00.50±0.34	03.00±0.37	04.33±0.33		
	23	11.00±0.85	05.50±0.61	01.67±0.56		
	24	07.67±0.42	06.50±0.67	02.67±0.49	161	3.49
	25	01.83±0.48	03.50±0.42	02.67±0.33		
	26	01.50±0.61	01.83±0.30	02.50±0.42	35	0.75
	27	06.33±0.56	06.50±0.42	03.33±0.42	188	4.08
	28	06.83±0.48	04.67±0.42	03.67±0.56		
Urban	29	06.83±0.40	06.17±0.30	04.67±0.33	106	2.29
	30	05.50±0.42	05.17±0.30	03.67±0.42	159	3.45
	31	02.33±0.33	04.33±0.49	04.50±0.42		
	32	08.67±0.76	09.00±0.73	07.33±0.49	462	10.01
	33	21.17±1.37	15.67±1.14	15.17±0.54		
	34	01.00±0.63	00.00±0.00	00.00±0.00	46	0.13
	35	03.33±0.42	02.50±0.42	00.83±0.40	40	0.87

Table 3.4 Changes (in percentage) in the population in the intensive study points

	Population changes (%)		
	2006-2007	2007-2008	2006-2008
Sl No	**Village**		
1	-0.95	-1	1
2	3.06	0	-3.06
3	0	-0.4	0
4	0	0.38	0
5	0	1.33	0
6	0.25	-0.32	0.14
7	0.25	-0.26	0.08
8	0.27	-0.31	0.13
9	-0.05	-0.39	0.42
10	0.46	-0.32	0
11	0.64	-0.25	0.23
12	0.23	-0.55	0.44
13	0.09	-0.31	0.25
14	0.5	-0.14	-0.29
15	-0.01	-0.46	0.47
16	0.38	-0.32	0.06
17	0.03	0.1	-0.13
18	0.06	-0.32	0.28
19	0.1	-0.35	0.29
20	0	-1	1
	Suburb		
1	1.75	-0.45	-0.5
2	6.33	-0.55	-6.33
3	-0.45	-0.81	0.89
4	-0.04	-0.75	-1
5	1.27	-0.04	-1.18
6	0.56	-0.14	-0.33
7	0.16	-0.66	0.61
8	-0.17	-0.53	-1.18
	Urban		
1	0	-0.41	0.41
2	0.24	-0.56	0.45
3	1.21	-0.29	-0.57
4	0.21	-0.44	-1.18
5	-0.13	-0.33	-1
6	-1	0	-1
7	-0.25	-0.67	0.75

Compared to the village the population fluctuations were more visible in urban and suburban areas (Figure 3.1, 3.2 and 3.3). Most of the points showed a considerable population decrease (Table 3.4). The tendency for greater decline was notable in the urban area (Figure 3.4).

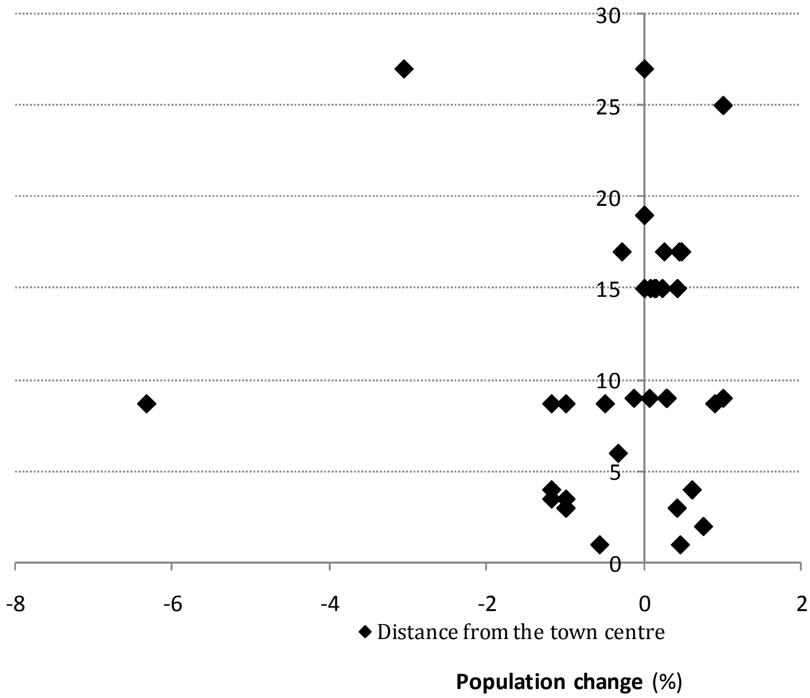

Figure 3.4 Population change of House Sparrow in relation with the distance of each study points from the town centre

3.5.3 Habitat utilisation

The Sparrows were largely distributed in the commercial area where shops were more, followed by residential area and open areas with some houses (Figure 3.5); while it was low in areas with open and office places.

The House Sparrow abundance was positively correlated with number of provision stores (r=0.840, p<0.001), weedy patches (r=0.729, p<0.001), number of hotels (r=0.229, p<0.001), waste dump (r=0.312, p<0.001) and negatively correlated with number of trees (r=-0.387, p>0.05) and vehicles (r=-0.018, p>0.05). It is also correlated with the building characteristics such as number of shutter hood (r=0.708, p<0.001), open ventilation (r=0.339, p<0.001), not sophisticated buildings (r=0.870, p<0.001) and negatively but not significantly correlated with covered ventilation (r=-0.039, p>0.05).

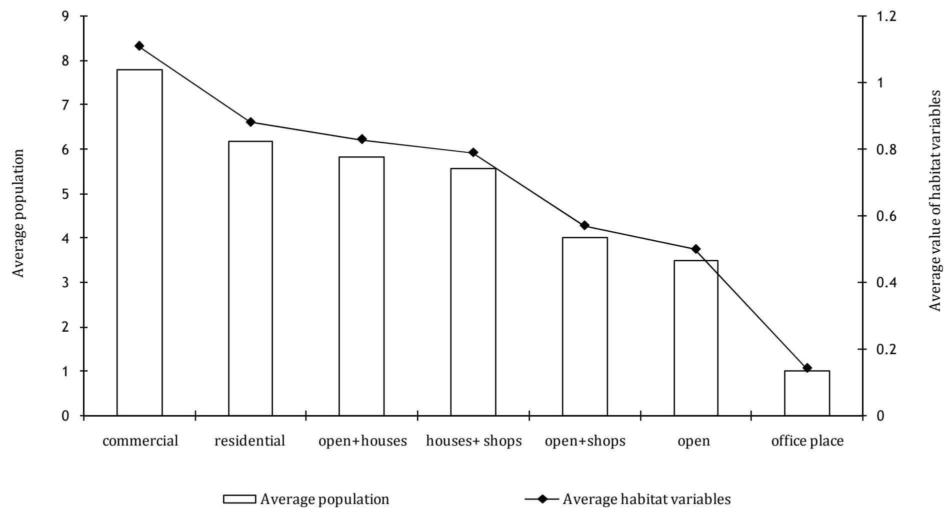

Figure 3.5 Distribution of the House Sparrow at different landscape usage type

While comparing the habitat characteristics of Sparrows in used (n=108) and unused (n=108) points, showed that number of large trees were low in used points (Table 3.5). Number of waste dumps, water sources, shutter hood, hotels, provision stores and weedy patches were also high in used points. In class II the number of weedy patches and the shutter hood was higher than class I.

Eleven habitat variables of Sparrow used points were compared with that of unused points. Significant differences were recorded corresponding to the number of trees in the points (Mann-Whitney U = 4778, $p < 0.001$) and the number of water sources (Mann-Whitney U = 2244, $p < 0.001$). The other significant factors related to food source were number of waste dumps (Mann-Whitney U = 2209, $p < 0.001$), number of hotels (Mann-Whitney U = 3398, $p < 0.001$), number of provision stores (Mann-Whitney U = 3061, $p < 0.001$) and number of weedy patches (Mann-Whitney U = 2742, $p < 0.001$). The road type (Mann-Whitney U = 4364, $p < 0.001$) and the landscape type (Mann-Whitney U = 4028, $p < 0.001$) were also found to be significant.

Table 3.5 Habitat characteristics in Sparrow-used and unused sites

Habitat variables	**Unused points** Mean ± SE	**Used points (Class I)** Mean ± SE	**Used points (Class II)** Mean ± SE	***U***	*P*
Number of Trees	11.10±0.65	8.49±0.56	7.44±0.75	4778	0.001
Number of water sources	0.45±0.07	1.70±0.12	1.56±0.21	2244	0.000
Number of waste dumps	1.71±0.11	3.64±0.20	3.61±0.32	2209	0.000
Number of shutter hood	4.13±0.53	5.41±0.50	6.61±2.17	5206	0.017
Number of Hotels	1.20±0.14	2.63±0.17	2.89±0.59	3398	0.000
Number of provision stores	0.86±0.12	2.25±0.17	2.78±0.59	3061	0.000
Road type	1.07±0.02	1.49±0.07	1.78±0.20	4364	0.000
Landscape type	2.99±0.27	4.43±0.30	4.28±0.69	4028	0.000
Number of pedestrians	11.23±0.67	14.13±0.93	13.50±1.99	5209	0.018
Number of vehicles	12.06±0.86	12.12±1.03	11.39±1.54	5940	NS
Number of weedy patches	4.98±0.283	10.17±0.62	15.33±1.80	2742	0.000

NS = Not significant

Of the 15 variables entered, SDFA retained 11 variables to segregate used and unused sites (Table 3.6). When 11 habitat variables are entered the Wilks'λ dropped to 0.357 with a significant difference between used and unused sites (Wilks'λ=*0. 357*, χ^2= *226.28, df=11, p<0.001*). The SDFA between class I and class II retained, number of weedy patches (Wilks'λ=*0. 921*, χ^2= *9.28, df=1, p <0.05*).

Table 3.6 Summary of *stepwise* discriminant function analysis

Step	**Number of Variables**	***F*-Statistic**	**Wilks'λ**	**Sig.**
1	Number of water source	82.822	0.731	0.000
2	Number of weedy patches	72.567	0.607	0.000
3	Number of waste dump	66.384	0.528	0.000
4	Type of road	59.722	0.482	0.000
5	Number of pedestrians	53.789	0.451	0.000
6	Roof type	51.557	0.416	0.000
7	Characteristics of drainage (open/closed)	47.910	0.395	0.000
8	Number of trees	44.949	0.377	0.000
9	Distance from drainage	41.012	0.370	0.000
10	Number of provision stores	37.881	0.363	0.000
11	Number of roof garden	35.251	0.357	0.000

PCA derived five components that account for the Sparrow used site. The first three principal components accounted for 50.7 percent of the total variance (Table 3.7). The first components explained a variation of 23.5 percent followed by second and third component by 17 and 10.2 percent respectively. The first component was positively loaded with number of provision stores, hotels, water sources and shutter hood. The second component was positively loaded with number of pedestrians and vehicles. The third component was positively loaded with the distance and characteristics of drainage. The factors highly correlated with these three components were those that directly relates to the habitat selection of the Sparrow.

Table 3.7 Principle components analysis (Varimax Rotation) explaining habitat variables. The high correlations with their respective Principal components were given in bold.

Variables	**PC1**	**PC2**	**PC3**
Number of trees	-.527	-.012	-.483
Number of roof garden	.034	-.011	.234
Distance from the drainage	.153	-.072	**.904**
Characteristics of drainage	-.049	-.045	**.877**
Number of water sources	**.634**	-.460	.190
Number of waste dumps	.506	-.027	.334
Number of shutter hood	**.587**	**.572**	.025
Number of hotel	**.754**	.345	.030
Number of provision stores	**.728**	.181	-.111
Road type	-.108	-.013	.055
Landscape type	-.153	.196	.069
Roof type	-.026	-.363	-.106
Number of pedestrians	.273	**.829**	-.018
Number of vehicles	.040	**.832**	-.141
Number of weedy patches	.044	-.501	-.338
Eigenvalue	*3.52*	*2.54*	*1.53*
Variance explained (%)	*23.48*	*16.97*	*10.22*
Cumulative variance (%)	*23.48*	*40.46*	*50.69*

3.6 Discussion

3.6.1 Population

A significant difference in population among years (2006 to 2008) was reported in the current study. In the intensive study area points total bird sightings was higher in village followed by urban and suburb area. In 2008, both urban and suburban populations showed a decreasing tendency. The decline of urban Sparrows has been reported from several studies such as Vincent (2005), Peach et al. (2008), Anderson (2006), Hole et al. (2002), Summers-Smith (1988 and 2003), Laet and Summers- Smith (2007), Crick (2002), and Shaw et al. (2008). One of the main reasons apparently is the destruction of the species's habitat with the built environment (Bokotey and Gorban 2005,). In the suburban area population fluctuation was high as the developmental pressure is more compared to village and urban area (Stief 2008). Already, the urban area compacted with the built-up structures. In the case of suburban and village still offer enough space for urban sprawl. Hence the developmental pressure will be higher in the immediate surroundings of the urban premise i.e., in suburban area. In another study by Siriwardena et al. (2002), suburban areas experienced a minor decline than those in village and urban area. According to Vincent (2005) the relatively low numbers of House Sparrows close to the urban centre reflects the low density populations after a substantial decline. A study by Raven and Noble (2006) showed that the population declines are happening severely in the urbanised areas of England. Likewise, a study conducted in the UK under the Nest Record Scheme showed that nest failure rates in House Sparrows were higher in urban/suburban than rural habitats (Crick 2002) and this may be an important reason for the population decline in the urbanized area. According to Peach et al. (2008) the suburban and urban population decline in England is due to inadequate reproductive success. However studies of Witt (1996) showed that the Berlin city has not experienced a decline in the House Sparrow population and Heij (1985) found a positive correlation between house sparrow density and human population density across an urban–rural gradient.

3.6.2 Habitat utilisation

In the current study the abundance of Sparrows were highest in areas with more shops. The studies of Vincent (2005), Khera et al. (2009) and Daniels (2008) showed a higher density of the species in the market place. This too may be because of the plenty of food availability from the shops (restaurants and provision stores; Shaw et al. 2008). In the market area the abundance of the shutter hoods will provide more nesting sites (Khera et al. 2009, Daniels 2008). In the case of residential and open areas with some houses, the food availability and nesting sites play an important role. The type of herbs and shrubs present in our vicinity is essential for success of reproduction of the House Sparrow as it feeds mostly on grains, buds, leaves, nectar, weed seeds, insects and cooked food (Crick et al. 2002). Open area with small bushes harbours insects and provide food (Vincent 2005, Shaw et al. 2008) and roosting place. According to Wilkinson 2006, Chamberlain et al. 2007b, Dan et al. 2007, House Sparrows significantly associated with and within bushes and gardens in residential habitat.

Similarly the number of House Sparrows were positively correlated with number of provision stores, weedy patches, number of hotels, waste dump and showed a negative correlation with number of trees and vehicles. According to Chamberlain et al. 2007a the vegetation characteristics like herbs and weedy patches are linked to increased bird diversity in urban areas. It is also noted that the abundance of House Sparrows are considerably higher in the place where bushes and gardens are present (Wilkinson 2006), as it form an important habitat for them. When the characteristics of used and unused points were compared the number of large trees was low in used points. This may be to avoid the competition for nesting from the other species such as Common Myna. They used to nest both in naturally existing holes in trees and also in buildings (Dhami 2009). Crow and Common Myna generally use tall trees with high canopy density for roosting and nesting (Peh and Sodhi 2002). Thus avoiding big trees may be a measure to avoid competition for feeding, breeding and roosting habitat. Similarly the disturbance due to heavy traffic may be a reason to avoid some places (Summers-Smith 2003, Bergtold 1921). Number of waste dumps, water sources, shutter hood, hotels, provision stores and weedy patches were more in used points. The waste dumps, water sources, hotels, provision stores and weedy patches will provide variety of food sources for the species (Peach et al. 2008, Khera et al. 2009, Daniels 2008, Summers-Smith 1988, Chamberlain et al. 2007a). The spill over of grains from provision stores can be a food source for the Sparrow (Chamberlain 2007a and Vincent 2005). But the changes of such conventional stores into sophisticated super markets had considerably reduced spillage as they used to sell provisions in well packed polythene cover (Khera et al. 2009 and Daniels 2008). Likewise weedy patches may provide the food sources such as insects, seeds and tender vegetative parts. It the current study the building characteristics such as number of shutter hood, open ventilation, not sophisticated buildings, roof extension. All these building characteristics could provide potential nesting sites for the Sparrow. However, House Sparrow populations may decline even if there are enough nesting opportunities (Vincent 2005).

According to Robinson et al. (2005) and Wooton et al. (2002) socially deprived areas may provide more waste ground and gardens that have less management may provide greater food availability. Shops with shutter hoods and less building maintenance (Wooton et al.

2002) offer greater nest sites availability and nest success. According to Summers-Smith (2003), Vincent (2005) availability of nesting sites and insect food resources (Peach et al. 2008) are vital factors for Sparrow survival. In the current study PCA positively loaded factors associated with food sources and nesting sites i.e., provision stores, hotel, water sources and shutter hood, which can considerably influence the sparrow survival.

Summary

- The Sparrow population showed significant difference among years ($F=3.199$, $df=5$, $p<0.05$).
- The birds were uneven in distribution in village, suburban and urban areas ($\chi^2 = 2.12$, $p<0.05$).
- In the intensive study points total bird sightings were higher in the village (3237) followed by urban area (773) and suburb (603).
- The highest number of individuals was observed during 2006 with 1610 and the least from 2008 with 1428.
- In 2008, both urban and suburban populations showed a decreasing tendency.
- Compared to village the population fluctuation was higher in urban and suburban area.
- The Sparrow distribution of different landscape usage type was high in the area where the shops were more, followed by residential area and open areas with sparse houses.
- Sparrow distribution was examined in view of habitat variables. Pearson rank correlation was performed with the sparrow population and habitat variables. The population was positively correlated with number of provision stores ($r=0.840$, $p<0.001$), weedy patches ($r=0.729$, $p<0.001$), number of hotels ($r=0.229$, $p<0.001$), shutter hood ($r=0.708$, $p<0.001$), waste dump ($r=0.312$, $p<0.001$) and negatively correlated with number of trees ($r=-0.387$, $p>0.05$) and vehicles ($r=-0.018$, $p>0.05$).
- Also the building characteristics were studied in view of sparrow distribution. It is also correlated with the building characteristics such as number of shutter hood ($r=0.708$, $p<0.001$), open ventilation ($r=0.339$, $p<0.001$), not sophisticated buildings ($r=0.870$, $p<0.001$), roof extension ($r=0.185$, $p<0.05$) and negatively correlated with covered ventilation ($r=-0.039$, $p>0.05$).
- Similarly, in the points which were used by the Sparrow the number of waste dumps, water sources, shutter hood, hotels, provision stores and weedy patches were high.

- Stepwise Discriminant Function Analysis (SDFA), used to analyse the difference in habitat variables (n=15) between Sparrow used and unused points; retained 11 habitat variables (Wilks'$\lambda=0.357$, $\chi^2=226.28$, $df=11$, $p<0.001$).
- Similarly, DFA is performed between as class I (≤10 individuals) and as class II (≥11 individuals), retained a number of weed patches (Wilks'$\lambda=0.921$, $\chi^2=9.28$, $df=1$, $p<0.05$).
- Multivariate statistical technique such as the Principal Component Analysis (PCA) PCA showed high positive loadings for the number of provision stores, hotel, water sources and shutter hood.

Chapter IV
Breeding performance and productivity of House Sparrow along an urban to rural gradient

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Chapter IV

Breeding performance and productivity of House Sparrow along an urban to rural gradient

4.1 Introduction

Monitoring the causes and consequences of reproductive strategies is a major area of avian life history studies (Martin 1987). Estimation of reproductive success is basic to study the cause of animal population declines. According to Martin (1995) the reproductive success of birds depends on different environmental factors, predation and food availability. The breeding season is fixed for most species. To reproduce successfully, birds should breed when the environmental conditions are most favourable (Earle 1981). The variable factors determining favourable environmental conditions will play a major role in breeding success (Sankaran 1991). Urban development produces some of the greatest local extinction rates (Marzluff 2001). It largely contributes to the landscape fragmentation. This may have significant effect on breeding birds as there will be more risk of predation and other stresses. It is often assumed that there is a direct relationship between species distribution or abundance and the associated habitat characteristics. Although this correlative relationship between observed patterns may be misleading (Wiens 1989). Rotenberry (1981) concludes that quantitative measurement of the habitat is essential to comprehend "patterns of life history, adaptation, and evolution of any species".

Owing to the long lasting nature of the nests structures, small birds used to reuse their nests (Barclay 1988, Gauthier and Thomas 1993). The passerine birds which build open-cup nests may reuse old nests during the same season as well as in consecutive breeding seasons (Cavitt et al. 1999 and Friesen et al. 1999). The structuring of bird species assemblages has been explained by competition for food (Martin 1995, Wiens 1989), by the partitioning of nest sites among co-occurring species in response to density-dependent nest predation (Reitsma and Whelan 1999), or by abiotic influences on the differing physiological tolerances of coexisting species (Wiens 1989, Martin 2007). These ideas remain both influential and attractive in understanding the factors that may have led to the observed patterns of resource partitioning among co-existing species. Thus nest sites are a resource that has important fitness consequences for birds (Martin 1987).

The food availability has been considered the primary factor for timing of breeding activities in birds (Perrins 1965, Harrison et al. 2010), because it can significantly influence the parental fitness which will directly affect reproductive success (Clutton-Brock 1991). Also if the food is a limiting factor during breeding season then it may affect nest attentiveness which will determine the quantity and quality of reared young ones (Cody 1966). Likewise climate is accorded a role in nesting success but usually only indirectly as a determinant of food abundance. Weather condition also can have a major effect on reproductive output at a site (Mitchell et al. 1973, Balakrishnan 2007). Birds thus could be expected to construct nests to reduce the detrimental influence of weather (Collias and Collias 1964, Austin 1974, Inouye 1976, Schaeffer 1976, Mertens 1977).

4.1.1 Scenario of House Sparrow

The estimation of natality is fundamental to understand the population dynamics of a species such as House Sparrow. Sparrows are a species that are generally regarded as monogamous although extra pair paternity seen in the species can vary from population to population (Summers- Smith 1988). Also they are considered as discrete breeder and tend to breed in small colonies and are better described as clumped rather than a colonial breeder (Summers-Smith 1988). The male declares his ownership by regular ‘chirrup’ calling beside the nest sites (Summers-Smith 1988). Nest building is most intense between January and May with a wide variety of nest sites being used, ranging from holes and crevices in manmade structures, nest-boxes and even on the top of electricity poles (Summers-Smith 1988). House Sparrows use a broad range of materials for nest building including feathers, grass inflorescences, stalks and roots of plants, bark, threads, string and even pieces of paper and wool (Indykiewicz 1990).

The present study investigates the breeding performance and the factors affecting it.

4.2 Objectives

- Study breeding performance of the House Sparrow along an urban to rural gradient
- Assess the factors determining the breeding

4.3 Methods

4.3.1 Nest searching and monitoring

Nests were located by following adult birds seen carrying the nesting material or food, and by searching suitable location as described by Martin and Geupel (1993). The nests were also located by intensive search in built up areas and also using the behavioural cues of parental birds such as vocalization and the bird activity (birds flew off from nests carrying nest materials or food to the nestlings) as described by Martin and Geupel (1993), , Reale and Blair (2005), and Peach (2008) in the study sites. Almost all nests were discovered during the time of building, egg laying and early incubation. Located nests were marked and monitored thereafter at 4-6 day intervals as many days as possible to determine nest fate (Martin and Geupel 1993). Care was taken to avoid trampling or disturbance at nest sites. A mirror attached at the tip of a graduated pole was used to view contents of otherwise inaccessible nests. The graduated pole allowed easy measurement of nest heights.

A total of 35 intensive study points along the gradient were monitored by taking 50 m point counts as mentioned earlier. After field experiments five minutes observation was considered as standard for counting the Sparrows at each study points (Bibby et al 1998). A minimum of 100 m distance was maintained between the points.

The breeding biology of House Sparrows was monitored in naturally existing nest sites in the built environment from 2006 to 2008. The accessibility to monitor naturally existing nest sites (holes, roof space and shutter hood) was restricted in most of the places. Hence, close observation of the nest materials, eggs, nestling during incubation and food provisioning of the parents was restricted only to the exposed nests in the buildings. At one field station nest boxes were installed as a part of SACON's Sparrow monitoring programme (Table 4.1). These were boxes made of bamboo box (n=9), wooden box (n=11), and mud pots (n=12). Observations made on incubation and provision of food for nestlings in artificial nests were used for analysis since the easily observable natural nests were less in subsequent years. In almost all the nests attempt was made to monitor the factors on nest construction, nest materials, incubation, eggs laid and hatched as well as any events of predation or egg or hatchling loss, nestling diet. Care was taken to avoid disturbance to the nest sites. All observations were carried out with binoculars (Pentax 8'X40").

Table 4.1 Details of artificial nest sites installed at SACON campus

Site	Bamboo box	Wooden box	Mud pots
Office	1	4	3
Library	2	3	2
Laboratory	3	2	3
Hostel	2	1	2
Canteen	1	1	2
Total	**9**	**11**	**12**

4.3.2 Breeding Seasonality

The breeding seasonality was determined based on the total number of nests constructed during each month from 2006 to 2008. The relationship between numbers of nests with rainfall, rainy days and with temperature (max-min) were also examined.

4.3.3 Nest substrate and material

Nest substrate was defined as the substrate on which the nest was built. Total eight types of nest substrata were found. They were seen on roof support (space between the roof and supporting pole), shutter hood, holes in the building, ventilation, sign board, switch board, light cover and pipe holes in the buildings (found in the incomplete constructions made for electric wiring/water supply). Use of nest substratum was observed for three years. The placement of the Sparrow's nest at different buildings was also observed. The buildings were classified based on its functional use as shop, house and/ or others. Since the nest site fidelity and nest reuse was observed in many cases, no attempts were made to completely remove the nests for close examination and weighing the nest materials. Hence the nest materials were identified and calculated in percentage immediately after fledgling period. In total 30 nests were monitored to identify the nest materials. Of these, 15 nests were f rom village, eight from suburbs and seven from urban area. Incubation period was determined by watching the nests periodically at the interval of five days. The nest materials were classified as plant matter, animal matter, others and unidentified. The materials which were dried and converted to powder that could not be identified were classified as unidentified matter. Most of the plant materials used for nest could be identified up to species level using standard field guide pertinent to the study area and field keys (Henry et al. 1984). The division of labour among the pair during nest construction, male and female assistance and nest construction activities were monitored for 20 nests. The observation timings on each nest were scheduled in a way to observe the maximum nest building activity between 8:00 – 17:00 hrs.

4.3.4 Nest site selection

The method for determining nest-site selection was similar to that applied in a number of nest site selection studies. After the completion of nesting activity, nest site variables were measured at two spatial scales: at microhabitat level (i.e., nest site attributes such as plant and location of the nest with reference to the buildings) and mesohabitat level (attributes of habitat patch surrounding the nest). The nest site was defined as that area within one meter radius of the nest, whereas the nest patch was that area within a 50 m radius of the nest. Thirty five points mentioned above, were covered for the nest-site selection studies (Bibby et al. 1998, Pennington and Blair 2007). The following nest site variables were recorded:

Micro-habitat variables

The following micro-habitat variables were recorded from the study points;

- Height of the nest (m)

- The height of the building/structure on which nest is situated
- Nest substratum: roof support/shutter hood/holes in the building/ventilation/sign board/switch board/light cover/pipe holes
- Functional use of buildings: house/shop/others
- Roof type: tiled/thatched/sheet/concrete

Meso-habitat variables

The following meso-habitat variables were recorded from the study points:

- Number of ventilation
- Distance to the nearest nest (m)
- Total number of nests
- Number of houses, hotel and provision shops around the nests
- Distance to the nearest road (m) and type of the road (tarred/concrete/gravel)
- Distance to the light sources (an average distance of the four nearest artificial light sources)
- Distance to the water sources (m) - water supply pipe, small stagnant water sources
- Distance to the nearest food sources (an average distance of the four food sources such as hotel, provision shop, house, temple and waste dump)
- Distance (m) and characteristics of drainage (open or closed)
- Number of waste dumps
- Distance to the nearest vegetation(m)
- Traffic volume in the nearest street (number of vehicles passed in both the sides within five minutes)
- Landscape variables
    - Bushes – percent cover
    - Herbs - three 1x1m quadrat at each point

      Number of trees available in the 50m radius point

4.3.5 Nest site and random site

Nest site variables were recorded by considering nests at the centre of the 50 m radius plot and these were compared with similar measurements recorded for random sites. . All random sites were located at a minimum of 100m distance from the nest sites since the species largely confined its activities within a territory of 50m. Identical measurements were taken at both used nest site and random site. Fourteen parameters were considered for the analysis; 1) number of houses, 2) number of shops, 3) roof types (concrete, tile, sheet, thatch), 4) number of roof extension (hanging roofs from the buildings), 5) distance to other bird species nests, 6) bush cover (%), 7) number of trees, 8) number of waste dumps, 9) distance to water source (m) and 10) distance to drainage (m).

4.3.6 Nest site parameters for the successful and unsuccessful nests

Located nests were marked and monitored thereafter at regular intervals as many days as possible to determine nest fate. Nest fate was determined (Martin and Geupel 1993) either as successful (at least one young fledged) or as unsuccessful (no young fledged). Identical measurements were taken at both used nest site and random site.

4.3.7 Egg laying and breeding cycle

Direct observation at the nest was made to record nest building, clutch size, incubation, number of young ones and diet of the nestlings (Pettingill 1985**).** The nest accessibility was very difficult for naturally existing nests. Monitoring of the activity of nest building, division of labour and assistance during nest building were carried out as soon as the nest building started. For this 20 nests were selected along the urbanization gradient. To monitor the incubation activity ten well exposed nests were taken in such a way to cover single day's activity (08:00– 17:00 hrs).

4.3.7.1 Territorial behaviour

The territory maintenance and the nest 'reserving' behaviour were monitored by following focal animal sampling method Altman (1974).

4.3.7.2 Provisioning food for nestling

Foraging observations of the nestlings was started once they became 2-3 days after hatching and continued until they disperse from the nest. The number of feeding trips by each parent, sex of the parent, timing, type of food, and distance from the nest to the foraging location and other activities of parents around the nests were noted. Binoculars were used to observe closely the food given to the nestlings by the parents (Wendy and Mannan 2003).

The observations were made from an optimum distance so as to avoid disturbance. Parents generally avoided a direct entry to the nests while bringing the food for nestlings. Parents preferred stopover near to nest in order to scan the surrounding before entering the nest. This behaviour allowed the observer to identify the food materials that the parents carried to the nest. Out of the 22 nests monitored for examining the provision of food to the nestling, six nests were from urban, four from suburban and 12 from village. Feeding data were sampled during 06:30 to 17:00 hrs in order to cover a day's activity per nest.

4.3.7.3 Vegetation characteristics

The landscape and vegetation variables were noted from active nest points; located at village, suburban and urban areas. The variables noted were the number of natural fencing or hedges made of tree/shrub stumps which measured more than three meters and home gardens (3x3 m minimum). The artificial lawns and maintained gardens were not taken into account. The tree count was taken in the 50m radius point and three 1x1 m quadrat was laid to measure herbs.

4.3.8 Reproductive success

The nesting success was studied by intensive monitoring of eggs in the nest. The nest survival rates was calculated as the number of successful nests divided by the total number of nests found (Jehlel et al. 2004). Annual reproductive success was calculated from the total number of eggs laid and the number of fledgling (Murray 2000). Nests failed because of predation, abandonment and damaged were counted as unsuccessful (Bibby et al. 1993). The nest that fledged at least one young was considered successful and that which lost all eggs at one attempt were considered as preyed upon. Observations of fledgling in or near the nest were taken as evidence of a successful nesting.

4.4 Statistical analysis

Following statistical analyse were performed.

- The Mann-Whitney U test was used to compare nest-site characters with random site and also for comparison between successful and unsuccessful nests.

- Principal Component Analysis (PCA) was used to identify the patterns of covariation among the nest-site parameters. This multivariate statistical technique reduces the dimensionality by deriving a few uncorrelated components from a set of variables. The first few components (with Eigen values above one) explain most of the variation in the data set.

- Stepwise Discriminant Function Analysis (SDFA) was done to find out important factors which discriminate the nest site from the random site. In the SDFA variables enter in a forward manner; using F = 3.84 for entering, and F = 2.71 for removal. Statistical differences were considered significant where *p*-value = 0.05

- Pearson correlation was done to relate the nest abundance in different months with environmental factors such as Minimum temperature and Maximum temperature, rainfall and rainy days.

- The reproductive success was calculated by the index,

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

4.5 Results

In total, 335 nests were found during January 2006 to December 2008. More nests were found in Village (n=259) followed by suburb (n=44) and urban (n=32) area.

4.5.1 Breeding season

Breeding continued throughout the year (Figure 4.1) with a peak in April (n=114) followed by January (n=87). The fewer number of nests was found in December and October. The number of nests showed significant positive correlation with maximum temperature (r=0.455, p<0.05 ; Figure 4.2) and negatively but not significantly correlated with minimum temperature (r=-0.021, p>0.05), rainfall (r=-0.298, p>0.05) and rainy days (r=-0.299, p>0.05).

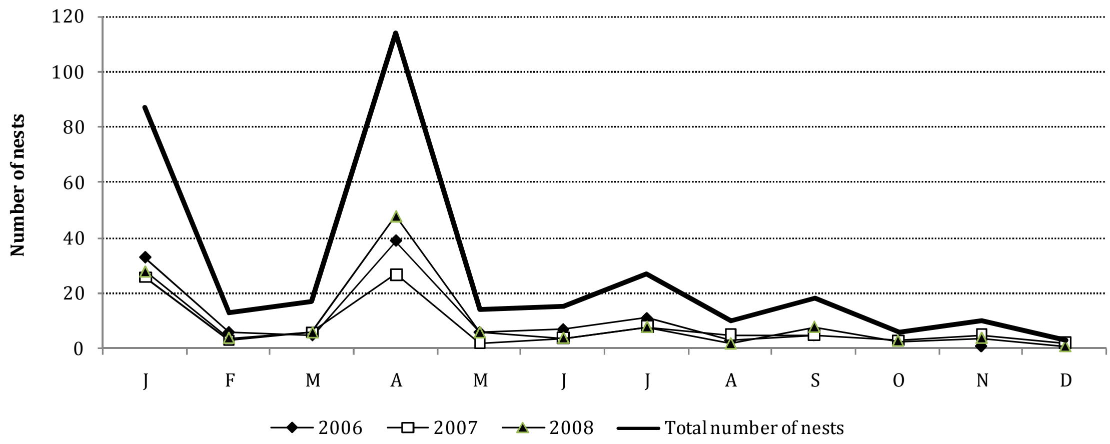

Figure 4.1. Breeding seasonality of House Sparrow during 2006 to 2008

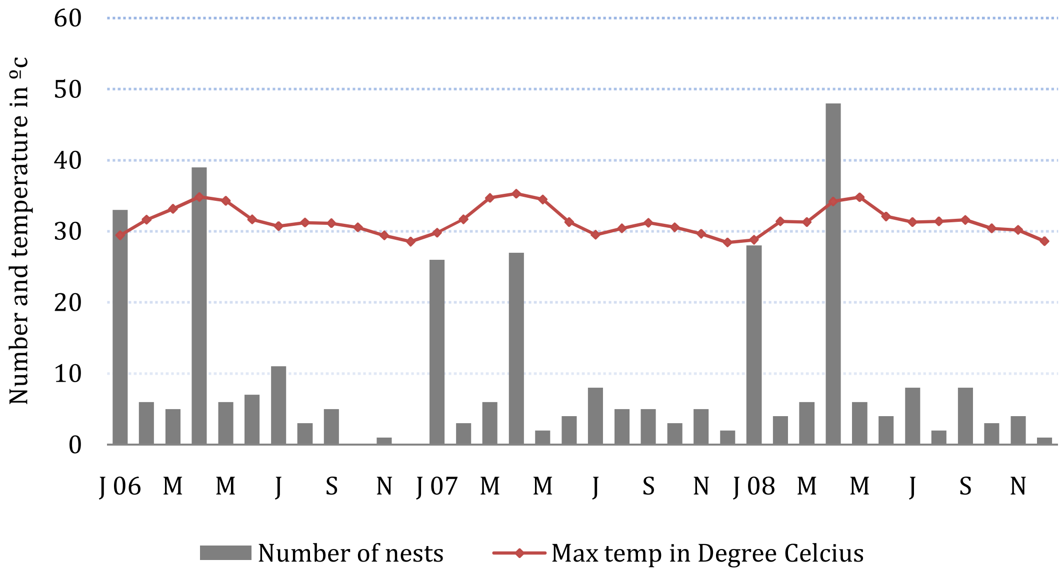

Figure 4.2. Number of House Sparrow nests and the maximum temperature

4.5.2 Nest and nest site selection

4.5.2.1 Nest material and architecture

Thirty nests were monitored and analysed to identify the nesting materials. Of these, 15 nests were from village, eight from suburban and seven from urban area. The nests were cup shaped and loosely built. The nests had two distinct layers, namely, structural layer and inner lining. In the majority of the nests examined, the structural materials appeared as a uniformly constituted single layer. The structural layer formed the base of the nest and was constituted predominantly of plant matter. A distinct layer inside the structural layer having no significant structural role was qualified as lining. The lining was the thinnest layer which was in direct contact with the eggs and the nestling. This is made of fine and soft materials such as paper pieces, cotton and jute (Table 4.2) which probably protected the nestlings and eggs by giving a cushion effect.

Plant materials from eleven species were identified from the structural layer of the nests. The whole or parts of the flower, leaf, stem or the dried herbs itself formed the building material of the structural layer. Similarly the lining material is composed of one plant matter, two animal matters, six others and unidentified plant parts (Table 4.2).

Table 4.2. Nest layer constituents of the House Sparrow nest.

Species/materials	Parts used	Nest layers
Plant matter		
Aerva lanata	Flowers/stem	Structural
Azadirachta indica	Leaf/flowers	Structural/lining
Boehmaria sp.	stem/whole plant	Structural
Cynodon dactylon	Whole plant	Structural
Cyperus sp.	Leaves/whole plant	Structural
Dactyloctenium aegyptium	stem/whole plant	Structural
Eleusine indica	Leaves/whole plant	Structural
Grass sp.	Leaves/inflorescence/whole plant	Structural/lining
Moringa oleifera	Leaves	Structural
Parthenium hysterophorus	Stem and flowers	Structural
Musa paradisiaca	Thread/leaf	Structural
Others		
Paper	Small piece	Lining
Plastic	Small piece/jute rope	Structural/lining
Thread	Small piece	Lining
Coir	Rope/fine	Lining
Cotton	rope/fine	Lining
Jute	Fine/fine	Lining
Animal matter		
Chicken feather	Fine feathers	Lining
Hair	Hair	Lining
Unidentified	Parts of leaf, flower, stem etc	Lining

The nest material was classified into four categories as plant matter, animal matter, others and unidentified (Table 4.2; Figure 4.3, 4.4 and 4.5). In total, the sparrow used whole/parts of four grass species, four herb species, one shrub and two tree species excluding unidentified matter. Nests constructed in village are comprised of about 90 percent plant matter followed by 10 percent materials of other category (Figure 4.3). In suburban areas the nests contained 86 percent of plant matter, 13 percent other materials and one percent animal matter (Figure 4.4). In the urban area the plant matter was 77 percent, 22 percent others and 10 percent animal matter (Figure 4.5). Herbs formed the majority of the plant matter used for nest building. Herb constitution in nest material was high in village (n=19) followed by suburb (n=10) and urban (n=9).

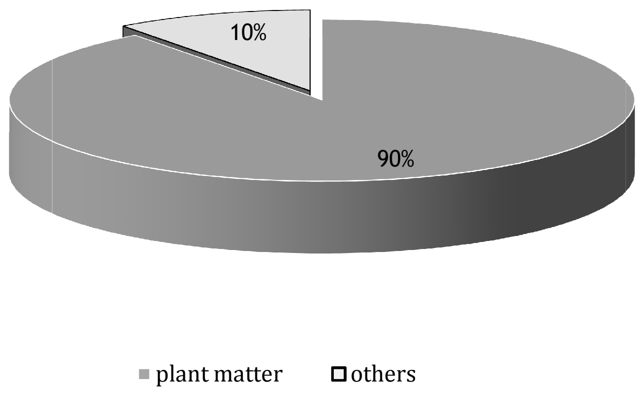

Figure 4.3 Nesting material (n =15) used in villages

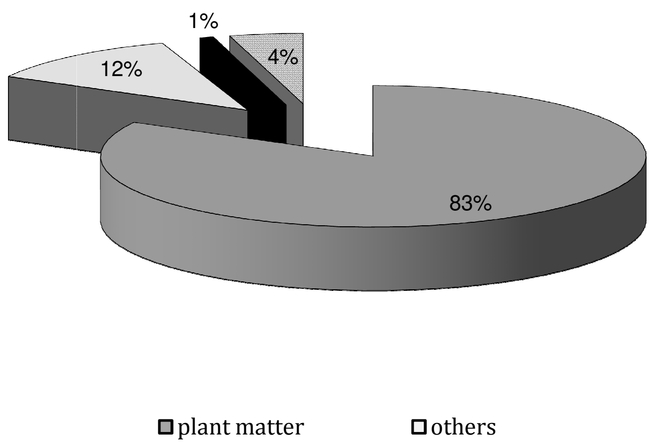

Figure 4.4 Nesting material (n = 8) used in suburban area

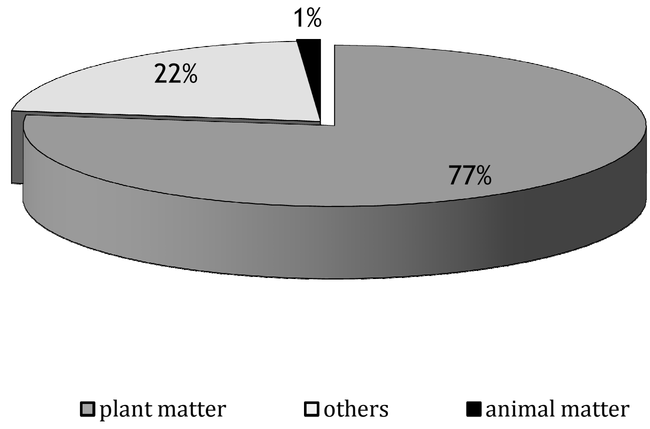

Figure 4.5 Nesting material (n =7) used in urban area

4.5.2.3 Nest substratum

A total of 335 nests were monitored during 2006-2008. Eight types of substratum were used for placing the nest. Shutter hood (n=135) was the commonly used substratum followed by roof support (n=104), sign board (n=32), holes in the built area (n=30), ventilation (n=24), light cover (n=6), switch board (n=3) and pipe hole (n=1; Figure 4.6). In village, shutter hood (n=105) was the most used substratum followed by roof support (n=80). Similarly in suburban, shutter hood was mostly used substratum (n=28) than in urban where it was roof support (n=19; Figure 4.7). During 2006 and 2007, the highly used substratum was shutter hood followed by roof support. In 2008, roof support was the mostly used substratum followed by shutter hood (Figure 4.8).

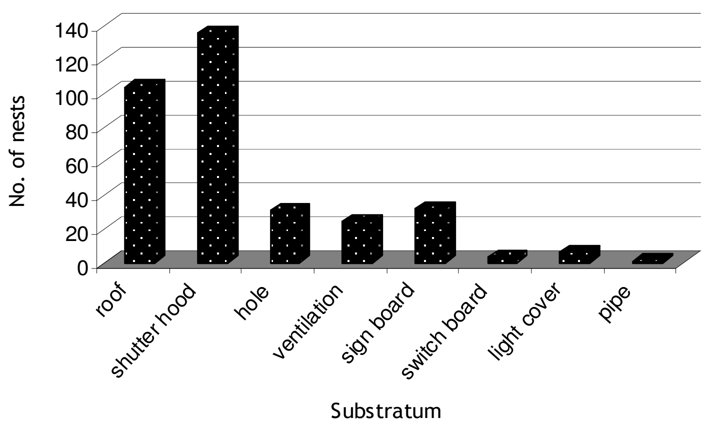

Figure 4.6. Substratum used by House Sparrow (during 2006-2008) for placing their nests

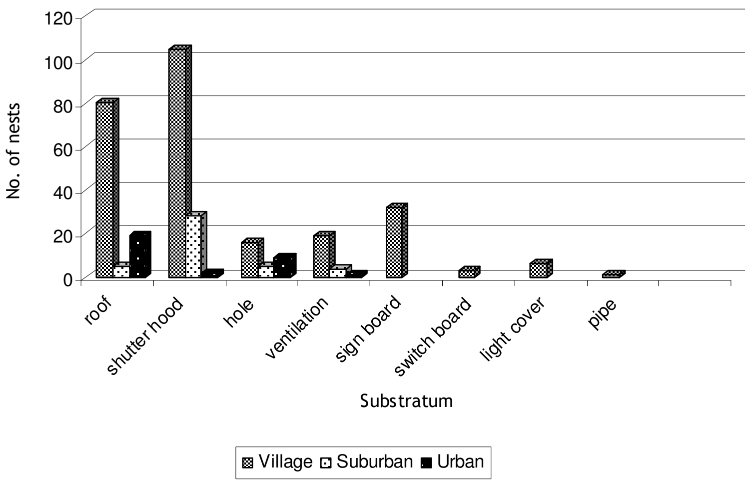

Figure 4.7 Use of nest substratum at village, suburban and urban (2006-2008) locations

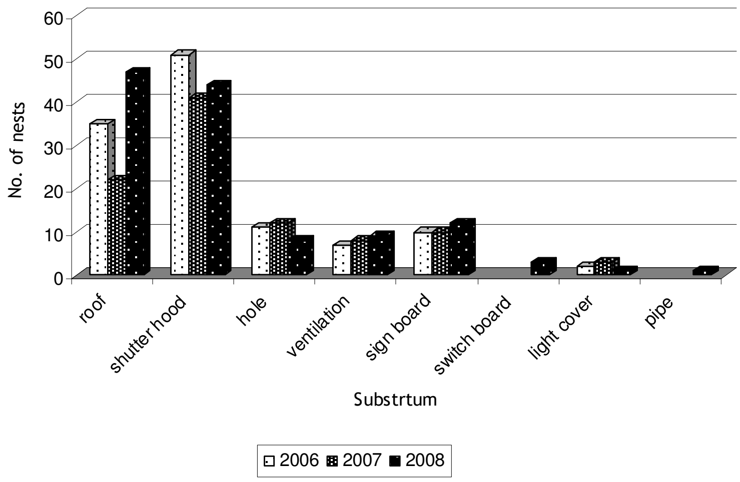

Figure 4.8 Classification of nest substratum used by House Sparrow (2006-2008)

4.5.2.4 Use of building for nest placement

The nest placement at different building types along an urbanization gradient was studied by observing 257 nests in village followed by 56 and 32 nests in suburban and urban area respectively (Table 3).

During 2006 in village, suburban and urban area the nest placement was high in shops and least in other category buildings. In village 49 nests were found in shops, 28 in houses and six in other category. Likewise, in suburban area, shops had 15 nests while houses had only two. The same trend was seen in urban area where shops had 13 nests while and houses had only three (Table 4.3). Thus, during 2006, shops were mostly used (n=77) for nest placement than house (n=33) and buildings of other category (n=6).

In the consecutive year too, shops were used more for nest placement (n=56) followed by other building category (n=21) and houses (n=19). Shops in village and suburban had 39 and 10 nests respectively. In Urban area, the other category buildings were not used. The houses in village category had 15 nests and suburban and urban area had two each (Table 4.3).

During 2008 too, shops were frequently used for nest placement. Similarly, houses in village had 41 nests and shops at suburb and urban had each three and two nests respectively. The other building category was the least used since the village and suburban had only four and three nests respectively (Table 4.3).

Table 4.3 Nest placement at different buildings along an urban to rural gradient from 2006-2008.

Area	**House**			**Shop**			**Others**		
	2006	2007	2008	2006	2007	2008	2006	2007	2008
Village	28	15	41	49	39	58	6	17	4
Suburban	2	2	3	15	10	5	0	16	3
Urban	3	2	2	13	7	5	0	0	0
Total	33	19	46	77	56	68	6	33	7

4.5.2.5. Vertical stratification of nests

Sparrows used mostly the height class 01-03 m (n=174) followed by 03-06 m (n=119) and 06-09 m (n=44) for nest building (Figure 4.9). The height classes largely used in village was 01-03 m (n=152) and 03-06 m (n=26) in suburbs. Likewise in urban area more nests was found in 03-06 m (n=22) and the least by 06-09 m (n=5), (Figure 4.10). During 2007 and 2008 the most used height class was 01-03 m and in 2006 it was 03-06 m.

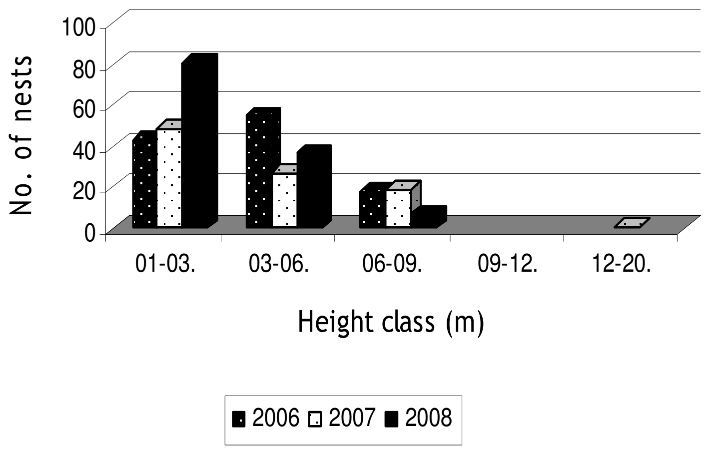

Figure 4.9. Vertical stratification of House Sparrow nests (2006-2008).

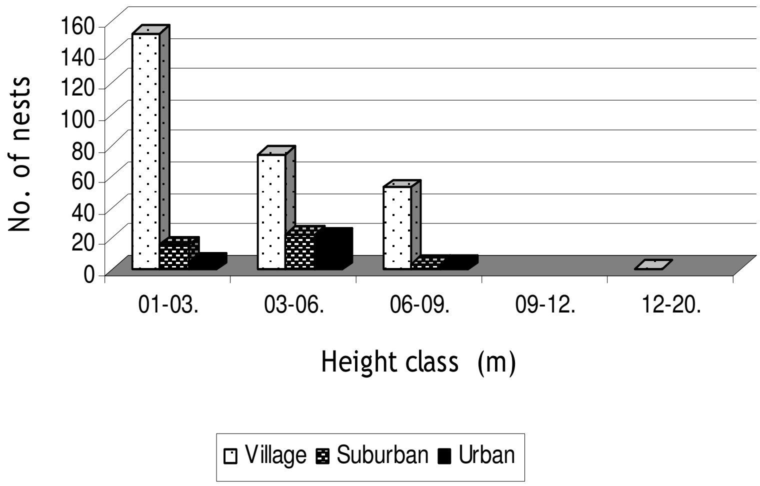

Figure 4.10 Vertical of House Sparrow nests along the urban gradient.

4.5.2.6 Nest site characters

The Principal Component Analysis of the factors influencing nest-site selection of 136 nest sites showed that three components accounted for 37.9 percent of the variance (Table 4.4). The PC I was positively loaded for the nest placement at different buildings categories, bush cover and distance from drainage, and negatively with number of vehicles. The PC II was positively loaded for the distance from water source, storey of building, and roof type and storey of the building were the variables most correlated with the PC III component.

Table 4.4. Principle Components Analysis (Varimax Rotation) performed on nest site characteristics. The high correlations with their respective Principal components were given in bold.

	Components		
Variables	**PC1**	**PC2**	**PC3**
Roof type	0.360	-0.228	**0.680**
Substratum	0.530	-0.079	0.296
Storey of building	-0.270	**0.517**	**0.411**
Road type	0.646	-0.214	0.069
Distance from drainage	**0.670**	**0.290**	-0.053
Distance from water source	0.243	**0.611**	-0.003
No. of vehicles	**-0.767**	0.095	0.122
Bush cover	**0.664**	-0.031	**0.510**
Nest placement at different buildings	**0.712**	0.253	0.090
Eigen value	*3.589*	*1.740*	*1.484*
Variance explained (%)	*19.941*	*9.666*	*8.244*
Cumulative variance (%)	*19.941*	*29.607*	*37.851*

Nest site variables were compared with that of successful and unsuccessful nests (Table 4.5). Significant difference in nest success was showed with respect to nest height (Mann-Whitney U = 7346 , $p < 0.05$) and number of nests (Mann-Whitney U = 7162, $p < 0.05$). The ventilation in the building where the nest is placed is found to be significant (Mann-Whitney U = 1043 , $p < 0.05$) and the number of vehicles passed was also significant (Mann-Whitney U = 4090, $p < 0.05$). The bush cover in the region and (Mann-Whitney U = 5099, $p < 0.001$) distance from other bird species nest (Mann-Whitney U = 3582, $p < 0.001$) and distance from road (Mann-Whitney U = 2254 , $p < 0.001$) were also found to be significant. The other significant factors were distance from artificial light source (Mann-Whitney U = 3057, $p < 0.001$), distance from drainage (Mann-Whitney U = 2. 2488, $p < 0.001$), number of waste dumps (Mann-Whitney U = 4272, $p < 0.001$), distance from water source (Mann-Whitney U = 4726, $p < 0.001$), and distance from food source (Mann-Whitney U = 2120, $p < 0.001$).

Table 4.5 Comparison of successful and unsuccessful nest parameters

Nest parameters	**Unsuccessful nest** (Mean ± SE)	**Successful nest** (Mean ± SE)	***U***	***P***
Number of nests	1.78 ±0.10	1.20 ± 0.05	7162	.000
Nest height (m)	4.27 ± 0.23	3.56 ± 0.19	7346	.003
Distance from other bird species nest (m)	1.91 ± 0.08	3.89 ± 0.25	3582	.000
Distance from road (m)	1.57 ± 0.09	3.46 ± 0.15	2254	.000
Distance from drainage (m)	4.63 ± 0.33	1.44 ± 0.08	2488	.000
Distance from water source (m)	2.79 ±0.17	1.62 ± 0.08	4726	.000
Distance from artificial light source (m)	1.52 ± 0.06	2.79 ± 0.09	3057	.000
Distance from food source (m)	2.57 ± 0.11	1.17 ± 0.05	2120	.000
No. of grocery shops	2.26 ± 0.10	2.35 ± 0.10	9124	*NS*
No. of hotels	1.88 ± 0.13	2 ± 0.16	9056	*NS*
No. of houses	14.79 ± 0.57	15.34 ± 0.65	8744	*NS*
No. of ventilation in the building where the nest is placed	2.06 ±0.11	7.21 ± 0.29	1043	.000
No. of waste dumps	1.45 ± 0.08	2.62 ± 0.09	4272	.000
No. of vehicles	9.87 ± 0.57	3.43 ± 0.20	4090	.000
Bush cover (%)	35.07 ± 0.67	28.26 ± 0.76	5099	.000

**NS = Not significant*

Stepwise Discriminate Function Analysis (Table 4.6) was done for the 25 nest-site variables of the successful (n=136) and unsuccessful (n=136) nests. The DFA predicted 16 variables (Wilks'λ *=0.123, χ^2=540.68, df=16, p<0.0001*). It retained variables associated with food and nesting habitats such as bush cover, number of hotels, number of waste dumps, number of houses, distance from water sources, number of ventilations, nest substratum, nest placement at different building. It also retained other significant variables like distance from artificial lights, number of other species nest and distance from the road.

Table 4.6. Summary of stepwise discriminant function analysis

Step	Number of Variables	*F*-Statistic	Wilks'*ë*	Sig.
1	Number of ventilation in the buildings	256.101	.509	.000
2	Number of vehicles	227.897	.368	.000
3	Distance from vegetation	217.777	.288	.000
4	Distance from food source	195.123	.252	.000
6	Bush cover (%)	170.419	.203	.000
7	Number of waste dumps	168.613	.181	.000
8	Distance from road	166.066	.163	.000
9	Nest substratum	162.003	.150	.000
10	Number of hotels	152.624	.144	.000
11	Distance from the nearest nest	142.809	.140	.000
12	Number of houses	139.174	.132	.000
13	Number of other species nests	131.208	.130	.000
14	Distance from water sources	124.261	.127	.000
15	Distance from artificial light source	117.731	.125	.000
16	Nest placement at different buildings	111.862	.123	.000

4.5.2.7 Nest site and random variables

Thirteen nest site variables of nesting sites were compared with that of non-nesting sites (Table 4.7). Significant differences were recorded corresponding to number of houses (Mann-Whitney $U = 132$, $p < 0.05$), number of shops ($U = 375$, $p < 0.05$), bush cover (Mann-Whitney $U = 214$, $p < 0.05$), number of trees (Mann-Whitney $U = 268.5$, $p < 0.05$) and number of waste dumps (Mann-Whitney $U = 360$, $p < 0.05$), distance from drainage (Mann-Whitney $U = 327.5$, $p < 0.05$), distance from water source (Mann-Whitney $U = 73$, $p < 0.05$) roof characteristics such as tiled (Mann-Whitney $U = 397.5$, $p < 0.05$), sheet (Mann-Whitney $U = 178$, $p < 0.05$) or thatch ($U = 292$, $p < 0.05$) and roof extensions (Mann-Whitney $U = 312$, $p < 0.05$).

Table 4.7 Nest site and random variables

Parameters	Nest site (Mean ± SE)	Random site (Mean ± SE)	*U*	*P*
No. of houses	9.19 ± 0.66	3.10 ± 0.28	132.000	.000
No of shops	9.19 ± 1.08	4.81 ± 0.79	375.000	.001
Roof-concrete	4.97 ± 0.34	4.70 ± 0.57	602.000	NS
Roof-tile	4.55 ± 0.38	3.05 ± 0.38	397.500	.003
Roof-sheet	6.55 ±0.42	3.05 ± 0.31	178.000	.000
Roof-thatch	2.41± 0.30	0.73 ± 0.22	292.500	.000

Roof extension	5.88 ± 0.60	2.83 ± 0.43	312.000	.000
Nests of other bird species	1.36 ± 0.207	1.78 ± 0.36	618.000	NS
Bush cover (%)	0.44 ± .016	.616 ± 0.02	214.500	.000
No. of trees	2.94 ± 0.26	5.67 ± 0.48	268.500	.000
No. of waste dumps	2.89 ± 0.27	1.54 ± 0.20	360.000	.001
Distance from water source	7. 28 ± 0.77	23.59 ± 1.93	73.000	.001
Distance from drainage	1.19 ± 0.6	1.70 ±0.07	327.500	.000

**NS = Not significant*

Stepwise Discriminant Function Analysis done for the thirteen variables of nest-site (n=37) and random site (n=37), retained four variables namely number of houses, distance from water source, percent bush cover and concrete roof type segregating the nest site from and random sites (Wilks' $\lambda=0.269$, $\chi^2=90.49$, $df= p<0.0001$).

4.5.3 Egg laying and breeding cycle

4.5.3.1 Nest building

Total 20 nests were monitored to find out the nest building activities of House Sparrow. Two peaks hours in the nest building activities were noted, i.e., between 10:00 – 11:00 and 16:00 -17:00 hrs (Figure 4.11). The female contribution was high (64.96%) than males (35.04%) in nest building. Mostly males assisted females in bringing nest materials to nest. Males assisted females in 76 percent cases and in the remaining instances (24 %) the situation was vice versa.

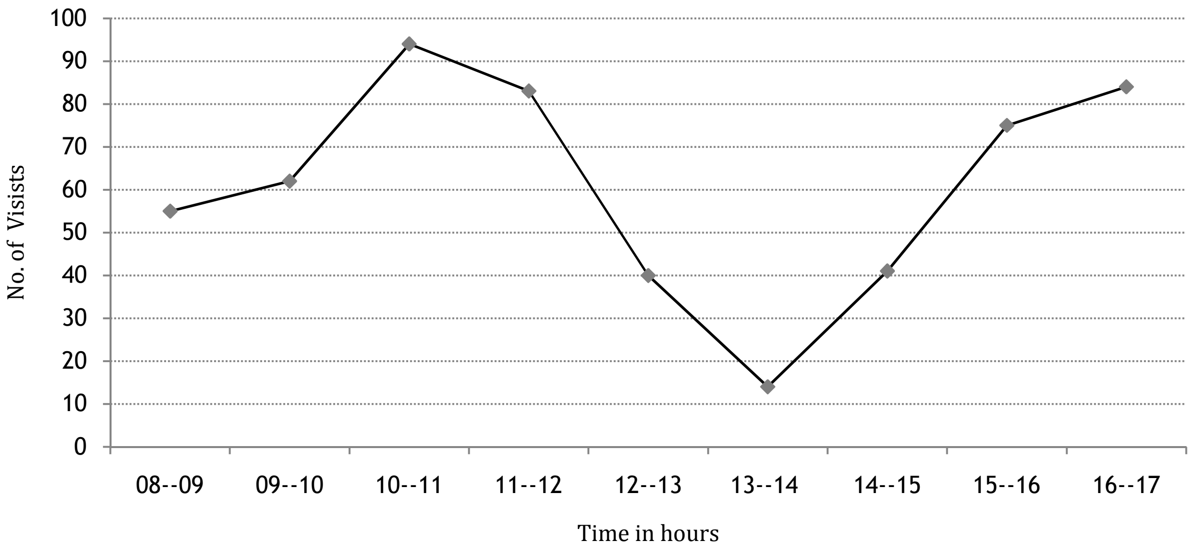

Figure 4.11 Temporal variations in nest building activities of House Sparrow.

4.5.3.3 Territory and nest 'reserving' behaviour of House Sparrow

House Sparrows are territorial especially during breeding season. Males seem to be aggressive once they occupied the nest site. Territory is largely confined to 8-10 m around the nest site. However, there are cases in which males showed its territorial behaviour more than 50 m far from the nest by chasing an intruder. When a new nest site is located such as shopping complexes with shutter hoods, the male reserve them by keeping nest materials which are easily available, especially plant materials. If some other males attempt to occupy the site, they used to confront each other. Usually male threatens the invader first by loud call notes of short duration. If the invader persist with the action, and still approach the site, the owner would make longer calls and attain usual threatening posture (spreading wings and puffing body). Such 'reservation' of the nest site was seen at almost all the study points. During nest construction, egg laying, incubation and provisioning food to the nestlings, generally males used to guard the nest from invaders. Other females sometimes intrude by making a feeding attempt/casual visit to the active nest, especially while rearing hatchlings. In such cases mostly male and in some cases female parent used to chase them off. But immediately after such emergency flights the parents used to land near the nest.

4.5.3.4 Incubation

The incubation timing of House Sparrow was monitored in ten nests. Of these, seven nests were located in village, two in suburban and one in urban. Incubation was done mostly by females and males assisted in cleaning the nest, providing food and in protecting the territory. There were two peaks in the incubation activity; from 11:00 to 12:00 hrs and from 16:00 and 17:00 hrs (Figure 4.12).

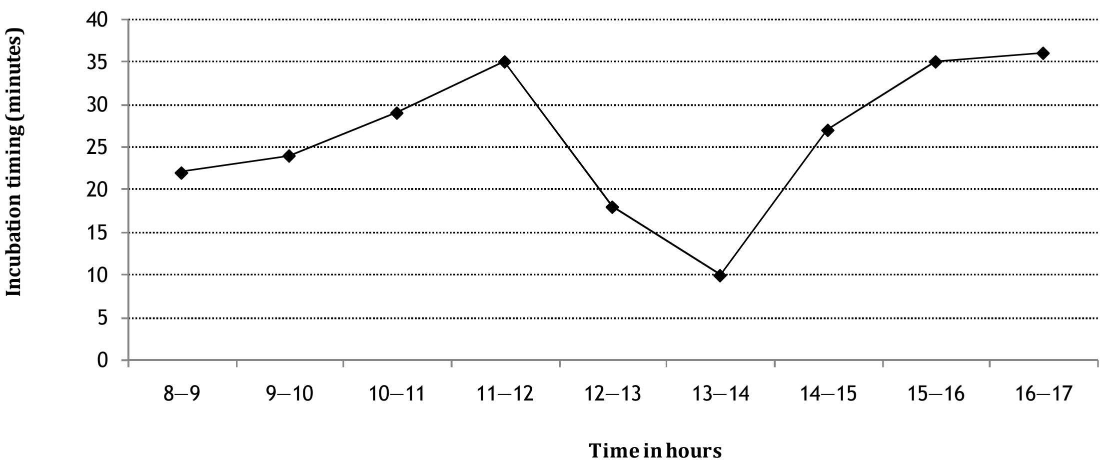

Figure 4.12 Temporal variations in the incubation activity of House Sparrow

4.5.3.5 Provisioning of nestling

Altogether five food items were provided to the nestlings. They were cooked food, caterpillars, moths, grass hoppers and other insects. The category 'other insects' included the insects that could not be identified due to difficulty in close observations. In the village, the nestling diet was dominated by insect food followed by artificial/cooked food (Figure 4.13). Among the insects, grass hopper was important (43%) followed by moths (7%), unidentified insects (5%) and caterpillars (1%). In suburban area (Figure 4.14) the major food item was cooked food (43%) followed by moths (26%), caterpillars (8%), grass hoppers (7%), unidentified insects (5%) and unidentified (11%). In urban area (Figure 4.15) important food item was cooked food (55%) followed by moths (13%), grass hoppers (11%) unidentified insects (11%), caterpillars (6%) and some unidentified food items (4%).

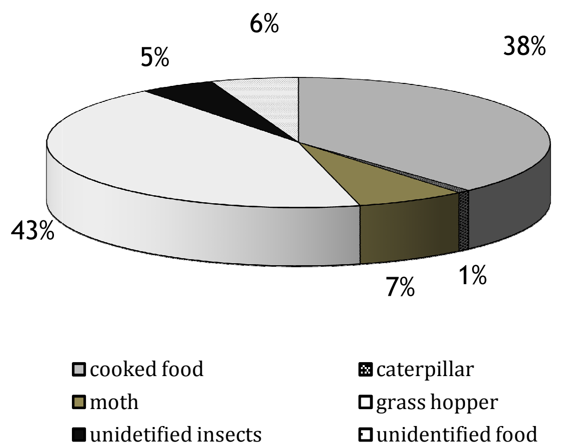

Figure 4.13 Composition of House Sparrow nestling diet at village

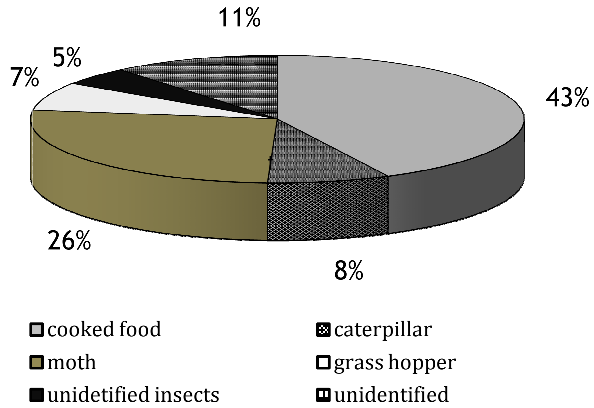

Figure 4.14 Composition of House Sparrow nestling diet at suburban location

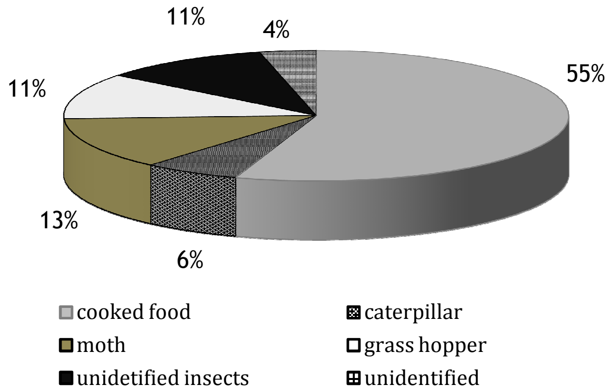

Figure 4.15 Composition of House Sparrow nestling diet at urban area

4.5.3.6 Vegetation characteristics

The herb species richness was high in village (n=19) followed by suburban (n=10) and urban (n=9). The species richness of trees in the village was high (n=25), suburb (n=16) and urban (n=14). The number of home gardens present was high in village (n=103), suburb (n=56) and fewer was in urban area (n=7). Similarly the number of natural fencing was also high in village (n=47), suburban (n=16) and low in urban area (n=11).

4.5.3.7 Reproductive success

Reproductive success was highest during 2006 followed by 2007 and 2008 (Table 4.8). Urban area had the least reproductive success compared to the suburban and village area. During 2008, in urban area no eggs in the nest hatched. In suburban area during 2007 there was a small hike in success (42.1%) than in 2006 and success was considerably less in 2008 (20%). In village, reproductive success gradually reduced from 2006 to 2008.

Table 4.8 Number of nest and reproductive success of House Sparrow from 2006-2008

Year/ Area	**Total nests**			**Nests with egg**			**No of eggs**			**Egg hatched (Percentage in parenthesis)**		
	2006	2007	2008	2006	2007	2008	2006	2007	2008	2006	2007	2008
Village	83	72	104	29	31	50	69	78	128	27(39.13)	27 (34.62)	43 (33.6)
Suburb	17	16	11	4	8	2	8	19	5	3 (37.50)	8 (42.11)	1 (20)
Urban	16	9	7	10	3	1	6	6	2	2 (33.33)	1 (16.67)	0 (0)
Total	116	97	122	43	44	53	83	103	135	33(39.76)	36 (34.95)	44 (32.6)

4.5.3.8 Nest reuse and reproductive success

Nest reuse was monitored for three years at different scales of urbanisation (Table 4.9). Reproductive success associated with the reuse was also monitored. During 2008 the reuse was high (71.31%) followed by 2006 (55.17%) and 2007 (51.54%). Of the three years the percent of reuse was more in urban area i.e., 87.5 percent (2006), 77.78 percent (2007) and 85.71 percent (2008). During 2006 and 2007 the reuse was less in villages and in suburban area. In village area the reproductive success in reused nests was high compared to the suburban and urban areas.

Table 4.9: Nest reuse and reproductive success

Area	**Total nests**			**Nest reuse**			**% of reuse**			**No. of successful nests**		
	2006	2007	2008	2006	2007	2008	2006	2007	2008	2006	2007	2008
Village	83	96	104	38	50	78	45.78	52.08	75	12	20	34
Suburban	17	16	11	12	9	5	70.59	56.25	45.45	2	6	1
Urban	16	9	8	14	7	6	87.50	77.778	75	3	3	0
Total	116	121	123	64	66	89	55.17	54.545	72.36	17	29	35

4.5.3.9 Nest placement and reproductive success

The reproductive success associated with the nest placement at different buildings is shown in Table 4.10. During 2007 and 2008 the success was high those built in other category buildings i.e., 45.45 percent and 57.14 percent respectively. Similarly in 2006 it was high in those nests built in houses and the success was 33.33 percent.

Table 4.10: Functional use of building for nest placement and reproductive success

Sl. No	Variables	2006	2007	2008
1	No. of nests in house	33	19	48
2	No of successful nests	11	8	22
3	% of success	33.33	42.11	45.83
4	No. of nests in shop	77	5	70
5	No of successful nests	13	24	26
6	% of success	16.88	42.86	37.14
7	No. of nests in others	6	33	7
8	No of successful nests	0	15	4
9	% of success	0	45.45	57.14

4.5.3.10 Nest failure

The nest failure happened mainly because of abandonment and anthropogenic disturbances such as knocking down (while opening/closing the shutter) and removal (while cleaning). The percentage of abandonment was higher during 2006 (41.4 %), than in 2008 (38.1 %) and 2007 (28.1 %). The percentage of abandonment at different locations is given in detail in Table 4.11. Nest abandonment was high during the initial phase of nest construction or after finishing the nest (Table 4.12). The percent of nest having knocked down was high in 2006 and nests having removed were high in 2007. In all the three years, both the removed and knocked down nests was high during nest construction phase (Table 4.13). Comparatively the nest disturbance was high in case of nests located on roof support and shutter hood (Table 4.14). Pongal, a local festival cause serious lose of the nests as people clean, paint and restore their buildings during the preparation for the celebration (*see chapter VI).* One of the natural causes for nest abandonment could be due to nest site competition with squirrels (*Funambulus palmarum)* and rats (*Rattus rattus)* (*see chapter VI*).

Table 4.11 Nest abandonment at different gradient of urbanization

Year/ Area	2006 (%)	2007 (%)	2008 (%)
Village	45.78	26.76	35.19
Suburban	41.18	31.25	63.64
Urban	18.75	33.33	42.86

Table 4.12 Nest abandonment observed at different phases of breeding

Year/ Stages	Nest construction/ completed	Number of eggs	Number of hatchlings
2006	30	3	1
2007	24	2	1
2008	43	4	1

Table 4.13 Nest disturbance at different stages across years

Year/causes	Knocked down			Removed		
	2006	2007	2008	2006	2007	2008
Nest construction	16	14	13	32	20	15
Eggs	8	2	10	4	11	12
Hatchling	*0*	2	1	*0*	3	1

Table 4.14 Nest disturbance at different nest substratum

Disturbance / Year	Shutter hood			Roof support			Board			Hole			Light cover			Ventilation		
	’06	’07	’08	’06	’07	’08	’06	’07	’08	’06	’07	’08	’06	’07	08	’06	’07	08
Abandoned	9	9	17	12	6	19	1	3	6	5	6	2	2	1	0	2	0	1
Knock down	12	11	11	5	2	3	3	1	7	2	1	1	0	1	0	2	2	2
Removed	16	12	8	12	10	14	3	5	0	3	0	2	0	0	1	2	2	1

4.6 Discussion

4.6.1 Breeding

As mentioned earlier Sparrows are loosely monogamous (Summers- Smith 1988) and are considered as discrete breeders and tend to breed in small, loosely arranged colonies (Summers-Smith 1988). In sparrows the peak breeding was in April. This seasonality was also reported by Murphy (1978), Mitchell and Haye (2009) and Vincent (2005). Birds tend to adjust the timing of their breeding attempts in such a way that nestling rearing coincides with the favourable environmental factors so that the energy costs of reproduction are lowest. For communally breeding species, Vaclav and Hoi (2007) suggested that individuals can improve their reproductive success by coordinating their breeding time with other members of the flock. In the current study only maximum temperature seems to be correlated with the nest abundance. Other factors such as minimum temperature, rainfall and total rainy days did not affect the nest abundance. According to Peach et al. (2008) warmer summers are said to be likely more conducive to successful reproduction. This may be because the rainfall will negatively affect nest construction, foraging and nestling provisioning. Hence it will restrict the activity of House Sparrow.

4.6.2 Nests and nest site selection

4.6.2.1 Nest architecture

Nest quality influences mate choice, breeding and parental behaviour in several birds (Hansel 2000, Szentirmai et al. 2005). Similarly the nest quality will affect the insulation and embryonic development (Webb 1987, Moller 1991). House Sparrows are facultative cavity nesters and will utilize nest boxes, as well as construct open nests. The structural layer's critical feature is that it gives integrity to the nest shape, preventing it distorting or falling apart. Any component of the nest considered to be performing this role is treated as a component of the structural layer. The inner layer, the lining will protect the eggs by giving a cushion effect (Hansel 2000). The present study recorded two distinct layers in the nest such as structural layer and lining.

4.6.2.2 Nest material

Nests were predominantly made of plant matter (87%), animal matter (1%) and other (12%) lining materials were paper, plastic pieces etc. Similar observation was also found in by others (Indykiewicz 1991, Rajashekar and Venkatesha 2008). According to them the species used a broad range of materials for building nests including feathers, grass inflorescences, stalks and roots of plants, bark, threads, string and even pieces of paper and wool. The plant material may repel or kill ectoparasites because of secondary compounds it contains (Wimberger 1984). Also the thickness of the plant material decreased the cooling rates with nest thickness (Szentirmai 2005). Hence it accelerates embryonic and nestling development and decreases the energy costs of incubation (Webb 1987).

4.6.2.3 Nest substratum

Khera et al. (2009), Show et al. (2008), Summers-Smith (1988) and Vincent (2005) reported that substrata of House Sparrow's nest include overhanging lower edge of roofs, holes, in ivy and creepers on houses, hedges, even in the electricity meters and manmade structures such as crevices and holes. The current study found eight natural nest substrata of which shutter hood was the most used one, as shops were the main provider of nest site. Generally exhaustive cleaning was less frequent in the shops compared to the houses. Hence this can be a reason to use shutter hood as a safe nesting location. Same trend was seen in village and suburban area. In urban area, roof support was the mainly used nest substratum. Installation of the 'hidden' hood types on shutters (in which the hood of the shutter would not be exposed) in modern shops in urban areas probably lead to limited space available for nest building. In urban area the extension of building roofs, predominantly made of sheets, served as sunshades. Such roofs were supported by wooden or iron bars which provided suitable nesting sites.

4.6.2.4 Nest placement

Shops were having the highest number of nests. In village, suburban and urban areas, the highest number of nests was found in shops. On all the grades of urbanization, shops were mostly used location for placing the nests probably due to the food availability from shops and hotels (Shaw et al. 2008). Shops and hotels offer shutter hoods as the nesting positions. Similarly in urban areas the drainage and waste dumps will provide good foraging ground for them (Bokotey and Gorban 2005).

4.6.2.5 Vertical stratification of nests

During the three years study, nests were found placed mostly within 01-03 m height. In villages, the most used height class for nest placement was 01-03 m probably due to the increased availability of short single storied buildings, tiled and sheet houses, and old shops. In suburban areas the nest height was 03-06 m while in urban areas the birds equally occupied both 01-03 m and 03-06 m height classes. The urban area of Coimbatore harboured old buildings while in suburban areas the buildings were relatively newer. The study conducted by Indykiewicz (1990) indicated that the most commonly preferred height for urban sparrows was between 3-4 metres. During a study conducted by Rajashekar and Venkatesha (2008) in Bangalore city the height class recorded was 2.5-6 m.

4.6.2.6 Nest site characteristics

Nest-site selection in birds refers to the choice of a particular location for nesting from all possible sites (Burger 1987). The selection of a poor nesting site could drastically lower the breeding success of birds (Mcgillivray 1981). Hence while choosing the nest-sites, birds must consider proximity to feeding areas, shelter and protection or camouflage against predators. In the case of social birds, they must add social factors, strongly influenced by the relative position of the nest within the colony and distance to neighbouring nests. In the present study the important factors that affected choosing the nest sites were different buildings category, bush cover (%), distance from drainage and distance from nearest water sources and roof type. Nests placement at building category, distance from drainage and nearest water sources were connected with the availability of food sources (Vincent 2005). Bush cover can be a source of insect availability. It also provides concealment from predators and serves as a place for day roosting during hot hours. SDFA retained four variables; number of houses, distance from water, bush cover (percent) and concrete roof type to segregate the nest site and random sites. Out of 25 variables SDFA predicted 16 significant variables for successful and unsuccessful sites. These variables were mainly associated with the food sources, distance from the nearest nest and other bird species nest.

4.6.3 Egg laying and breeding cycle

4.6.3.1 Nest building

Among bird species exhibiting biparental care, females are typically involved in all or most parental care duties, generally including nest building, incubating eggs and rearing offspring (Kendeigh 1952). Current study also showed that the female contribution was more (65%) than males (35%) while nest building. Mostly males assisted females in bringing the nest materials to the nest. In 76 percent of cases males assisted female and only in the remaining 24 percent the reverse happened. There were two peaks in the nest building activities i.e., 10:00 – 11:00 hrs and 16:00 -17:00 hrs. A study conducted on Nilgiri Pipit *Anthus nilghiriensis* also showed a similar nest building activity pattern (Vinod 2006).

4.6.3.2 Incubation

Parental care can greatly influence reproductive success, the quantity and quality of reared young ones. Nest attentiveness affects egg temperatures (White and Kinney 1974, Haftorn 1988), which influence the length of the incubation period (Martin 2002, Fontaine et al. 2007). In the present study there were two peaks in the incubation activity of the House Sparrow i.e., 10:00 – 11:00 and 16:00 -17:00 hrs. Mainly females committed more time for incubation than males (Bartlet 2005). A study by Hinsly and Ferns (1994) on *Pterocles* sp. (Sandgrouse) also supported this view. Their study revealed that the division of labour among male and female Sandgrouse where the females parental expenditure was high during incubation.

4.6.3.3 Provisioning of nestling

Recording of feeding frequency during nestling period leads to a greater understanding of the foraging strategies and of the effort made by the parents to raise their young, as well as to a better identification of the factors which might affect birds' activity (Freitag et al. 2001). Energy or nutrient constraints affect nestling growth and survival to independence and possibly body condition and survival of breeding adults (Hinsly and Ferns 1994). According to Crick et al. (2002) Sparrows will feed its nestlings mostly with grains, fruit buds, flower nectar, weed seeds, human food waste and insects (aphids, weevils, grasshoppers, and caterpillars).

Suburban and urban environments are rich in anthropogenic food sources, particularly human refuse (Heiss et al. 2009). The current study also supports that frequency of feeding the nestlings with cooked food was more in the urban area followed by suburban and village areas. Essential amino acids such as lysine which are found in animal protein are vital for rapidly growing nestling passerines (Ricklefs 1983). Coleoptera, Diptera and Lepidoptera were most commonly seen in the diet of village House Sparrows in the current study which also reported by Anderson in Poland (1984). In the current study also showed that the insect diet is more in villages than in urban and suburban areas. According to Vincent (2005) nestlings were more likely to starve if their diet contained a high proportion of vegetable material (mainly supplementary food) than that of insects. According to Heiss et al. (2009) in an experimental study the supplemented rural nestlings were significantly smaller than unsupplemented rural ones, suggesting that parents use easily accessible food even when it is nutritionally suboptimal.

4.6.3.5 Vegetation

According to Heij (1985) the amount of green space was important factor in determining the House Sparrow density. In the current study, the species richness of both herb and trees were more in village followed by suburb and urban area. As expected, the number of home garden and natural fencing/hedges was also more in village than in suburban and urban area. Vegetative support may help to have more insects in the area (Crick et al. 2002). Hence the nestling diet in the village area had more insect food contribution than in suburb and urban area. According to Vincet (2005), there is a positive relationship with good quality habitat which is likely to harbour more native invertebrates, which may indirectly affect an increase in brood biomass and survival.

4.6.3.6 Reproductive success and failure

Urban area had the least reproductive success compared to suburban and village areas. This can be a reason for the drastic decline in population which is happening in the urban areas (Summers-Smith 1963, Seel 1968, Summers-Smith 1988 and Vincent 2005). Nest reuse was high in urban area. This is may be due to the scarcity in nest sites and nesting materials (Friesen et al. 1999). In the reused nests, success was high in village area and less in suburban and urban areas. However, in urban area reuse was high. The nest reuse can affect the success in two ways, when old nests serve as a cue for breeding (Pöysa et al. 2001) and poses higher risk by way of in growth in of nest parasites from the old nest materials.

Nest abandonment seriously affected the demography of the population. Anthropogenic disturbance is the main reason for the nest abandonment and removal. In the study area nests were mostly concentrated in shops and houses. Shutter hoods in the shops provided the one of the important nest site substrata for House Sparrow. Nevertheless during opening or closing the shutter, the nests experienced impact and sometimes fell down. Nest removal was also associated with the cleaning of the houses and shops. Usage of dried plant materials and easily available scraps in nest construction forced people to clean such places. During restoration and renovation associated with festivals such as Pongal, nest removal happened in significant numbers crucially affecting sparrow's breeding. Similarly in one of the study locations (Ukkadam market) selling of House Sparrow nestlings to the aviaries for Rs.15-20 per pair was reported. Such activities could also significantly influence nest abandonment either due to destruction or disturbance to the nest while procuring the nestlings.

Selection of nesting habitat is a behavioral decision which has been done by the bird. As demonstrated by Parody and Parker (2002) it has to be noted that correlational studies, even when based on careful comparisons across a species' range, can never conclusively demonstrate that members of a species make decisions based on a particular habitat variable for their nesting. Generally, studies reporting evidence for the adaptive basis of nest-site selection are very scarce (Clark and Shutler 1999). There will always be the possibility that unmeasured correlates are the important proximate cues. In all species, finding what exactly determines settlement and habitat use patterns will be impossible without manipulative experimentation. This is probably true for a wide variety of species because most of them do not seem to show unambiguous correlations with habitat variables. The real meaning of these intrinsic relationships is still not clear, and is a promising topic for future research. This will show us how important is the knowledge of natural history and field ecology of tropical birds in helping us to understand the observed patterns that emerge from conservation studies.

Summary

- The House Sparrow is a discrete breeder with a peak in April and a second peak in January.
- The number of nests showed significant positive correlation with maximum temperature (r=0.455, p<0.05; Figure 4.2) and negatively but not significantly correlated with minimum temperature (r=-0.021, p>0.05), rainfall (r=-0.298, p>0.05) and rainy days (r=-0.299, p>0.05).
- Comparison between successful and unsuccessful nest site variables using Mann-Whitney U showed significant difference for nest height, bush covered area, distance from other bird species nest, distance from road, drainage, water source, artificial light source and food source, ventilation in the building, number of nests, waste

dumps and number of vehicles. The Mann-Whitney U test was used to compare nest-site characters with random site and significant differences were recorded corresponding to number of houses, number of shops, area under bush cover, number of trees and number of waste dumps, distance from water source and roof extensions.

- Eight different nest substrata were used by the species for nest construction. Shutter hood (n = 135) was the most widely used substratum in suburban and village areas.
- In urban area roof support was the most used nest substratum. Throughout the study period the nest placement was found high in shops.
- The height class mostly used for nest construction was 01-03 m.
- The PCA analysis resulted in components that were positively loaded towards factors such as the nest placement at different buildings, number of vehicles, bush cover and distance from drainage.
- DFA, performed to find important factors which discriminate the nest site from the random site, retained four variables; number of houses, distance from water source; percent bush cover and concrete roof type (Wilks' λ=0.269, χ=90.499, df=4, $p<0.001$).
- The nest building activities in the House Sparrows were having two peaks, i.e., between 10:00 – 11:00 and 16:00 -17:00 hrs. The female contributed more (64.96%) than males (35.04%) in the nest building activities.
- The nests were predominantly made of plant matter (91%). Animal matter (1%) and lining materials such as paper, plastic pieces (8%) were seen in lesser quantity.
- In village area nestling diet was dominated by insects followed by cooked food or leftover food items.
- The reproductive success was high in 2006 than that of 2007 and 2008. Urban area had the least success compared to the suburban and village area.
- The nest failure happened mainly because of abandonment and anthropogenic disturbances such as knocking down (while opening/closing the shutter) and removal (while cleaning). The percent of nest abandoned was high during 2006 (41.38%), 2008 (38.10%) and 2007 (28.13%).
- Nest abandonment was high during the initial phase of nest construction or after completion of the nest. In all the three years, the number of removed and knocked down nests were high during nest construction phase.

Chapter- V

Characteristics of nocturnal roosts of House Sparrow in relation to environmental variables

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Chapter- V

Characteristics of nocturnal roosts of House Sparrow in relation to environmental variables

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5.1 General introduction

One of the most remarkable behavioural tendencies of an individual is its effort to keep in contact with the group, which is, keeping track of its partner, family, and flock (Schmitt 1994). The roost behaviour of the birds can be due to the social development, as a mean of keeping the contacts with the members. Roost is a phenomenon that involves wide-ranging and long-lasting relationships among bird species (Caccamise et al. 1983). Hence majority of the communal roosting birds associate together through some social attraction and do not disperse even if alternative roosting sites are available (Gadgil and Ali 1976). A 'roost' may be defined as a place where a bird rests during a long inactive period, and a 'communal roost', one where many birds, converge which have been feeding solitary or in flocks which are not of constant composition (Ward and Zahavi 1973). The difference between the communal and non communal roosts is in the nature of feeding groups. Species which feed in flocks upon an unevenly distributed food supply tends to roost communally, and birds which feed solitarily generally roosts alone (Ward and Zahavi 1973, Gadgil and Ali 1976).

Communal roosting has most likely evolved to increase foraging efficiency in flock-living birds, but may then have been maintained because it also may decrease predation risk, thermal stress and the cost of mate selection (Beauchamp 1999, Blanco and Tella 1999). According to the Information Centre Hypothesis (ICH), the main function of communal roosts is the transfer of information about the spatial location of ephemeral food sources (Ward and Zahavi 1973, Heinrich 1988). One hypothesis assumes that selection of communal roosts with more favourable microclimates than surrounding areas aids in thermoregulation and energy conservation (Keister et al. 1985). According to Gadgil (1972) smaller birds will be more susceptible for heat loss because of their greater surface to volume ratio. Kelty and Lustick (1977) reported that European Starlings selected favourable microclimates provided by pine woods and thereby reduced daily energy expenditure by 12 percent to 38 percent. Likewise, Stalmaster (1984) found that Bald Eagles conserved energy by preferring to roost in coniferous than deciduous riparian areas. However, in contrast Walsberg and King (1980) found that such behaviour by the American Robin produced only a slight thermoregulatory benefit. They suggested that the thermal significance attributed to selection of nocturnal roosts in other studies (Calder 1973, Kelty and Lustick 1977) may not be applicable to most species and settings. In spite of the number of hypotheses that have been proposed the adaptive significance of communal roosting in birds is not well understood. As per the existing hypothesis, knowledgeable individuals have to join communal roosting than roosting solitarily because of the following reasons,

(1) To achieve safe roost sites (Weatherhead 1983, Aradia 2001 and Dobbs 2000)
(2) As a hedge against sudden severe environmental conditions (Zahavi 1996)
(3) As a status signalling through revealing information to non kin conspecifics about the location of newly discovered food sites (Heinrich 1988) and
(4) To gain advantage from group foraging the next day at the food sources that they have discovered (Richner and Heeb 1996)

Pre roosting aggregations (PRAs), or site-specific gatherings of individuals made prior to flying into a night roost, are frequently seen among birds (Zahavi 1971, Loman 1985), is particularly obvious in the evening (Schmitt 1994). As the evening progresses, individuals will be shifted to PRA sites closer to the location of night roosts. The function of pre-roost gathering is explained by four hypotheses:

(1) The pre-roost gathering is an aggregation of birds in a foraging area which functions as a supplement to the daytime territory or the diurnal activity centre, minimizing the distance from this supplemental foraging area to the communal roost (Caccamise and Morrison 1986, Stouffer and Caccamise 1991, Caccamise et al. 1997).
(2) Pre-roost gathering decreases predation risk, either through the dilution effect (Hamilton 1971), or through increased vigilance by giving warning signals before a predator's attack (cf. Kenward 1978).
(3) By attending a pre-roost gathering a bird will increase its chances of joining a communal roost of conspecifics (Zahavi 1971).
(4) The pre-roost gathering provides individual birds with knowledge about the location of rewarding foraging sites through its close connection with communal roosts (Ward and Zahavi 1973).

While comparing with other species very few investigations have been available revealing pre-roost and roost behaviour in House Sparrow. But there is some information available on the Sparrow roost time and the number of individuals (Stoddard 1923, Anonymous 1972, Leck 1973). Being a flock living bird in suitable habitats, Sparrows tend to collect in fairly compact breeding colonies and communal activities such as nocturnal roosting, feeding and dust-bathing (Summers-Smith 1952). The present study is taken up in the context of scarce information available on the species on its roosting behaviour.

5.2 Objectives

The objectives are to examine

- The pre roost and roost activities of the species
- Nocturnal roosts population
- Nocturnal roost site characteristics

5.3 Methodology

To identify the roosting sites of House Sparrow surveys was conducted along an urban to rural gradient (Figure 5.1). Special attention was given to areas where House Sparrows were present and information from local people was also gathered. Point counts were used to record the roosting population (Bibby et al. 1998), considering the roost tree as the centre of the 50m radius circle. Following Engel and Young (1992), a 'roost' was considered as a stand of one or more adjacent trees each with a population of at least five Sparrows perched together after sunset. The field visits were conducted between 17:00 and 21:30 hrs. Altogether 18 roosting points were recorded. Eighteen trees that were not used for roosting were also randomly selected along the gradient. With the help of GoogleEarth map grids were laid along the urbanization gradient (Thadagam road). Non roost trees were randomly selected from these grids as suggested by Yap et al. (2002). At sampling points with a cluster of trees, a non-roost tree was randomly selected (Gorenzeld and Salmon 1995) for the measurements. If any of these randomly selected tree / site that are considered as 'unused' appeared being used by House Sparrows, then another unused roost site was selected for recording its characteristics (Peh and Sodhi 2002). Monitoring the pre roost activities and roosting population was done once in two months for three years (2006-2008), except in Alamaramedu near SACON where the roost site was established only in 2007. On an average on a single visit 2:00-2:30 hrs were spent at each point recording pre roosting activities, roosting population and habitat requirements of the roosting House Sparrows.

Source: Source: www.GoogleEarth.com Accessed on March 6, 2010

Figure 5.1 The nocturnal roost sites of House Sparrow

5.3.1 Pre roosting activities

Six sites from villages were selected for detailed observations on the pre roost activities of House Sparrow. The observations were made once in three months from 2006 to 2008. The reasons for selecting these areas were to get a clear vision of the flock movement (area not disrupted with multi-storied building, large tree canopies and traffic), availability of an elevated area to have a close visibility of the flock movement and synchronization and finally the accessibility of the study area. The flock movements of the population were monitored from an elevated place to have proper visibility from all directions. After continuous observation I could standardise the timing of pre roost activities as around 30 minutes before the last flock's entry to the roost tree.

5.3.2 Roosting population

The roosting population was monitored by point counts (Bibby et al. 1998). The observations were made once in two months from 2006 to 2008. Eighteen 50 m radius point samples were laid along the gradient. Observations were started approximately 30 minutes before the entry of the last flock to the roost tree.

5.3.3 Roost and non-roost characteristics

The habitat characteristics of roost and non roost sites were collected following Yap et al. (2002). After identifying both roost and non roost tree species I had given rank to each tree as one and two respectively for roost and non roost trees. The habitat characteristics which were appeared to be related to the presence of House Sparrow were included (Table 5.1). The following measurements were taken from both the roost and non roost sites.

Table 5.1 Habitat characteristics of House Sparrow roost site

Sl. No	Habitat variables	Description
1	Roost tree species	Identified using a field guide pertinent to the study area (Henry et al. 1984).
2	Roost tree height	Approximate height from the surface to the tip of the tree in meters by visual estimation, comparing with a known height.
3	Clear bole height	Approximate measure (in meters) from the base to the top of the visible portion of the trunk.
4	Canopy height	Calculated by subtracting clear bole height from tree height in meters.
5	Girth at breast height (GBH)	GBH at 130 cm, from the ground, measured using a measuring tape.
6	Canopy radius	Canopy radius (in meters) was estimated from the centre of the trunk to the edge of the crown (average of four measurements in four cardinal directions); Measured using a measuring tape.
7	Canopy density	Measured at four randomly selected positions under the canopy of the roost tree. At each position by employing an imaginary grid (1x1 m), the percentage of foliage covering was determined by visual estimation.
9	Distance to the adjacent tree	The distance from the roost tree to the adjacent tree was measured in meters.
10	Number of available trees at the point	Total count of the trees at the 50 m radius
11	Distance to adjacent building	The distance from the roost tree to the adjacent building was measured in meters.
12	Distance to adjacent road	The distance from the roost tree to the adjacent road was measured in meters.
13	Height of the adjacent tree	The height of the adjacent tree was measured in meters by visual estimation.
14	Type of the road	Tar/concrete/gravel

15	Nearest food source	An average distance of the four food sources (in meters)
16	Distance to nearest temple	The distance from the roost tree to the nearest temple was measured in meters. After *Pooja*/worship at the temple, they used to offer food for birds, cows etc. Similarly the temple can also provide nesting sites.
17	Distance to bus stand	The distance from the roost tree to the nearest bus stand was measured in meters. Bus stand can act as potential nesting and feeding sites.
18	Distance and characteristics of drainage (open or closed)	The distance from drainage to the roost tree was measured in meters; also noted whether it is closed with concrete tile or not.
19	Distance to artificial light source	An average distance of the four light sources was measured in meters
20	Distance to adjacent communal roost	The distance (in meters) of the Communal roost of other species such as Crow and Myna from the Sparrow roost was measured in meters
21	Number of bird feeding areas	A place where daily people used to offer food for the birds (as a cultural practice in Tamil Nadu, people offer food to birds after cooking their first meal)

The landscape type is also a significant factor for roosting. Hence, it is important to determine the percentages of different types of land uses around roost and non roost site. Following Yap et al. (2002), a 200 m radius circle was drawn, centred on the position of roost and non roost points. The land use classes in the 200 m radius (open, green and built area) were measured in percentage with the help of GoogleEarth, using EasyAcreage V1.0 software and later by ground truth for confirmation.

5.3.4 Human Activity Index

The individual components of the Human Activity Index (HAI) were rated for all roost and non roost sites and HAI was calculated by multiplying the scores of each individual component. HAI is composed of multiple components (Gorenzel and Salmon 1995) and each activity is given a score. The individual components were ranked from 1 to 5 (lowest to highest potential disturbance). Traffic volume at closest street was counted and ranked as (1=>1-10 vehicles per 5 minutes, 2=>11-20 vehicles per 5 minutes, 3=>21-30 vehicles per 5 minutes). Pedestrian movement was estimated and ranked as (1=>1-10 pedestrians per 5 minutes, 2=>11-20 pedestrians per 5 minutes, 3=>21-30 pedestrians per 5 minutes).

5.4 Statistical Analysis

- Principal component analysis (PCA) was performed to determine the most effective microscale variables for roosting.
- To examine the roost site preference Logistic regression analysis was performed.
- Linear regression was used to find relationship if any among local sunset timing and first flock entry to the roost tree.

5.5 Results

5.5.1 Pre-roost and roost behaviour

Pre-roost activities were actually seen around 30 minutes before the roosting time. The flocks aggregated near the roost sites and waited till all the members join to proceed to the roost tree. At the initial stage of flock aggregation the birds were engaged mainly in activities such as feeding and dust bathing. The last flock entry to the roost tree was three to four minutes just before the local sunset in the area. Birds were aggregated on elevated sites such as roofs and electric lines, while progressing towards the roosting time. On an average approximately six minutes is maintained between the entry of the first and the last flocks into the roost trees. Prior to the flock's entry to roost tree a hovering display was performed. During the hovering display each flock covered around 10-25 m radius around the roost point. These movements were not in any specific directions. The large roost group showed a comparatively more hovering display than small groups (Table 5.2). It was observed that site Kanuvai–1 had the highest roosting population followed by Kanuvai – 1 (85.33±4.00), Thadagam-1 (84.44±3.54), Kanuvai – 3 (25.11±0.68) and Virapandi – 1 (22.72±0.72). The number of hovering display was high in Kanuvai – 1 (6.08±0.28), Thadagam – 1 (5.57±0.29) and the least was in Kanuvai – 2 (2.08±0.25). The hovering display of the first roost flocks were reported at a mean of 11.75 minutes before the sunset. The entries of the last flock to the roost tree were reported with a mean of 6.37 minutes, in relation to local sunset timings. It is noted that local sunset timing was affecting the first flock entry to the roost tree (R^2=0. 499, $p > 0.001$).

Table 5.2 Pre roost and roost details of House Sparrow from six locations for three years

Area/Tree sp.	Roosting population	Total no. of hovering	Time of first hovering	Time of first flock entry	Local sunset timing
Thadagam-1 *Thespesia populnea*	84.44±3.54	5.57±0.29	06:15	06:20	06:54
Kanuvai–1 *Thespesia populnea*	85.33±4.00	6.08±0.28	06:45	06:50	07:01
Virapandi–1 *Azadirachta indica*	22.72±0.72	4.27±0.24	06:55	07:01	07:02
Kanuvai–2 *Aegle marmelus*	13.78±0.47	2.08±0.25	07:03	07:05	07:08
Kanuvai–3 *Psidium guajava*	25.11±0.68	4.18±0.19	06:43	06:59	07:00
Virapandi–2 *Michelia champaca*	15.39±0.58	2.91±0.17	06:53	06:58	07:02

5.5.2 Roosting population

Of the 18 roost sites observed 16 were from village and two from urban area. Village areas viz., Kanuvai, Thadagam and Virapandi had four each roost points while Uchayannur and Alamaramedu had two roosting sites each. In urban area, Gandhi Park and Ukkadam had one point each (Table 5.4). The roost population varied from 6-105 birds. The largest roost population was recorded at Kanuvai (n=105) and the least number of individuals at Ukkadam (n=6). Among the four roost trees observed in the village Kanuvai, roost tree *Thespesia populnea* was having the highest average number of birds. During 2007 – 2008 a gradual decline was observed in the roost population of Kanuvai - 1 (*Thespesia populnea),* while the rest points the population remained almost stable.

The village Thadagam also had four roost sites. In Thadagam, the highest population was observed in *Thespesia populnea*-1, the roost population showed a decreasing tendency from 2007 to 2008. The population in the rest of the three roosting points in Thadagam was almost stable. The village Virapandi also had four roosting points and *Michelia champaca* showed a slight increase from 2006 – 2008. In the village Uchayannur the highest roosting population was seen on *Azadirachta indica-1*. During 2006-2007 a minor decline in the population was observed in *Azadirachta indica-1* from 27 to 20 individuals. At Alamaramedu the highest population was reported on *Pithecelobium dulce.* During 2007 the roosting population in Ukkadam (*Thespesia populnea*) has shown a slight decrease. Also in Gandhi Park (*Prosopis juliflora*) dropped from 18 to 9 individuals.

It was very difficult to locate a roosting site in suburban areas as the number of individuals in the groups was small. There were no specific trees with more than five Sparrows and it was difficult to have continuous observation since the group was constantly changing the roost trees because of the local disturbance. However, five attempts of roosting were observed; one with three individuals and the remaining four with four individuals. As these groups were not consistently roosting at specific sites (trees) due to local disturbances, data collection on pre roosting and roosting population was not possible. The possible disturbances in the suburban area are as listed in Table 5.3.

Table 5.3 Disturbances recorded in the suburban areas for the Sparrow roost population

Place	**Disturbances**
TVS Nagar	Roost tree loss, construction work near the roost sites
KNG Pudur	Roost tree loss
Venkitapuram	Pruning of the roost tree, roost tree loss

The roosting Sparrow population did not show any association with other bird species. House Crow was observed for seven times in the roost trees of Sparrows even after the last flock's entry to the roost tree. But in all the cases the Crows subsequently left the roost trees occupied by the Sparrow. Roost population largely showed roost site fidelity during the study period. They changed their site only when disturbances such as roost tree loss, pruning and construction activities happened near or in the roost sites. The roost population of House Sparrow did not show any considerable seasonal variations in their number (Table 5.4).

Table 5.4 The roost population during 2006-2008 (n=18 points)

Area/ Places	**Roost tree species**	**2006**	**2007**	**2008**
Village/ Kanuvai	*Thespesia populnea*	93.33±3.07	86.67±2.47	77.50±2.81
	Aegle marmelus	13.50±0.92	15.00±0.63	12.83±0.31
	Psidium guajava	24.67±1.09	22.17±0.70	22.50±0.99
	Azadirachta indica	13.33±0.95	13.83±0.70	14.00±0.37
Village/ Thadagam	*Azadirachta indica* 1	15.67±0.71	12.17±0.48	10.00±0.37
	Thespesia populnea 1	13.67±0.71	16.50±0.99	16.83±0.95
	Azadirachta indica 2	92.50±2.14	87.50±2.81	73.33±1.67
	Thespesia populnea 2	17.83±0.95	19.17±0.40	17.50±0.43
Village/ Virapandi	*Azadirachta indica* 1	16.83±0.87	19.50±0.43	17.33±0.88
	Azadirachta indica 2	23.67±0.99	22.83±0.31	21.67±0.67
	Thespesia populnea	13.67±0.71	16.50±0.99	15.50±0.89
	Michelia champaca	18.50±0.67	19.67±0.67	19.00±0.63

Village/ Uchayannur	*Azadirachta indica* 1	13.67±0.71	16.17±0.91	16.33±0.92
	Azadirecta indica 2	24.83±1.58	26.50±0.85	21.50±1.09
Village/ Alamaramedu	*Pithecelobium dulce*	13.67±0.88	15.50±0.50	15.00±0.45
	Azadirachta indica	0.00±0.00	19.83±0.65	22.50±0.56
Urban /Ukkadam	*Thespesia populnea*	0.00±0.00	11.00±0.37	10.00±0.82
Urban / Gandhi park	*Prosopis juliflora*	10.67±0.61	9.67±0.88	7.50±0.43

5.5.3 Roost and non-roost habitat characteristics

The habitat characteristics of Sparrows were analysed (Table 5.6) which showed that of the seven species of roost trees *Azadirachta indica* (n=8) was most used for roosting (Table 5.4). Among the non-roost trees *Tamarindus indica* (n=5) was the highest followed by *Delonix regia* (n=4) *and Ficus religiosa* (n=4). When compared to non roost trees, Sparrows roosted on smaller trees with mean canopy height of 2.28m, mean crown radius of 2.16 m and with low crown density of 53.06 percent.

In the roost point the number of trees was less compared to non roost site. The adjacent tree to the roost trees was comparatively smaller in all the points. The roost trees were found comparatively closer to the buildings (2.45 m) and to the road (1.72 m). The roost trees were also found closer to the food source (2.21 m) and to places which had more bird feeding areas. It is also noted that the roost tree is closer to other food sources such as drainage (3.74 m), bus stand (27.39 m) and temples (13.47 m). Near to the roosting trees the human activity index was high and there were less green areas surrounding the roosting tree (17.22%).

Table 5.5 Number and percentage of roost tree species of House Sparrow and randomly selected non-roost trees in the study area.

Sl. No	Tree species	Roost trees		Non-roost trees	
	Scientific name	No. of trees	Percent (%)	No. of trees	Percent (%)
1	*Thespesia populnea*	5	27.78	0	0
2	*Aegle marmelus*	1	5.56	0	0
3	*Psidium guajava*	1	5.56	0	0
4	*Azadirachta indica*	8	44.44	2	0.13
5	*Prosopis juliflora*	1	5.56	0	0
6	*Michelia champaca*	1	5.56	0	0
7	*Pithecelobium dulce*	1	5.56	0	0
8	*Tamarindus indica*	0	0	5	0.28
9	*Ficus bengalensis*	0	0	2	0.11
10	*Pongamia pinnata*	0	0	2	0.11
11	*Delonix regia*	0	0	3	0.17
12	*Ficus religiosa*	0	0	3	0.17
13	*Bombax sp.*	0	0	1	0.06

Table 5.6 Tree and habitat characteristics of House Sparrow roost (n=18) and non-roost (n=18)

Tree and habitat characteristics	**Roost site**	**Non- roost site**
	Roost tree (Mean ± SE)	Non roost tree (Mean ± SE)
Tree height (m)	5.83±0.39	7.44±0.32
Bole height (m)	3.44±0.39	4.36±0.35
Canopy height (m)	2.28±0.15	3.42±0.22
Diameter at breast height (cm)	46.22±3.08	158.72±28.29
Average crown radius (m)	2.16±0.11	4.28±0.25
Adjacent tree distance (m)	4.89±0.62	5.75±0.91
Adjacent tree height (m)	8.22±0.57	15.61±0.88
No. of available trees in the point	9.44±1.24	7.50±0.59
Distance from road(m)	0.97±0.18	3.89±0.60
Distance from light source (m)	1.72±0.41	11.53±1.58
Distance from building (m)	2.45±0.19	5.39±0.99
Distance from food source (m)	2.21±0.21	6.14±0.79
Distance from other species roost site (m)	34.89±2.34	6.17±0.76
Distance from temple (m)	13.47±3.09	37.22±4.66
Human activity index in the point	15.72±0.87	5.28±1.06
Distance from bus stand (m)	27.39±3.67	36.67±4.26
No. of bird feeding areas	4.67±0.31	1.39±0.32
Open area (%)	39.44±2.97	32.78±3.51
Area under green (%)	17.22±2.29	31.39±1.66
Built area (%)	45.56±3.31	37.50±3.90
Crown density (%)	53.06±1.35	68.33±3.20

The variables like number of trees in the point, distance from food source, HAI and built area may increase the chances of selecting a roost site (Table 5.7). Unit change in the variable distance from the building and distance from the drainage can decrease the chances of selecting a non roost site. Model accuracy was about 70 percent.

Table 5.7 Summary of Logistic regression

Variables	B	S.E.	Wald	Df	Sig.
No. of available trees in the point	**-4.109**	2.256	3.319	1	0.07
Tree height	-3.282	2.9	1.281	1	0.26
Bole height	2.433	4.431	0.301	1	0.58
Canopy height	-2.763	1.897	2.122	1	0.15
Diameter at breast height	3.395	2.848	1.421	1	0.23
Average crown radius	0.372	0.994	0.14	1	0.71
Adjacent tree distance	1.953	2.327	0.704	1	0.40
Adjacent tree height	-2.659	1.771	2.254	1	0.13
Distance from road	2.372	2.147	1.221	1	0.27
Distance from light source	1.048	2.265	0.214	1	0.64
Distance from building	-3.147	1.953	2.597	1	0.10
Distance from food source	6.971	3.976	3.075	1	0.08
Distance from drainage	-9.222	4.718	3.821	1	0.05
Distance from other species roost site	-1.119	1.36	0.677	1	0.41
Human activity index in the point	**5.861**	2.886	4.125	1	0.04
No. of bird feeding areas	-2.329	1.828	1.622	1	0.20
Open area	1.723	1.911	0.813	1	0.37
Area under green	1.694	2.783	0.37	1	0.54
Built area	**4.162**	2.582	2.598	1	0.10
Crown density	4.515	3.244	1.937	1	0.16
Constant	-24.657	13.794	3.195	1	0.07

PCA derived relatively small number of components that can account for the roost site selection. The first two principal components accounted for 61.3 percent of the total variance (Table 5.8). The first and second component explained a variation of 44.49 and 16.79 percent respectively. The first component was positively loaded with tree height, bole height and crown radius. The second component loaded with crown density and tree species. The factors highly correlated with these two components were those that directly related to roost tree selection.

Table 5.8 Principal component analysis (Varimax Rotation) explaining roost site habitat variables at microscale. The highest correlations with their respective Principal components were given in bold.

Roost tree and habitat variables	PC I	PC II
Tree species	-0.578	0.552
Tree height	0.942	0.049
Bole height	0.836	0.024
Canopy height	0.546	-0.219
Diameter at breast height	0.569	-0.358
Crown radius	0.708	0.212
Crown density	0.163	0.831
Eigenvalue	3.11	1.17
Variance explained (%)	44.49	16.79
Cumulative variance (%)	44.49	61.29

5.6 Discussion

5.6.1 Pre roost and roost behaviour

The birds aggregated at the roost were typical for their restlessness during the pre roosting activities (Eiserer 1984) such as feeding, calling and mud bathing. The behaviour was supported by many studies as pre-roost gathering is an aggregation of birds in foraging area which functions as a supplement to the day time territory or the diurnal activity centre and minimize the distance from supplemental foraging area to the communal roost (Caccamise and Morrison 1986, Stouffer and Caccamise 1991, Caccamise et al. 1997). House Sparrows showed pre roost aggregations. During the initial stage of flock aggregation most of them were engaged in feeding and mud bathing, then moved to elevated places such as building roofs and electric lines. While the flock movement (hovering) started prior to roosting, the individuals from these elevated areas joined the flock. It is found that occupying the elevated area maybe to get higher visibility of the flock movement and to attain flock synchronization (Schmitt 1994). Moore and Switzer (1998) also monitored the same behaviour in pre roost aggregation of the American Crow, *Corvus brachyrhynchos* in California. In the current study it is observed that the number of hovering was higher in large populations. This may be a technique to get the attention of the large population spread around on the site for roosting.

The last flock entry to the roost tree was three to four minutes just before the local sunset. Thus light condition may be an influencing factor for the departure of the flocks to their roosts. As suggested by Krantz and Gauthreaux (1975) and Schmitt (1994) the day-to-day variation in the time and the initial arrival of birds at the roosting site and time for entering in the roost tree is greatly influenced by the daily solar radiation impinging on the bird. In the case of Sparrows the last flock entry to the roost tree was highly depended on the time of local sunset. This view has been supported by Bliese (1955) who reported as light intensity and cloudiness being the main factors correlated with roosting behaviour.

5.6.2 Roost population

From the study it is observed that the Sparrows were not successful enough to find roost sites in suburban areas. Disturbances such as distressing noises and movements from the construction sites, loss of roost trees by cutting and pruning frequently made movements of Sparrows from place to place. Generally garden planters prefer exotic attractive plants and proper maintenance by pruning, which may not give the birds appropriate shelter for roosting (Donald 2006). Similarly the roost tree loss is also one of the important factors as the suburban vegetation is always under threat because of developmental activities (Shaw et al. 2008). As a consequence, they choose places of poorer quality, where they are more prone to threats (Bokotey and Gorban 2005). Compared to the urban cores of the city, developmental activities happen at a higher scale in the suburban areas because of urban sprawl and suburbanization (Hua and Pei 2005) and as the ecological wealth of these areas are always be in predicament. A gradual decrease in urban roost population was observed in Gandhipuram and Ukkadam. There are many studies stating that the overall urban Sparrow population is under threat (Summers-Smith 2000, Khera 2009, Bokotey and Gorban 2005) because of various reasons. The current study also demonstrated a decline in the urban Sparrow population. In the villages roost population showed a mixed trend. In most of the roost sites the population maintained the same trend in the roost population. But almost all the large roost sites showed a decreasing tendency as observed in Kanuvai, Thadagam and Virapandi. The villages are considered as haven for viable Sparrow population, but the gradual decrease in the roost population of Sparrow ought to be taken seriously.

5.6.3 Roost and non-roost characteristics

In a suitable habitat, the birds are inclined to collect in fairly compact breeding colonies and communal activities such as nocturnal roosting, feeding and dust-bathing (Summers-Smith 1952). House Sparrow was not associated with any species during nocturnal roosting i.e., it used to roost with the same species. This may be to reduce the risk of competition and predation from other bird species.

The birds used to roost in comparatively smaller trees with less canopy density. This may be to avoid competition with other big bird species such as Crow and Myna. Generally such species use tall trees with high canopy density for roosting and nesting (Peh and Sodhi 2002). The height of the tree adjacent to the roost tree was also low compared to the non roost trees. This strategy may also help them to avoid the presence of other big bird species. The landscape around roost tree was having less green area than non roost trees. This may provide protection, since Sparrows may be able to effectively scan for potential predators (Peh and Sodhi 2002).

The roost trees were closer to roads. Protection from the predators may be one of the explanations for the birds roosting in highly urbanized and less vegetated areas (Peh and Sodhi 2002). The roost sites were associated with good artificial lights. The light levels during the night might enable Sparrows to detect approaching predators or humans. A study conducted by Gyllin and Kallander (1976) noted that Jackdaws first initiated roosting in the centre of Orebro, Sweden, when street lighting was introduced in the 1930s.

The proximity of roost sites for food centres was identified as one among important factors in roost site selection of Sparrows. House Sparrows mostly depend on scraps of human refuse as a food source. The food leftover from uncovered waste dumb and waste bins also acts as an important feeding ground for them (Bokotey and Gorban 2005). Similarly nearness to the direct and indirect food centres is one of the important factors for choosing a roost site. This has been observed in European starlings (*Sturnus vulgaris*), Common grackles (*Quiscalus quiscula*), American robins (*Turdusm igratoriush*) Grey starlings (*Sturnus cineraceus),* Common ravens *(Corvus corax)* and White-vented mynas (Kuroda 1973, Caccamise and Morrison 1988, Engel and Young 1992, Peh and Sodhi 2002, Yap et al. 2002,).

Bird feeding practice is an old custom in Tamil Nadu. After cooking food at home as a custom people offer some meal to birds. Similarly in most of the temples it is very easy to find the leftover of the offerings. Feeding as a practise in most of the temples, in turn would offer a potential feeding ground for the birds. In the study it is found that the bird feeding practice is also an important factor for roost site selection by the Sparrows as the number of feeding areas is higher in roost site than non roost site.

Summary

- The pre-roosting activities were observed in House Sparrows. Flock synchronization and hovering happened just before roosting. Prior to the roost tree entry a hovering display was also reported.
- During the hovering display each flock covered around 10-25 m radius circle around the roost point.
- Of the seven species of roost trees *Azadirachta indica* (n=8) was mainly used for roosting.
- Number of hovering made prior to the roosting was high in large populations.

- The suburban Sparrow roost aggregation has been usual with very less members and the groups continuously changed the roost site because of local disturbances such as loss of roost trees, pruning of the roost tree and construction activities near the roost sites.
- The Urban roost population was slowly decreasing over the years.
- In the case of village areas all the large roost population (Kanuvai and Thadagam) showed a decreasing tendency.
- The hovering display of the first roost flocks were reported at a mean of 11.75 minutes before the local sunset timings. The entries of the last flock to the roost tree were reported with a mean of 6.37 minutes, before the local sunset timings. It is noted that local sunset timing was affecting the first flock entry to the roost tree (R^2=0. 499, p > 0.001).
- Local sunset timing was affecting the first flock entry to the roost tree.
- The birds roosted on comparatively smaller trees.
- The adjacent tree was smaller than the roost tree. The roost trees were found comparatively closer to the buildings and roads.
- The roost trees were found closer to bird feeding areas and to the other food sources such as drainage (3.74 m), bus stand (27.39 m) and temples (13.47 m).
- Near to the roosting trees the human activity index was high and there were less green areas surrounding the roosting tree (17.22%).
- To examine the roost site preference Logistic regression was performed. Variables like distance from food sources, HAI and built area would have increased the chance of selecting a roost site would have affected the roost site selection.
- PCA showed first component to have a positive loading with tree height, bole height and average crown radius. The second component was loaded with crown density and tree species.

Chapter VI

Plausible threats to the House Sparrow *(Passer domesticus)* population

6.1 General introduction

In the last century humans have changed Earth's ecosystems (Alberti et al. 2003) in an alarming pace by controlling and consuming resources (Vitousek et al. 1986), altering habitats and species compositions (Brown et al. 2005, McKinney 2002). It is estimated that between one-third and one-half of Earth's landscapes have been altered by human actions (Vitousek et al. 1997). Birds are an often used taxonomic group to investigate the ecological effects of human-induced landscape because of their great abundance, diversity and functional importance, and the ease with which they can be sampled (Bibby 1998, Das 2008). Birds respond to a number of structural and functional elements of the environment based on a diverse array of microhabitat requirements (Taylor 2008). The urbanisation and other anthropogenic factors often lead to direct and indirect impact on the House Sparrow population. Urban development causes habitat loss (Czech et al. 2000), local extinction rates and frequently eliminates the large majority of native species (Vale and Vale 1976, Marzluff 2001). Very little has been done in order to foretell the influence of urban expansion on wildlife and to develop management strategies aimed at diminishing these impacts (Hadidian et al.1997, Grimm et al. 2000). The current chapter is aimed to provide a baseline data on the direct and indirect factors which can affect the House Sparrow population such as; homogenization, urban heat island (UHI), intra and inter specific competition and the impact of cultural festivities which can affect the House Sparrow population which can affect the House Sparrow population.

A great conservation challenge of urban growth is the replacement of the species. In the urbanized area the species richness and abundance decreases as the built up area engulf the natural patches. This replacement constitutes the process of biotic homogenization that decreases the biological uniqueness of local ecosystems (Blair 2001). Physical homogenization is also a serious concern in this regard. When it comes to the urban landscape, the more homogenized built up area dominates and the construction pattern will also become distinctive. For example the concrete roof type buildings dominate the city and may indirectly affect the nesting sites of House Sparrows as it provide a lesser amount of nesting space for the House Sparrow. Such homogenization may seriously affect the feeding and roosting sites of the bird and may change the bird's tolerance limit. It appears that progressive urbanization has resulted in the replacement of many species by a smaller number of widespread and successful species that thrive in urbanized habitats. This process of a few 'winners' replacing many 'losers' in disturbed systems has been termed 'biotic homogenization' and has become increasingly recognized as a serious threat to global diversity, resulting in ecological communities that become both more pauperized and more similar (Baskin 1998, McKinney and Lockwood 1999).

According to Fernandez-Juricic and Jokimaki (2001) there are several features of urban ecosystems such as mosaic phenomena, specific disturbance regimes, and the 'heat island' phenomena that are expected to influence the dynamics and structure of urban populations and communities. The modification of the natural surface, the release of artificial energy and polluting materials into the atmosphere over the cities alter the radiation and energy balance in the urban environments (Unger and Makra 2007). Urban heat islands refer to the elevated temperatures in built up areas (sidewalks, buildings and roads) compared to more rural surroundings (Unger and Makra 2007), which will trap heat energy during the day and let it out slowly at night (McKinney 2002). This causes two types of heat islands, a surface heat island and an atmospheric heat island respectively (Akbari 2005). The conversion of agricultural/forest land into built area creates warmer areas because concrete material has less albedo in comparison to natural landscape, lesser heat capacity, and more retention capacity and thermal conductivity. Hence densely built up area is responsible for more intensity of heat and leads to high energy use, subsequently intensifies UHI. It affects air and soil pollution, soil compaction, soil alkalinity, average ambient temperature and average annual rainfall. The UHI can greatly affect animals also especially which survive in the urban area. It is already reported that the species tend to avoid such UHI or it leads to local extinction (Ayodeji 2009). In such case it will be miserable to lead a life in the urban premises as the bird has to tolerate added stresses beyond its behavioural plasticity, driving them to move out or perish.

Competitive interactions between different species may lead to suppressed breeding of one or another species (Smith 2006). Nest site selection by birds is a critically important life history trait as competition for suitable sites can be intense (Brightsmith 2005). The reproductive success of birds depends largely on environmental factors, levels of predation, intra and inters specific competition and food availability (Martin 1995). The nest site competition is very high among the cavity nesting species (Newton 1994). Long term competition for resources may cause local extinction of the weaker species (Marzluff 2001).
House Sparrow nests on small holes, cavities and eaves (Khera et al. 2009) in the buildings. In the current study, it was observed that Sparrow faced a considerable threat from the

species such as Squirrel and Rat especially for nest sites, mainly on the artificial Nest boxes. Such severe competition can cause local elimination of the species. In the present study the competitors for the artificial nest site provided for House Sparrow were monitored. The reduction in food-supply may be one of the variables causing declines or local extinction of avian fauna (Martin 1995). In the urban system where the resources are limited the competition can lead to a miserable condition. The inter-specific feeding association was noted as a measure of competition.

Anthropogenic factors are considered to be an important reason of loss in nest sites of House Sparrow. In that context cultural festivals has significant impact. Pongal is such an event widely celebrated in Tamil Nadu during the month of January. The celebrations will continue for four days. People observe the first day of Pongal (otherwise known *Bhogi*) by bonfire of old unusable items. The festival is celebrated widely in the rural areas with all its fun, festivities and frolics. As part of the Pongal festival they clean, plaster and paint the buildings, which are the main nest provisioning sites of the Sparrow. This would lead to loss of nests and nest sites. Though the House Sparrows will start reconstruction of the nests within a few days after removal, it can arrest the breeding activities for a small but crucial duration and also cause higher energy requirements for the bird to build a new nest. People used to decorate their houses by hanging the bunch of leaves (*Mangifera indica* and *Azadirachta indica*) and flowers (*Aerva lanata* and *Cassia auriculata*) on the roof support and also in the small crevices seen in the roof which in turn disturbed nests.

6.2 Objective

- Examine major plausible threats to the House Sparrow (*Passer domesticus*) population in the study area

6.3 Methodology

6.3.1 Homogenization

The landscape change due to urbanization in the study area was analysed by taking six each 300 x 300 m quadrat from the village, suburban and urban. Each quadrat was selected in order to have at least one intensive study point. The area under different land use characteristics was measured using digitized images of Google earth and the EasyAcreage V1.0 software to measure the area. The land use was categorized as open land (including small patches of bushes), cultivated lands, tree cover, and built up area based on the roof types as tiled, concreted and others. Factors such as trees (count) and herb (1x1 m, quadrat) were measured from the intensive study points. Other variables as the number of natural fencing or hedges (tree/shrub stumps) that are more than three meters long and home gardens (3x3 m minimum) were also noted. The artificial lawns and gardens were not taken into account.

6.3.2 Atmospheric Temperature

Temperature data for the past thirty years of Coimbatore (11°0′45″N 76°58′17″E) is acquired from the database of the National Climate Centre (1969-2005), Indian Meteorological department, Pune, India. In the current study an attempt was made to monitor the variation in air temperature and the House Sparrow population change.

6.3.3 Competition

Nest monitoring was conducted from 2005 December to 2007 December in one of the intensive study sites. Data from nine bamboo boxes, 11 wooden boxes and 12 mud pots were used together with 80 (selected based on the accessibility to monitor) naturally existing ventilations inside the buildings were used for the present analysis. Population monitoring was done following point count (50m) from 2005 - December to 2008 - December conducted from 06.30 – 11.00 AM. The population survey and species occupancy in the nest sites were monitored once in two months and also monitored the type and arrangement of nest materials to confirm the species occupancy.

Data on feeding habitat and inter-specific associations were collected from the 35 intensive study points described earlier i.e. from village, suburban and urban area. The feeding micro habitats were classified as open land with greenery, drainage and surrounding, waste dump and surrounding, road sides and home premises. The associated species monitored were House crow *(Corvus splendens),* Jungle crow (*Corvus macrorhynchos),* Common myna (*Acridotheres tristis*) and Rock pigeon (*Columba livia*) and the niche overlap was estimated. Feeding observations was taken following direct observation (Pettingill 1985). The observations made for a minimum duration of five minutes only was considered for further analysis.

6.3.4 Cultural festivities

The present study monitored the effect of the major festival in the area, namely Pongal, on the nesting behaviour of House Sparrow at the 35 intensive study points. Observations were made from December 15th - January 15th consecutively for three years as the restoration works associated with the festival will be high during the end of December.

Based on the functional use, the buildings were categorized as houses, shops and other buildings (office, water tank, street light, well etc.).

6.4 Statistical analysis

Feeding niche Overlap between species was calculated using Pianka's overlap index (Pianka 1973).

Pianka's overlap index $$)\mathrm{i}) = \frac{\sum p_{ij}\, p_{jk}}{\sqrt{\sum p_{ij}^{2} p_{jk}^{2}}}$$

Where, P_{ij}, P_{jk} = Proportion of individual of species j and k occupying the i^{th} resource category. Average niche overlap in each niche dimension and altitude category was calculated as the mean of all inter-specific overlaps. Overall niche overlap among each belt transect was obtained as an average of three resource dimensions. Many studies considered different overlap values greater than 0.90 as "nearly complete" and 0.75 or greater as "very high". In the present study, niche overlap value was categorized as low Φ 0.01-0.33, medium Φ 0.34-0.66 high Φ 0.67 -0.99 and complete Φ = 1.

One-way ANOVA was used to test the landscape variables across the urban gradients.

6.5 Results

6.5.1 Homogenization

6.5.1.1 Landscape level

Towards urban (56.87%) and suburban area (51.94%) the landscape are becoming more homogenized with concreted area becoming more predominant. The village was dominated by open lands (56.88%) followed by cultivated area (13.41%) (Table 6.1). In urban and suburban area the cultivated lands were not recorded. The landscape variables significantly varied across the gradients i.e., urban, suburban and village (F=3.61, df=5,12, p<0.05).

Table 6.1 Percentage variations in the amount of different landscape

Landscape variables	Urban (%)	Suburban (%)	Village (%)
Tiled roof	15.48	4.29	5.98
Other roof types	4.40	0.00	0.84
Concreted area	56.87	51.94	12.29
Tree cover	13.77	26.21	10.60
Cultivated lands	0.00	0.00	13.41

Open land	9.47	17.57	56.88

6.5.1.2 Vegetation

The species richness of herbs was high in the village (19) followed by suburban (10) and urban (9). The species richness of trees in the village was high (25), followed by suburb (16) and urban (14). The highest number of home gardens was in the village (103) followed by suburb (56) and urban area (7). Similarly the number of natural fencing was also high in the village (47), followed by suburban (16) and urban area (11).

6.5.2 Urban Heat Island

The average temperature showed an increasing tendency (Figure 6.1). From 1969 to 1984 there was a gradual decline and later it showed an increasing tendency. The highest temperature was recorded in 2004. In the urban and suburb areas under study, the landscape was dominated by concreted area which would be responsible for the local increase in temperature (Table 1.1). In the current study, it was observed that the House Sparrow population decline was higher in urban and suburban area compared to village locations (*Chapter **3***).

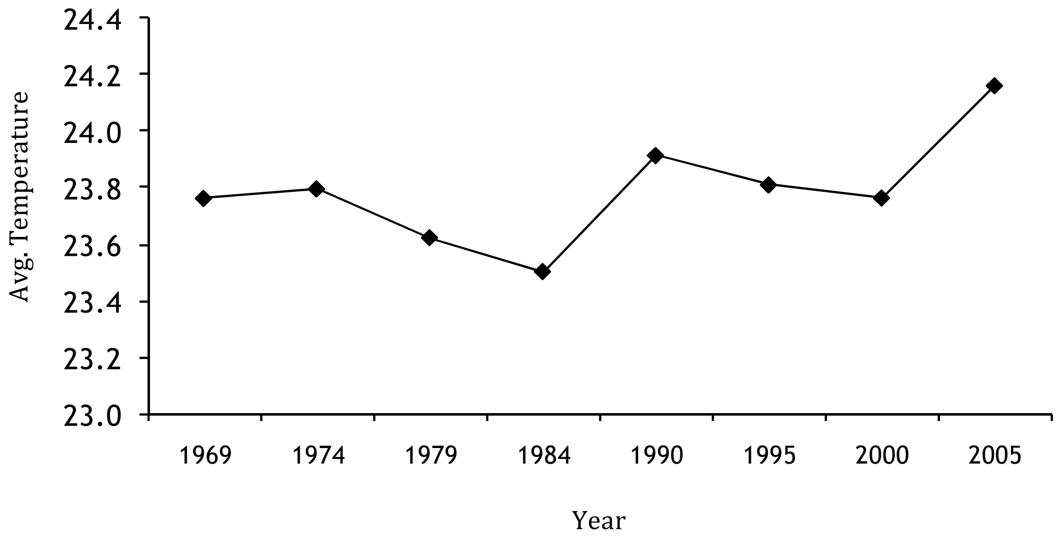

Figure 6.1 Temperature of Coimbatore during the last thirty years

6.5.3 Competition

6.5.3.1 Nest site competition

The experiment was conducted in SACON campus. In December 2005 the Sparrow occupied all types of nest site provisions (Figure 6.2). Of these, the highest number of nests (n=9) were built in ventilations followed by mud pots (n=6) and bamboo box (n=5). In 2006, Sparrow nests were present in all types of nest site provisions but the total number of nests was considerably lower and the total occupied nests were eleven (Figure 6.3). Similarly the nest occupancy by the Squirrel increased from 21 (2005) to 28 (2006). In December 2007, House Sparrow completely failed to establish nests in the area (Figure 6.4). The nest occupancy by Squirrels (37) and rats (5) increased considerably in 2007. The number of abandoned nests was also increased (n=10). The population of House Sparrow during 2006 was gradually declining, the highest being only 14 individuals. During 2007, the Sparrows were absent from the area except by the end of the year (Figure 6.5). Only three individuals visited the place during November-December. But they did not attempt to occupy any of these nest sites. The population was completely disappeared from SACON campus during 2008.

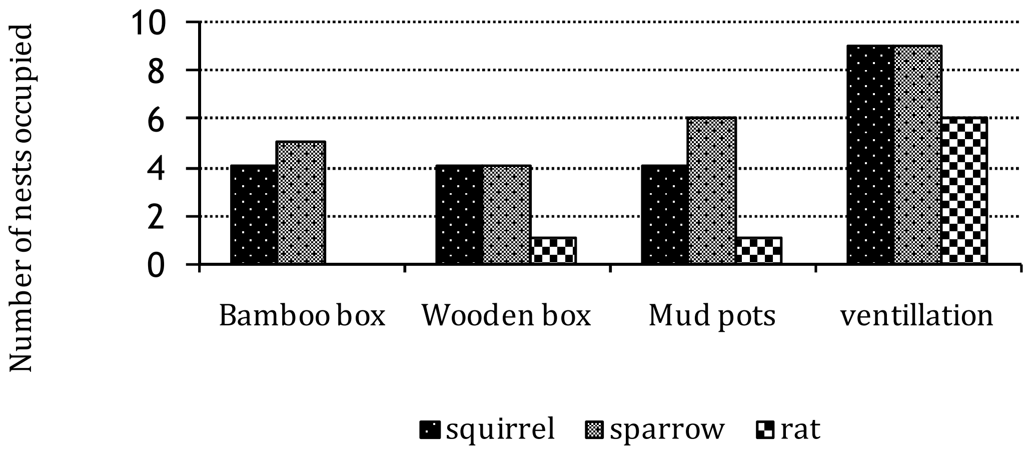

Figure 6.2 Nest site occupancy by Sparrows and other species during 2005

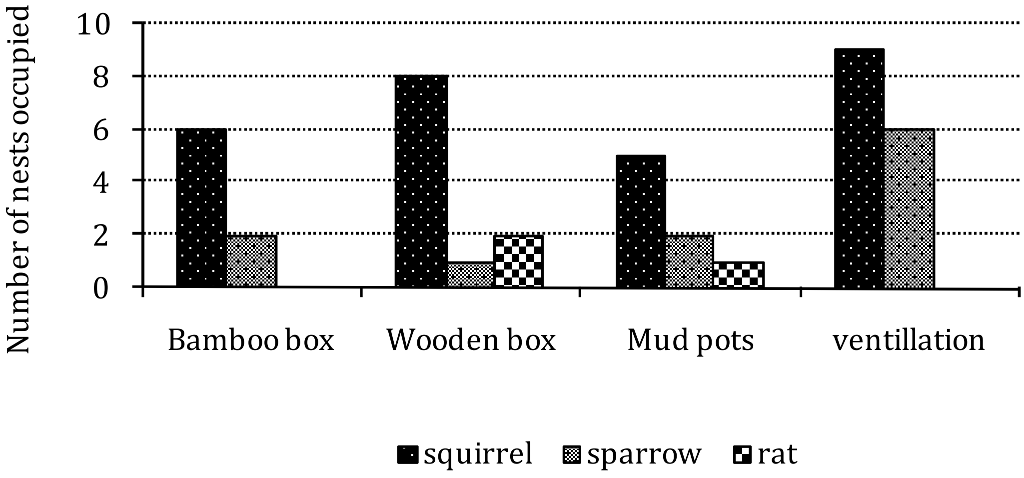

Figure 6.3 Nest site occupancy by Sparrows and other species during 2006

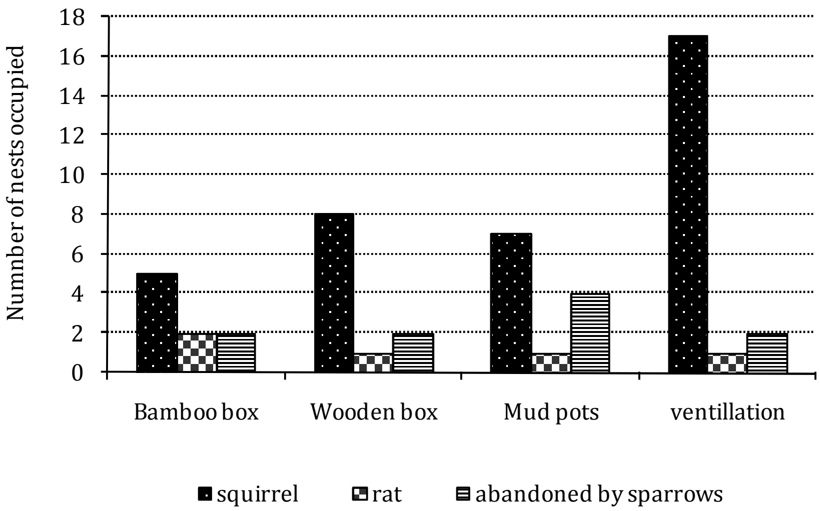

Figure 6.4 Nest site occupancy by other species during 2008

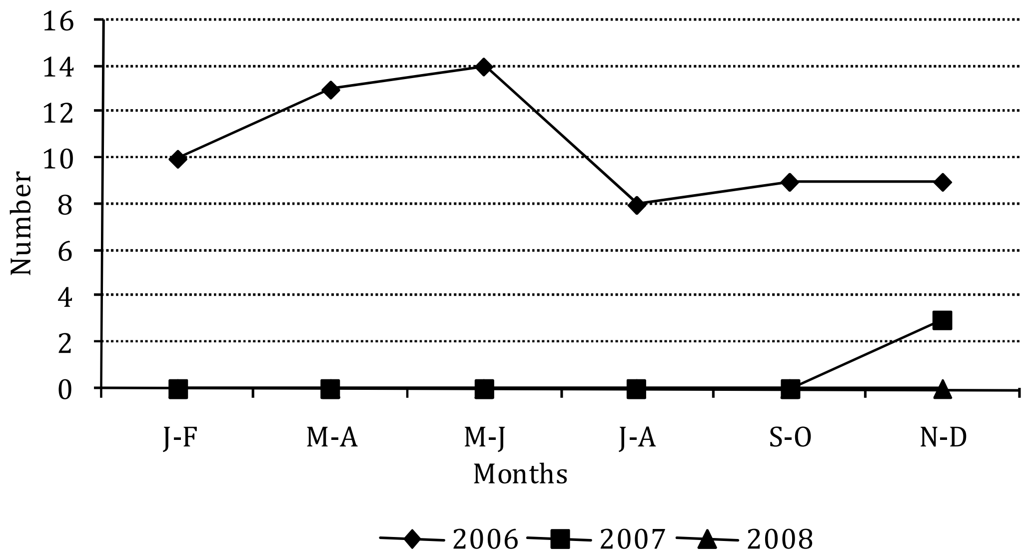

Figure 6.5 House Sparrow populations at SACON campus

6.5.3.2 Associated species in the feeding ground

The niche overlap in the study points of the House Sparrow during feeding was calculated. The associated species were House Crow *(Corvus splendens),* Jungle Crow (*Corvus macrorhynchos),* Common Myna (*Acridotheres tristis*) and Rock Pigeon (*Columba livia*). The niche overlap was high with Rock pigeon (Φ=0.67), followed by Common Myna (Φ=0.32), Jungle Crow (Φ=0.27) and House Crow (Φ=0.27).

6.5.4.3 Cultural festivities

Altogether 93 nests were monitored, of which 59 were removed during the Pongal festival. Of the 93 nests 25 were from houses, 21 from shops and 12 from buildings grouped under other category. Nest removal was high during Pongal in 2006 followed by 2007 and 2008 (Table 6.2). During 2007 and 2008 the nests associated with the houses were found more prone to removal (Figure 6.6). Similarly in 2006 the nests removed from shops were high.

Table 6.2 Year wise nest removal during Pongal (Dec15th-Jan15th)

Year	Total number of nests	Removed nests
2006	33	22 (66.67%)
2007	29	17 (58.62%)
2008	31	20 (64.51%)

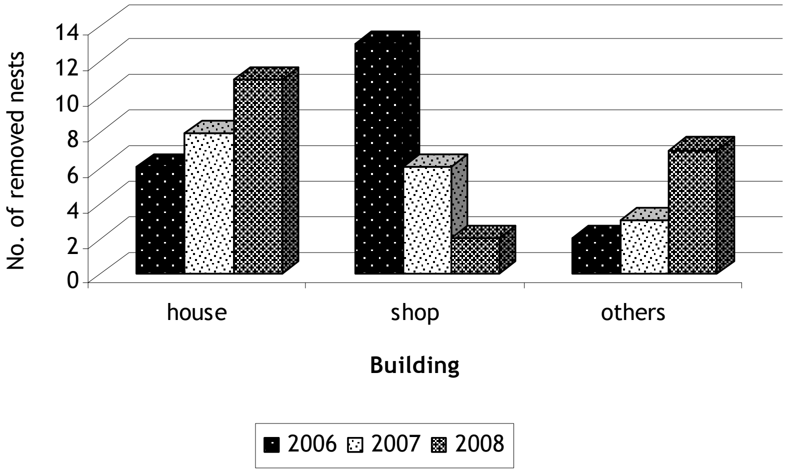

Figure 6.6 Nest removed from different types of buildings (2006-2008)

The nest removal was high in the village (n=56) followed by suburban areas (n=3). In total, 43 eggs from the village and three eggs from suburb were lost during the nest removal associated with Pongal.

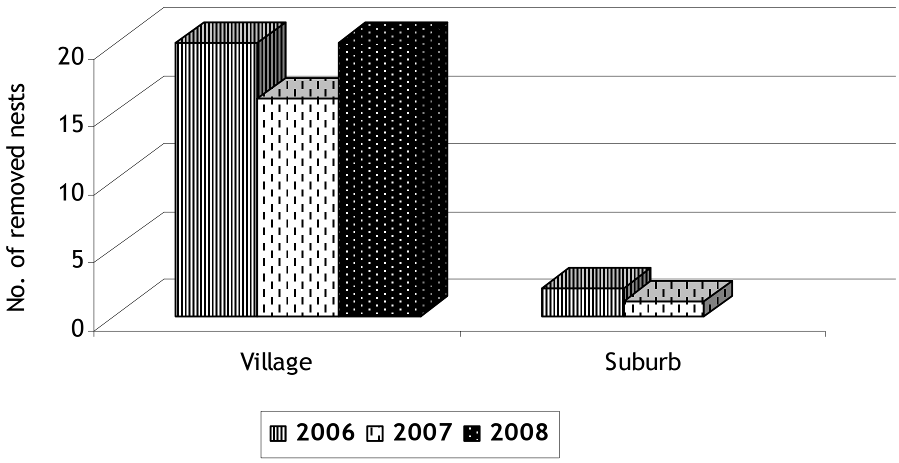

Figure 5: Nests removed during the festival from village and suburban (2006-2008)

6.6 Discussion

6.6.1 Homogenization

An extensive urbanization process enhanced faster developmental activities, which in turn caused a homogenized landscape. Similarly, the replacement of natural species with cosmopolitan species, was gradually homogenizing the global fauna and flora. As the city grows it will impart much pressure on suburban and village area. The open and cultivated lands will be under pressure for land conversion. In the present study village area holds high percent of open and cultivated lands. Both the urban and suburban areas have more homogenized landscape with prominent built up areas. House Sparrow mainly depended on vegetation (grasses/bushes/small trees) for preening, roosting (Dandapat et al. 2010, Tobolka 2011) and feeding (Vincent 2005, Summers-Smith 2003). A study in UK predicted that a small increase in the proportion of flats would be enough to cause fast declines in House Sparrow abundance (Chamberlain et al. 2007). Wilkinson (2006) found that the house sparrow occurrence was positively related to native bush cover and Heij (1985) suggested that the amount of green space was an important factor to determine the House Sparrow density. The homogenized built up area would not be able to support vegetative components such as trees, herbs, home gardens and natural fencing/hedges. Such a scenario obviously will lead to a lack of insect food source for the birds. Several studies explained that the House Sparrow chicks were more likely to starve if their diet contained a high proportion of supplementary food (Anderson 2006, Vincent 2005, Bokotey and Gorban 2005, Summers-Smith 2003, Hole et al. 2002, McIntyre 2000, Magrath 1991 and Garnet 1981). Similarly Vincent (2005) also mentioned that House Sparrows have more breeding success in areas containing a good amount of deciduous shrubs and relatively little concrete. The current study also deals a similar state with respect to breeding success in village areas, having a high amount of vegetation and less concrete space compared to suburban and urban areas.

6.6.2 Urban Heat Island (UHI)

The decline of House Sparrow can be a cumulative effect of different factors including the process of UHI formation. It was observed that the average temperature of the urban area showed an increasing tendency. The reason may be the growing large-scale concreted landscapes in the urban and suburban gradients (Unger and Makra 2007). In the current study, urban and suburban area showed a homogenized landscape dominated by concreted areas. The urban areas tend to have higher air temperatures than their rural surroundings as a result of gradual surface modifications that include replacing the natural vegetation with buildings and roads (Akbari 2005) and structures that prevent easy air movement and dispersal heat waves. The surface of buildings and pavements absorb solar radiation, become extremely hot, in turn warming the surrounding air. Detailed profiling of thermal pattern in cities was an urgent need to learn the process of UHI formation from the point of view of its ecological implications. Coimbatore being an industrialized city the urbanization associated with economic development was very high during 1980's-1990's. The large influx of people in search of jobs in urban and suburban area enhanced the process of urbanisation (City development plan- Coimbatore 2006). House Sparrow, being a sedentary species having a maximum home range of only about two km (Summers-Smith 1988, Vincent 2005), would find it difficult to survive in such environment of rather increasing temperature, different from the usual pattern.

6.6.3 Competition

In cavity-nesting species the breeding densities of birds are limited by the shortage of nest-sites (Newton 1994). According to Newton (1994) the shortage of nest-sites limits breeding density and may gradually influence the total population size. In the current case during the initial year (2005) Sparrows occupied all artificial nesting provisions such as bamboo box, wooden box, mud pots and ventilation. In 2006, the nests were built in all the provisions but the number was considerably lower than the previous year and it was reflected in population decline also. At the same time the nest occupancy of the squirrel increased in all those artificial nests. During 2007, the House Sparrow population completely vanished from the study point. But it was noted that the nest site occupancy of the squirrel and rats increased. The nest site shortage due to high competition could be a reason for House Sparrow decline in the site. Study of feeding association of the House Sparrow species shows that inter-specific competition was high with Rock Pigeon followed by Common Myna, Jungle Crow and House Crow. A study by Khera et al. (2009) also supports this as the House Sparrow showed a negative relationship with Rock Pigeon, Common Myna and House Crow. According to Vincent (2005) the Collared Dove *(Streptopelia decaocto)* and Wood Pigeon *(Columba palumbus)* would be the two most likely species to compete with House Sparrows for food and their rising population can be linked with Sparrow's decline (McCarthy 2003). Thus another plausible reason for restricted numbers of House Sparrow may be the competition from the sympatric common bird species.

6.6.4 Cultural festivities

The anthropogenic pressures are considered to be an important factor for species extinction. Human modifications of natural habitats changed the global distribution of organisms (Olden and Pofft 2003). Festivals are deeply rooted in our society and culture. It seems that in earlier days festivals did have relatively negligible or indiscernible impact on nature. The nest loss of House Sparrow during the Pongal festival, had considerably affected the population. Shaw et al. (2008) suggested that the redevelopment of the buildings may reduce the number of potential nest sites. In the current study redevelopment of the building such as cleaning and painting associated with the celebrations ends up in clearing away the nests from buildings. Similarly while plastering the buildings, the holes in the buildings are filled reducing the availability of potential nest site for Sparrows. Of the 93 nests that were observed, 59 were removed while cleaning and painting. During 2008 and 2007 the nests associated with the Houses were found more prone for removal. Similarly the active nests removed were high in village. This may be because in villages the celebrations associated with the festival are much more exuberant.

Summary

- The study area was more homogenized towards suburban and urban area, having more part occupied by concrete area.
- Due to lesser developmental pressure village was dominated by open lands (56.88%) followed by cultivated area (13.41%). The urban and suburban landscape is dominated by concrete area i.e., 56.87 and 51.94 percent respectively.
- The landscape variables such as open land, cultivated land, tree cover, concreted area, other roof types and tiled roof significantly varied along the urban gradient (F=3.61, df=5,12, p<0.05).
- Vegetative components such as herbs, home gardens and natural fencing/hedges showed a decreasing tendency in suburban and urban areas. Vegetative components are important as it could provide food and shelter for them.
- In the study area the temperature showed an increasing tendency from 1969 to 2004. The population of Sparrows in the urban and suburban centres has shown a trend of decrease compared to village areas.
- Squirrel and Rats were the major competitions for the nest site.
- The feeding niche overlaps between the Sparrow and other four species such as Rock pigeon, Common myna, Jungle crow, and House crow also adds to the factors for the decline of population.
- Sparrow's niche overlap with Rock pigeon (Φ=0.67) was the highest followed by that of Common Myna (Φ=0.32).
- Cleaning and painting of buildings during festivals seriously affected the population.
- Of the 93 nests monitored during the study, 59 were removed during the Pongal festival time.

Chapter – VII

Recap of findings, future prospects and conservation measures

This study, in its limitations of spatial contours, comes out with the following salient findings which are discussed below in view of conservation measures for the target species in the urban ecosystem.

- Coimbatore city is characterized by relatively high population density with an average annual growth rate of 2.7 percent. Industries such as textile, foundry and small scale engineering works to enhance the process of urbanization and caused significant inflow of workers from different parts of the nation. The land cover land use changes of the study area over a period of 15 years (1989-2004) showed a 58.2 percent urban growth.
- The House Sparrow population fluctuation was high in suburban and urban area compared to the village. The provisions for feeding such as waste dumps, water sources, hotels, provision stores and weedy patches were the determining factors for the occurrence of the Sparrows. Shutter hood and other nest anchoring structures were also contributed to this. The number of weedy patches and the shutter hood ($F=9.717$, Wilks'$\lambda=0.921$, $p<0.001$) discriminated class I (≥10 individuals) and class II (≤11 individuals). Variables such as number of provision stores, food, hotel, water sources and shutter hood accounted for the use of a site by the birds.
- The Sparrow is a discrete breeder; round the year with a peak in April followed by a smaller peak in January. The number of Sparrow nests was positively correlated with maximum temperature ($r=0.455$, $p>0.05$). Eight different nest substrata such as roof support, shutter hood, holes in the building, ventilation, sign board, switchboard, light cover and holes in the pipe were used by the birds for making nests. Mostly used height class for nest construction was 01-03 m followed by 03-06 m and 06-09 m. The factors such as the nest placement at different buildings, number of vehicles, bush cover and distance from drainage were significant in nest-site selection by the birds. The variables such as the number of houses, distance from water sources, bush cover percentage and roof type were discriminant factors between the nest site and non nest site. There were two peaks in the nest building activities (10:00 – 11:00 and 16:00 -17:00 hrs) and contribution of female was more (64.96%) than males (35.04%). The Sparrow nests were predominantly made of plant matter (91%). Animal matter (1%) and lining materials such as paper, plastic

pieces (8%) were also used. The Sparrow chick's diet in village is dominated by insects and cooked foods are also fed to the chicks. The apparent nest success was high in 2006 followed by 2007 and 2008. Urban area had the least nest success compared to suburbs and village areas. Many cases of nest desertion of the birds were reported, of these anthropogenic disturbances appeared to be the main reason for the nest abandonment.

- Flock synchronization and hovering display was observed just before the roosting. The number of hovering display was high in large roost population. The suburban roost aggregation was usually with very less members and groups were continuously changed the roost site possibility because of the local disturbances. For roosting Sparrow used comparatively smaller trees with less canopy density and DBH. Unit change in the variables such as number of trees in the point, distance from food source, Human Activity Index (HAI) and built area increased the odds of ratios of selecting a roost site. Factors such as tree height, bole height and average crown radius accounted for the roost site selection.
- Landscape homogenization is experiencing at a faster rate in the urban (57%) and suburban (52%) area with concrete constructions. The vegetative components such as herbs, home gardens and natural fencing/hedges were showed a decreasing tendency in suburban and urban areas. The average temperature in the area during 1969 to 2004 has shown an increasing tendency. Squirrels and Rats were the major competitors for the nest site. The feeding niche overlaps with the Rock pigeon (*Columba livia*) was high (Φ=0.66). Of the 93 nests monitored 59 nests were removed due to the building renovation as part of the native festival period.

Recommendations

Of late the urban birds have been in the limelight of scientific attention, especially in the wake of population decline of some of the common bird species. The present study examined the Sparrow population from an ecological perspective and found that there is a notable decrease in the species abundance and qualitative and quantitative degradation in the habitat in the study area. The study brings out the following recommendations.

The investigation on the House Sparrow with possible combinations of habitat specificity, nest and roost site fidelity are envisaged to have an increased resolution of the prevailing information on the habitat, which need to be preserved. Loss of roost tree has become very common in the suburbanized area where the landscape homogenization is happening in a faster rate. Such roost sites can be identified after survey and prioritised for conservation measures by not allowing cutting and pruning. To some extent we can increase the roost tree availability by planting the trees, which were used by the sparrows for roosting as given in the study. The concept has to be tested and validated across different areas with the different degree of the habitat modifications so as to elucidate the species ecological preference and their role played in the ecosystem.

To conserve any species it is very essential to have detailed information on the population status, distribution and ecology. Long-term studies covering wider geographical areas across the species' distributional range at landscape level are recommended to have a better inference on the magnitude and spatial extent of the decline. As in the case of many other cities in India Coimbatore also does not have any authentic record on the same. Hence detailed and wide study on the population dynamics have to graduate from the regional level to the landscape level, which in-turn would help to unwrap the intrinsic changes and variations in the urban ecosystem. In future the studies can be extended by including more environmental variables such as Urban Heat Island (UHI), homogenisation (biological and physical), Noise pollution and Allee effect. The protocol developed in this study for survey and monitoring has to be implemented in all the different regions of the area.

House Sparrow being a synanthropic bird, the plausible threats will be varying according to the location. The culture (bird feeding), festivals (pongal) and the building architecture had significant difference along the urbanization gradient. Hence, species conservation plan should be formulated by considering these local scenarios.

Extension programmes such as awareness creation for the students, shopkeepers, public, town planners and higher officials has to evolve to advanced levels. It was found that the participatory conservation programmes initiated during the present study such as Urban Bird Monitoring Programme and Spot the Sparrow Programme, have contributed greatly towards the creating an ecological consciousness in the common birds and Sparrows populations in the region.

Urban habitat conservation subtle changes in disturbance by way of modified architecture have had significant impact on House Sparrow population. This work has provided the start for infusing the concepts of House Sparrow conservation into the management plan of the area. As mentioned in the study number of shutter hood, open ventilation were high in Sparrow used areas. Similarly in breeding sites number of roof extensions and shutter hoods were high as it provides nesting sites. The study identified these building characters may function as a crucial for the Sparrow. It can be suggested for the local conservation practices and also among architects and local people.

Translating and applying the results of this scientific research into practical conservation guidelines that are executable by conservation practitioners and/or by policy makers is essentially the next step. An effective conservation action plan has to be made, in accordance with the results of this study so as to implement mitigation measures.

Clearly more research is necessary to determine how the disturbance of both natural and anthropogenic origin impacts the House Sparrow populations at the landscape level, and whether the effect is amplified by the co occurrence of both. Well-versed urban management decisions can be made only with a more refined understanding of how the disturbance impacts the target communities at local and landscape level. Bird species with wide distribution have been thought capable to make use of human-modified environments. The current study unequivocally showed that the population fluctuations were higher in urban and suburban habitats. These findings highlight the importance of an urban refuge approach to ecological monitoring.

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Appendix 1. Roosting tree species of Sparrows along Village and Urban areas

	Area	Roosting tree species	2006						2007						2008					
			Roost population																	
			J-F	M-A	M-J	J-A	S-O	N D	J-F	M-A	M-J	J-A	S-O	N-D	J-F	M A	M-J	J-A	S-O	N-D
Village	Kanuvai	*Thespesia populnea*	90	90	85	100	105	90	95	80	90	85	90	80	85	85	80	75	70	70
	Kanuvai	*Aegle marmelos*	12	16	10	15	13	15	13	17	16	14	16	14	14	13	12	12	13	13
	Kanuvai	*Psidium guajava*	25	20	25	28	26	24	25	20	21	22	22	23	21	19	24	23	26	22
	Kanuvai	*Azadirachta indica*	14	10	13	12	14	17	12	12	15	16	15	13	14	14	13	15	15	13
	Thadagam	*Azadirachta indica*	11	13	15	16	14	13	15	19	15	14	20	16	17	14	16	19	20	15
	Thadagam	*Thespesia populnea*	95	90	100	85	95	90	90	95	95	85	80	80	75	70	80	75	70	70
	Thadagam	*Azadirachta indica*	17	18	14	21	18	19	19	20	20	18	18	20	17	17	16	19	18	18
	Virapandi	*Thespesia populnea*	17	18	20	17	15	14	21	18	19	19	20	20	18	17	14	16	19	20
	Virapandi	*Azadirachta indica*	24	27	26	22	21	22	24	23	22	23	23	22	20	20	21	22	24	23
	Virapandi	*Azadirachta indica*	11	13	15	16	14	13	15	19	15	14	20	16	17	14	13	15	19	15
	Virapandi	*Thespesia populnea*	17	18	21	20	17	18	18	19	20	22	21	18	21	20	17	18	18	20
	Virapandi	*Michelia champaca*	11	13	15	16	14	13	15	19	15	14	19	15	14	20	16	17	14	17
	Uchayannur	*Azadirachta indica*	27	25	26	30	19	22	27	25	26	30	24	27	26	22	21	22	18	20
	Uchayannur	*Azadirachta indica*	16	10	15	13	15	13	17	16	14	16	14	16	14	16	14	16	14	16
	Alamaramedu	*Pithecellobium dulce*	*	*	*	*	*	*	18	22	20	20	18	21	20	24	23	22	23	23
	Alamaramedu	*Azadirachta indica*	*	*	*	*	*	*	12	11	10	12	11	10	8	9	12	13	9	9
Urban	Ukkadam	*Thespesia populnea*	12	10	13	9	10	10	11	12	10	7	11	7	9	7	8	6	8	7
	Gandhi park	*Prosopis juliflora*	16	18	13	15	17	15	14	12	11	13	12	11	10	11	9	10	11	9

* roost site was not established

Appendix 2. Herb species recorded from the study area

Sl.No	Herbs	Family
1	*Eragrostis amabilis*	Poaceae
2	*Amaranthus viridis*	Amaranthaceae
3	*Parthenium hysterophorus*	Asteraceae
4	*Eclipta alba*	Asteraceae
5	*Gomphrena decumbens*	Amaranthaceae
6	*Euphorbia geniculata*	Euphorbiaceae
7	*Eleusine indica*	Poaceae
8	*Cynodon dactylon*	Poaceae
9	*Malvastrum coromandelianum*	Malvaceae
10	*Alternanthera sessilis*	Amaranthaceae
11	*Lycopersicon esculentum*	Solanaceae
12	*Boerhavia diffusa*	Nyctaginaceae
13	*Dactyloctenium aegyptium*	Poaceae
14	*Mollugo pentaphylla*	Aizoaceae
15	*Ficus religiosa*	Moraceae
16	*Tridax procumbens*	Asteraceae
17	*Euphorbia thymifolia*	Euphorbiaceae
18	*Glinus lotoides*	Molluginaceae
19	*Amaranthus spinosus*	Amaranthaceae
20	*Euphorbia hirta*	Euphorbiaceae
21	*Portulaca oleracea*	Portulacaceae
22	*Momordica charantia*	Cucurbitaceae
23	*Cyperus* sp.	Cyperaceae
24	*Cassia auriculata*	Caesalpiniaceae
25	*Pithecellobium dulce*	Mimosoideae
26	*Chrysanthemum indicum*	Asteraceae
27	*Calotropis gigantea*	Apocynaceae
28	*Azadirachta indica*	Meliaceae
29	*Allamanda cathartica*	Apocynaceae
30	*Cyperus rotundus*	Cyperaceae
31	*Lantana camara*	Verbenaceae
32	Unidentified sp.	Apocynaceae

Appendix 3. Tree species recorded from the study area

Sl.No	Tree Species	Family
1	*Vitex altissima*	Verbenaceae
2	*Moringa oleifera*	Rubiaceae
3	*Cocos nucifera*	Arecaceae
4	*Azadirachta indica*	Meliaceae
5	*Mangifera indica*	Anacardiaceae
6	*Psidium guajava*	Myrtaceae
7	*Punica granatum*	Lythraceae
8	*Murraya paniculata*	Rutaceae
9	*Thespesia populnea*	Malvaceae
10	*Tamarindus indica*	Caesalpiniaceae
11	*Musa paradisiaca*	Musaceae
12	*Millingtonia hortensis*	Bignoniaceae
13	*Aegle marmelos*	Rutaceae
14	*Phyllanthus emblica*	Euphorbiaceae
15	*Prosopis juliflora*	Mimosaceae
16	*Averrhoa carambola*	Averrhoaceae
17	*Tecoma stans*	Bignoniaceae
18	*Michelia champaca*	Annonaceae
19	*Elaeocarpus sp.*	Elaeocarpaceae
20	*Albizia lebbeck*	Mimosaceae
21	*Delonix regia*	Caesalpiniaceae
22	*Cassia fistula*	Caesalpiniaceae
23	*Ficus religiosa*	Moraceae
24	*Ervatamia coronaria*	Apocynaceae
25	*Pongamia pinnata*	Fabaceae
26	*Polyalthia longifolia*	Annonaceae
27	*Phyllanthus acida*	Euphorbiaceae
28	*Ficus racemosa*	Moraceae
29	*Tectona grandis*	Verbenaceae
30	*Achrus sapota*	Sapotaceae
31	*Borassus flabellifer*	Arecaceae
32	*Casuarina equisetifolia*	Casuarinaceae
33	*Samanea saman*	Mimosaceae