



PART I

Study Of Urban Birds

CHAPTER I

TERRESTRIAL BIRD POPULATION OF VADODARA CITY

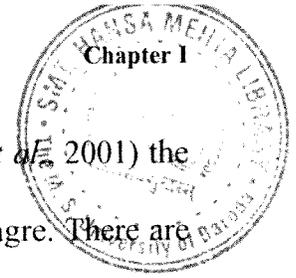
INTRODUCTION:

Urbanization is one of the major threats to the bird population. Under the tremendous pressures of urbanization the native habitats are lost, fragmented or modified. The native vegetation is affected and exotic species or ornamental plants get introduced (Strife, 2004). Here large areas of land are covered with concrete and coaltar thereby percolation of water to underground water table gets reduced. These result into a changed habitat that may retain in few original species of native plants. The changes divide an urban area into several micro habitats and produce strong effects on flora and fauna. Urbanization has been described by Marzluff *et al.* (2001) as: *“In developing world increasing populations move away from traditional city centers and cause city to grow resulting in strong gradient of human density of suburbs. These gradients of suburb become increasingly complex and take on urban characteristics. These processes are collectively known as urbanization.”*

Birds form one of the major fauna in urban area. Besides they are also known as one of the most important indicators of health of an ecosystem as they respond to secondary changes resulting from primary causes (Koskimies, 1989). Because of their high mobility birds react very rapidly to changes in their habitats (Morrison, 1986). A relationship between habitat loss and habitat fragmentation has been related with decline in the density and number of bird species (Traut, 2003). Although the changes in habitat are the main cause of

species decline, the mechanisms causing fragmentation and the spatial distribution of resources act at different scales (Flather and Sauer, 1996). Reports indicate that urbanization favours few species but selects against most such that the avian community composition of urban environment differs dramatically from local natural environments (Jokimaki and Suhonen, 1993; O'Connell *et al.*, 2000). According to Traut (2003) the increase in urban development decreases the species richness and diversity but increases the density of birds. That is, some species of birds prefer human settlements while others are reduced in number by the urban development (Marzluff, 2001). In other word increased urbanization with the elements such as housing density, typically leads to an increase in avian biomass but a reduction in species richness (Lancaster and Rees, 1979; Clergeau *et al.*, 1998; Chace and Walsh, 2004). This relationship has been further emphasized by Clergeau *et al.* (1998) stating that the urban communities are dominated by few omnivore species which are able to adapt to the additional resources available to them in urban environment. However, graminivore species like pigeon adapt well to man made environments and are considered the most troublesome bird pest of cities and suburbs (Marsh and Howard, 1982). The anthropogenically manipulated landscapes can create heterogeneous environment attracting specialized species (Strife, 2004).

Urban environment with its concrete jungles, recreation parks and gardens of private premises do provide nesting and roosting habitats with additional food supplies provided by man. Though the number of studies that describe avian



responses to urbanization are immense and growing (Marzluff *et al.* 2001) the number of such studies in Asia and particularly in India are meagre. There are an estimated 961 resident land and fresh water bird species in the oriental region belonging to 66 families (Welty and Baptista, 1988). With migratory species, 1,225 species of birds are recorded within India (Ali and Ripley 1969) that has now moved up by one after identification of new species Bugun Liocichla (*Liocichla bugunorum*) in Northeast India (Ramana, 2006). Almost half of these species i.e., 526 species are recorded in Gujarat (Parasharya *et al.*, 2004), of which 244 are in Vadodara district of Central Gujarat (Padate *et al.*, 2001) while 131 species of birds in and around Harni pond (Padate and Sapna, 1996) and about 80 species in various terrestrial habitat of the Vadodara city (Padate *et al.*, 1998).

Vadodara is one of the cultural and educational centers of Gujarat state. This city has a Palace, parks, ponds as well as industries. Vadodara (Long 73° 20' E and Lat. 22° 30' N) is known as industrial and cultural capital of the state thereby it is one of the metro city. The city is now expanding very fast with the development of residential as well as industrial areas and business centres. Though the checklists for birds in and around city are available, the density of various species and their distribution in the area is not reported. Several Species like House Sparrow, crows (House Crow and Large-billed Crow), Brahminy Starling which were common in past (unpublished observations by bird watcher in the area) are not commonly seen these days. Whereas,

population of Blue Rock Pigeon, House Swift, Rose-ringed Parakeet, Common Myna and Black Kite seems to be increasing in the area.

Hence, in the present study the influence of urbanization on species richness, density, species diversity and evenness of the avifauna and similarity index of birds between selected areas of Vadodara city are evaluated. Further, density of some common birds that are called “urban exploiter” (Kark *et al.*, 2007) and are known to be habituated to the urban areas is considered. In addition those species which are thought to be declining under urban conditions are specially evaluated for their densities and distribution.

STUDY AREAS

Nine areas of terrestrial habitats were selected in Vadodara city. These areas were divided into three categories according to the disturbances produced by human being.

I Disturbed areas (DA) (a) R. C. Dutt Road (RCDR) (b) City area (CA) and (c) Industrial area (IA). These areas include commercial buildings with sparse vegetation and lots of human movements.

II Moderately Disturbed areas (MD) (d) Sayaji Garden (Kamatibaug) (SG), (e) University Campus (UC), (f) Akota Garden (AG), (g) Residential area (RA). These areas have moderate human movements and few concrete structures.

III Undistributed areas (UD) (h) Model farm (MF) and (i) PTC campus (PTCC). With minimum human movements and one or two small concrete structures.

METHODOLOGY:

These study areas were visited once in a month from October 2005 to September 2007, 2 hours from sunrise in the morning, amounting to total 216 visits. Birds were observed using 8×50 or 7×35 binoculars and identified on the basis of standard books by Ali (1996) and Grimmett *et al.*, (1999). The birds were counted using transect method and / or point count method (Rodgers, 1991). The species richness (number of species), diversity indices like Shannon Wiener index ($H' = -\sum p_i \log p_i$, where, $p_i = n_i/N$ n_i = number of individuals of a species and N total number of birds) and equitability ($E = H'/H_{max}$, where, H' = Shannon- Wiener Index and $H_{max} = \ln$ of total number of species.) (Krebs, 1985), Densities ($D = n/2W \times L$, Where, n = Total number of birds, W = Width and L = Length of transect.) (Rodgers, 1991) were calculated for further analysis. Further, Jaccard's similarity indices between all the study areas are calculated by using formula $J = C/(A+B)-C$. (where, C = Number of Common species, A = number of species of site A, B = Number of species of site B.)

The abundance of very common species that have adapted to urban habitat and those species which are believed to be under the threat of decline were considered to find out of their status. These species are Blue rock pigeon, House swift, Rose-ringed parakeet, Common myna and Black kite which are found in all the parts of the city whereas House crow, House sparrow, Large-billed Crow, Bank myna and Brahminy Starling that are considered to be under the threat of urbanization. To find out their abundance (%) (Javed and Kaul, 2002), the data for 9 sites was pooled to calculate monthly data. From

this monthly data, mean % abundance was calculated using total monthly density of birds. The results are considered for three different categories of habitat. The transect area, approximate building cover and vegetation cover of different study areas surveyed in Vadodara city are given in Table 1.1.

The results are expressed as mean \pm SEM where $n = 24$ ($\times 9$). The data for each visit was used for statistical analysis with the help of one way ANOVA or t-test by using various software packages (SPSS 12 for windows, Graph-pad Prism-3, Ecological Methodology, and Excel). The p value for ANOVA and t-test is non significant if $P > 0.05$ (ns), significant if $P < 0.05$ (*), significantly significant (**) if P is < 0.001 and highly significant (***) if $P < 0.0001$. The positive and negative impacts of urban pressures on avifauna are discussed.

RESULTS

Species richness and Density (Table 1.2 and Fig 1.1)

Disturbed areas (DA): Among the three disturbed areas, RCDR, CA and IA, highest total species richness 33 was noted at IA with mean species richness 16.9 ± 0.4 , followed by CA with total 16 species (10 ± 0.3) and RCDR with 20 species (7.5 ± 0.4). The difference was highly significant ($P < 0.0001$, $F_{2, 69}$ 136.2). However, the density of birds was highest at RCDR (10500 ± 687.0 birds/ Km^2) followed by CA (7001 ± 569.7 birds/ Km^2) and lowest at IA (5075 ± 297.0 birds/ Km^2) again with highly significant differences ($P < 0.0001$, $F_{2, 69}$ 25.59).

Among the four **moderately disturbed areas (MD)**, SG, UC, AG and RA, the highest total species richness 56 was observed at SG with mean 25.3 ± 0.8 , followed by UC 49 with mean of 24.3 ± 0.5 , RA with 43 and mean of 19.0 ± 0.5 and lowest 37 at AG with mean 15.4 ± 0.4 ($P < 0.0001$, $F_{3, 92} 57.87$). The density of birds was also highest 4450 ± 171.4 birds/Km² at SG followed by 2819 ± 165.4 birds/Km² at AG, 2780 ± 101.6 birds/Km² at UC and 801.0 ± 55.4 birds/Km² at RA ($P < 0.0001$, $F_{3, 92} 127.2$).

Between the two **undisturbed areas (UD)**, the MF and the PTCC, the areas with good vegetation, total species richness was higher 58 at PTCC with mean of 22.3 ± 0.5 compared to MF where 51 species with mean of 19.0 ± 0.7 were observed. The differences were highly significant ($P < 0.0001$). However, the density of birds was higher at MF (1212 ± 294.8 birds/Km²) and low at PTCC (653.5 ± 35.97 birds/Km²) with insignificant ($P > 0.05$) differences.

Shannon-Wiener index (H')* and *Evenness (E): (Table 1.2, Fig 1.1)

These parameters help to evaluate the distribution of birds in an area.

Among the **Disturbed areas** at RCDR mean H' was 0.52 ± 0.2 and mean evenness 0.18 ± 0.01 ; at CA they were 1.72 ± 0.45 and 0.52 ± 0.02 respectively and at IA 1.89 ± 0.43 and 0.46 ± 0.02 respectively. Highly significant differences were noted in Shannon-Wiener indices ($P < 0.0001$, $F_{2, 69} 92.92$) as well as evenness ($P < 0.0001$, $F_{2, 69} 75.78$).

Among the **Moderately disturbed areas** mean H' for SG was 3.22 ± 0.32 and E was 0.69 ± 0.01 , for UC 3.18 ± 0.18 and 0.69 ± 0.05 , for AG 2.43 ± 0.39 and 0.61 ± 0.01 and at RA 2.87 ± 0.35 and 0.67 ± 0.01 respectively. Highly

significant differences were noted for Shannon-Wiener indices ($P < 0.0001$, $F_{3, 92}$ 31.52) as well as for evenness ($P < 0.0001$, $F_{3, 92}$ 7.4).

At MF the **Undisturbed area** H' was 2.51 ± 0.37 and E was 0.59 ± 0.01 and for PTCC 3.39 ± 0.28 and 0.75 ± 0.009 respectively. Highly significant ($P < 0.0001$) differences in diversity and significant differences ($P < 0.05$) in evenness were noted.

Jaccard's index (Similarity index):

At least 30% of birds are common in different parts of Vadodara city.

The Jaccard's indices between all 9 study areas are given in table 1.3. When the similarity index of RCDR, one of the most disturbed areas is compared with other study areas, the highest similarity is noted with CA (0.63). Both are disturbed areas with less vegetation. The similarity indices for RCDR with other areas in decreasing order are (0.51) IA, (0.42) AG, (0.36) RA, (0.36) UC, (0.33) MF, (0.33) SG, (0.3) PTCC. When similarity index between CA and other study areas are considered the highest similarity noted in descending order is with IA (0.43) followed by (0.35) AG, (0.32) MF, (0.28) RA, (0.26) SG, (0.25) UC and PTCC (0.23). The similarity index of third disturbed area, IA, was highest 0.65 with RA followed by AG (0.62), UC (0.58), SG (0.56), MF (0.52) and PTCC (0.4).

The similarity index between Moderately disturbed area UC and other study areas was 0.65 for RA, followed by 0.62 for SG, 0.6 for both PTCC and AG and 0.59 for MF. Similarly second moderately disturbed area SG had high similarity index of 0.65 with PTCC, 0.59 with RA, 0.55 with AG and 0.52 with

MF. Similarity index between AG and RA was 0.63, with MF 0.57 and with PTCC 0.5. The similarity index between RA and PTCC was 0.53 and between RA and MF 0.49, while between two undisturbed areas MF and PTCC similarity index was 0.62.

Density and abundance (%) of Common birds (Fig 1.2a and Table 1.4):

When the density and abundance of selected species were calculated **Blue Rock Pigeon** ranked at the top. The high densities of pigeons were noted at disturbed areas RCDR (9305 ± 756.9 birds/Km²) followed by CA (3718 ± 264.7 birds/Km²) and IA (3466 ± 301.5 birds/Km²) with highly significant differences ($P < 0.0001$, $F_{2, 69} 44.53$). At moderately disturbed areas such as SG the pigeon densities were 1359 ± 120.04 birds/Km², at AG 1305 ± 86.63 birds/Km², at UC 734.3 ± 44.31 birds/Km² and at RA 307.3 ± 34.07 birds/Km² with highly significant differences ($P < 0.0001$, $F_{3, 92} 39.98$). Low pigeon densities were observed in undisturbed area 374.3 ± 43.19 birds/Km² at MF and minimum at PTCC (177.7 ± 28.85 birds/Km²). The differences between the two areas were highly significant ($P < 0.0001$). Among all the common species the highest mean abundance (58.64 ± 1.4 %) and highest mean density (2305 ± 85.05 birds/Km²) were noted for Blue rock pigeon.

Next in the abundance was **House Swift**. Compared to pigeon a different trend was noted in the density and the abundance of House Swift. Its highest density was noted at CA 2155 ± 527.2 birds/Km², followed by 166.7 ± 33.33 birds/Km² at AG, 105 ± 46.22 birds/Km² at RCDR, 95.24 ± 27.18 birds/Km² at UC, 39.05 ± 12.38 birds/Km², at SG, 31.3 ± 12.75 birds/Km² at IA, $26.67 \pm$

7.84 birds/Km² at RA, 27.45 ± 14.71 birds/Km² at MF, and lowest 10.87 ± 4.04 birds/Km² at PTCC. Highly significant differences were evident among DA ($P < 0.0001$, $F_{2, 69} 8.807$) as well as MD ($P < 0.0001$, $F_{3, 92} 7.912$) and insignificant ($P > 0.05$) between UD. The total mean abundance and the mean density of house swift were 5.82 ± 1.33 % and 10.09 ± 2.98 birds/Km² respectively.

The next common species of the area was **Rose-ringed Parakeet** with total mean abundance of 5.65 ± 0.33 % and mean total density 219.6 ± 12.84 birds/Km². Highest density of parakeets was 485.7 ± 39.22 birds/Km² at SG, 404.3 ± 26.45 birds/Km² at UC, and 262.2 ± 44.65 birds/Km² at AG, 206.1 ± 37.39 birds/Km² at RCDR, 156.7 ± 15.77 birds/Km² at IA, 155 ± 29.84 birds/Km² at CA, 129.3 ± 37.86 birds/Km² at MF, 121.7 ± 11.33 birds/Km² at RA and 55.83 ± 8.25 birds/Km² at PTCC. Insignificant differences were noted among DA and UD ($P > 0.05$, $F_{2, 69} 0.9972$) and highly significant differences among MD ($P < 0.0001$, $F_{3, 92} 23.62$).

Being true to its name, **Common Myna** is also a common species in the study areas. However, compared to pigeon its abundance (4.62 ± 0.19 %) as well as mean total density (180.6 ± 8.27 birds/Km²) were low. Maximum density of common myna was observed at SG (477.3 ± 43.71 birds/Km²), followed by UC (432.9 ± 31.14 birds/Km²), RCDR (278.9 ± 32.64 birds/Km²), AG (104.4 ± 21.11 birds/Km²), MF (100.8 ± 10.81 birds/Km²), IA (75 ± 14.41 birds/Km²), CA (66.67 ± 16.45 birds/Km²), PTCC (58.33 ± 6.09 birds/Km²) and minimum at RA (31.25 ± 4.95 birds/Km²). Highly significant differences were noted among DA ($P < 0.0001$, $F_{2, 69} 28.10$) as well as among MD ($P < 0.0001$, $F_{3, 92}$

61.12) whereas significantly significant differences ($P < 0.001$) were noted between UD.

The **Black Kite** was next in abundance in this group with 0.69 ± 0.06 % mean abundance and 27.09 ± 2.47 birds/ Km^2 mean total density. Though the abundance was low, it was found in all the areas. Highest density of Black kite was observed at SG (63.57 ± 8.84 birds/ Km^2) followed by CA (50 ± 12.57 birds/ Km^2), UC (30.47 ± 4.94 birds/ Km^2), IA (28.33 ± 15.6 birds/ Km^2), AG (27.78 ± 4.67 birds/ Km^2), RC DR (21.11 ± 5.07 birds/ Km^2), RA (11.67 ± 1.89 birds/ Km^2) MF (7.93 ± 1.03 birds/ Km^2) and lowest at PTCC (2.91 ± 1.34 birds/ Km^2). Insignificant differences in Black kite density were noted among DA ($P < 0.05$, $F_{2, 69}$ 1.588), highly significant among MD ($P < 0.0001$, $F_{3, 92}$ 14.81) and significantly significant ($P < 0.001$) among UD.

Density and abundance (%) of common birds considered as under the threat of decline under urban condition (Fig 1.2b and Table 1.4):

House Crows were observed in all the study areas and throughout the study period with the mean abundance of 2.41 ± 0.21 % and mean total density of 91.68 ± 6.39 birds/ Km^2 . The density of house crow at different areas were 439.2 ± 38.23 birds/ Km^2 at CA, 194 ± 26.03 birds/ Km^2 at SG, 50.48 ± 6.26 birds/ Km^2 at UC, 41.11 ± 10.15 birds/ Km^2 at AG, 31.11 ± 10.24 birds/ Km^2 at RC DR, 25.86 ± 7.65 birds/ Km^2 at IA, 18.96 ± 4.82 birds/ Km^2 at PTCC, 15.13 ± 2.82 birds/ Km^2 at RA and 9.4 ± 1.91 birds/ Km^2 at MF. Highly significant differences were noted among DA ($P < 0.0001$, $F_{2, 69}$ 103.8) as well as among

MD ($P < 0.0001$, $F_{3, 92}$ 31.39) and insignificant differences ($P > 0.05$) among UD.

House sparrow the other common species which was very common a decade ago was not observed at MF and RCDR. However, it was present in other areas with density in descending order as CA (377.5 ± 31.24 birds/Km²), IA (89.58 ± 12.76 birds/Km²), AG (26.67 ± 8.64 birds/Km²), RA (15.83 ± 2.8 birds/Km²), UC (0.4 ± 0.47 birds/Km²), SG (0.95 ± 0.95 birds/Km²) and PTCC (0.2 ± 0.2 birds/Km²). The mean total abundance of the house sparrow was low at $1.46 \pm 0.1\%$ and mean total density 56.80 ± 4.07 birds/Km². Highly significant differences were noted among DA ($P < 0.0001$, $F_{2, 69}$ 102.5) as well as among MD ($P < 0.0001$, $F_{3, 92}$ 7.654).

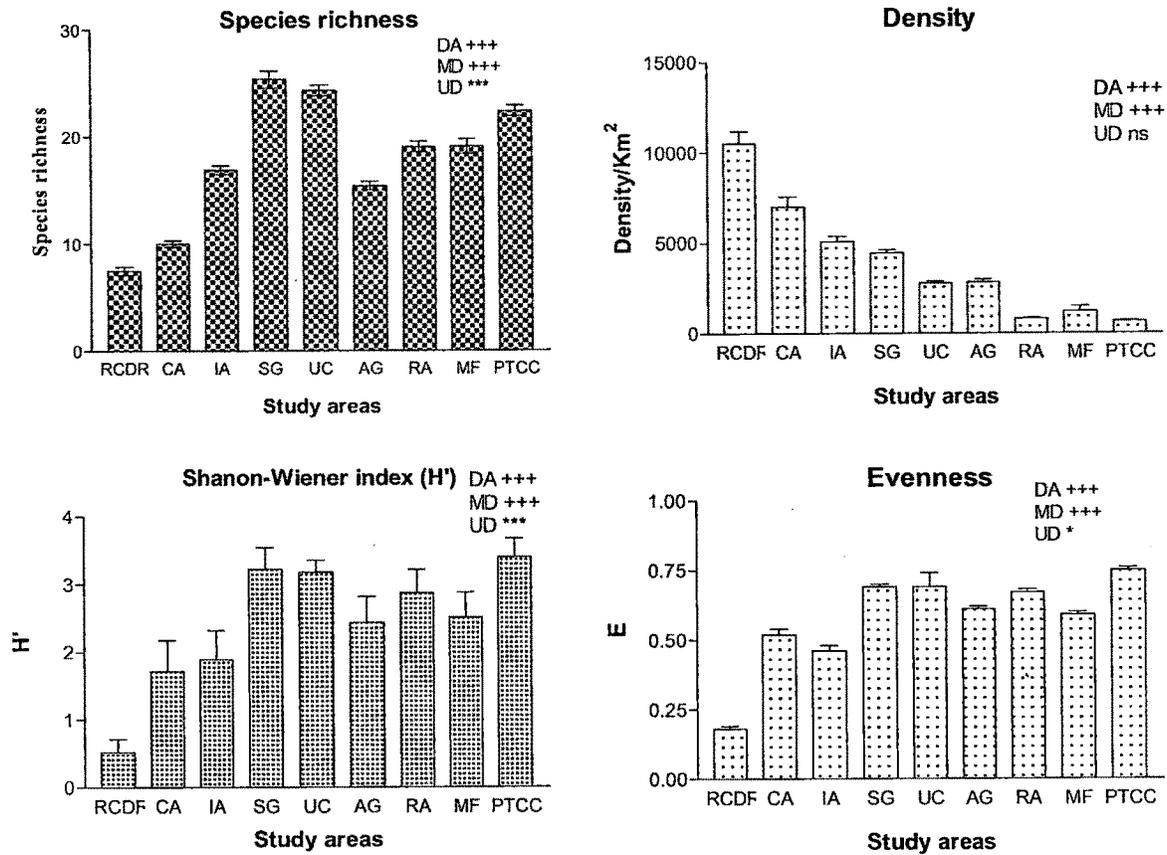
Large-billed Crow is one more species which is considered as under the threat of urbanization. It occurred with mean total abundance of $1.14 \pm 0.13 \%$ and mean total density of 45.44 ± 5.64 birds/Km². The maximum density of Large-billed Crow was 243.8 ± 49.65 birds/Km² at SG, followed by 39.05 ± 4.76 birds/Km² at UC, 27.78 ± 7.08 birds/Km² at AG, 25.21 ± 6.5 birds/Km² at CA, 25 ± 5.4 birds/Km² at IA, 21.11 ± 6.01 birds/Km² at RCDR, 11.25 ± 2.23 birds/Km² at PTCC, 10 ± 1.92 birds/Km² at RA and minimum 5.7 ± 1.2 birds/Km² at MF. Insignificant differences were noted among DA ($P < 0.05$, $F_{2, 69}$ 0.146), highly significant among MD ($P < 0.0001$, $F_{3, 92}$ 18.96) and significant ($P < 0.05$) among UD.

Among the three mynas **Bank Myna** that was a very common species a decade ago, occurred with a mean abundance $0.80 \pm 0.07 \%$ and total mean density

31.2 ± 2.77 birds/Km². Bank myna was absent at IA and MF. But it was present in increasing order from UC (0.95 ± 0.95 birds/Km²), PTCC (1.04 ± 1.04 birds/Km²), RA (2.91 ± 2.91 birds/Km²), RCDR (4.44 ± 3.07 birds/Km²), SG (7.61 ± 5.4 birds/Km²), AG (7.7 ± 5.89 birds/Km²) and CA (256.7 ± 23.95 birds/Km²). Highly significant differences ($P < 0.0001$, $F_{2, 69} 111.1$) were noted among DA and insignificant ($P > 0.05$, $F_{3, 92} 0.639$) among MD.

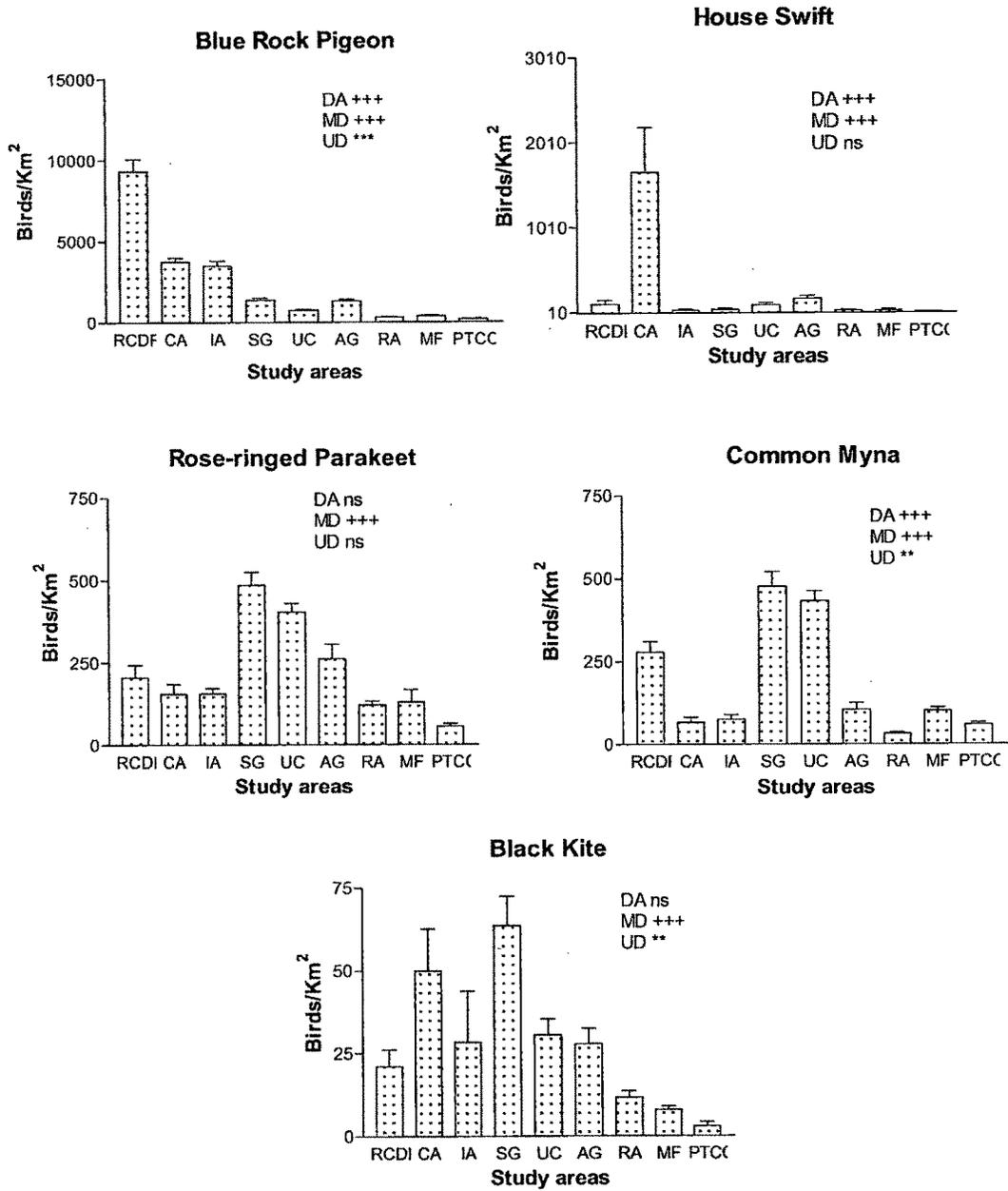
Brahminy Starling was not cited at two of the three disturbed areas RCDR and CA but was observed at IA (5.0 ± 2.7 birds/Km²). It was also absent at MF and PTCC (Undisturbed areas). Its high densities were observed at UC (11.43 ± 4.81 birds/Km²), followed by AG (6.66 ± 3.3 birds/Km²), SG (3.33 ± 1.61 birds/Km²) and low at RA (1.45 ± 0.7 birds/Km²). Its annual abundance and mean density were 0.08 ± 0.02 % and 3.99 ± 0.88 birds/Km² respectively. Significant differences ($P < 0.05$, $F_{2, 69} 3.286$) were noted among DA and insignificant ($P > 0.05$, $F_{3, 92} 2.054$) among MD.

Fig 1.1 Species richness, Density, Shannon- Wiener index and evenness of birds at different areas of Vadodara city.



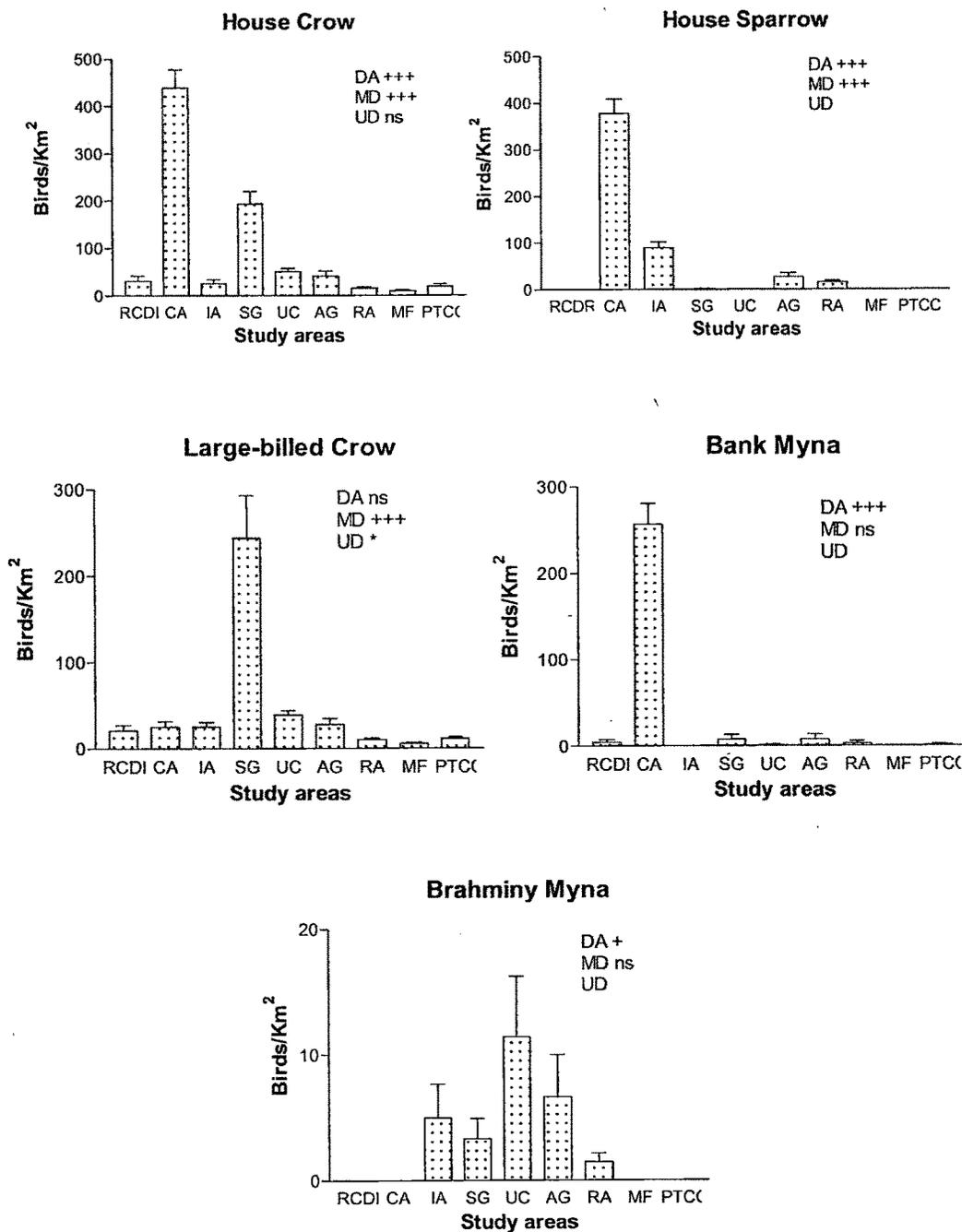
DA (Disturbed Areas) MD (Moderately disturbed Areas) and UD (Undisturbed Areas)
 */ + P < 0.05, ** /++ P < 0.001, *** /+++ P < 0.0001, ns = nonsignificant
 *For T-test, + For ANNOVA

Fig 1.2a Density of common birds at different areas of Vadodara city (Mean \pm SEM).



DA (Disturbed Areas) MD (Moderately disturbed Areas) and UD (Undisturbed Areas)
 */ + P < 0.05, ** / ++ P < 0.001, *** / +++ P < 0.0001, ns = nonsignificant
 *For T-test, + For ANNOVA

Fig 1.2b Density of common birds considered as under the threat of decline in different areas of Vadodara city (Mean \pm SEM).



DA (Disturbed Areas) MD (Moderately disturbed Areas) and UD (Undisturbed Areas)
 */ + P < 0.05, ** / ++ P < 0.001, *** / +++ P < 0.0001, ns = nonsignificant
 *For T-test, + For ANNOVA

Table 1.1 Transect area, approximate building cover and vegetation cover of different study areas of Vadodara city.

Study areas	Transect area (Km ²)	% cover (Approximate)	
		Buildings	Vegetation
Disturbed areas			
RCDR	0.03	75 %	25 %
CA	0.05	95 %	05 %
IA	0.05	50 %	50 %
Moderately Disturbed areas			
SG	0.087	05 %	95 %
UC	0.087	40%	60%
AG	0.03	05 %	95 %
RA	0.2	40 %	60 %
Undisturbed areas			
MF	0.35	05 %	95 %
PTCC	0.2	05 %	95 %

Table 1.2 Species richness, Density, Shannon-Weiner index and Evenness H' of total birds of study areas of Vadodara city (Mean \pm SEM, n = 24, from 2005 to 2007).

Study areas	Total number of Species	Mean Species richness	Density/Km ²	Shannon-Wiener Index (H')	E
Disturbed areas					
RCDR	20	7.5 \pm 0.4	10500 \pm 687.0	0.52 \pm 0.2	0.18 \pm 0.01
CA	16	10 \pm 0.3	7001 \pm 569.7	1.72 \pm 0.45	0.52 \pm 0.02
IA	33	16.9 \pm 0.4	5075 \pm 297.0	1.89 \pm 0.43	0.46 \pm 0.02
Moderately Disturbed areas					
SG	56	25.3 \pm 0.8	4450 \pm 171.4	3.22 \pm 0.32	0.69 \pm 0.01
UC	49	24.3 \pm 0.5	2780 \pm 101.6	3.18 \pm 0.18	0.69 \pm 0.05
AG	37	15.4 \pm 0.4	2819 \pm 165.4	2.43 \pm 0.39	0.61 \pm 0.01
RA	43	19.0 \pm 0.5	801.0 \pm 55.4	2.87 \pm 0.35	0.67 \pm 0.01
Undisturbed areas					
MF	51	19.0 \pm 0.7	1212 \pm 294.8	2.51 \pm 0.37	0.59 \pm 0.01
PTCC	58	22.3 \pm 0.5	653.5 \pm 35.97	3.39 \pm 0.28	0.75 \pm 0.009

Table 1.3 Jaccard's index of birds between different study areas in Vadodara city.

Site	PTCC	MF	RA	AG	SG	UC	IA	CA	RCDR
RCDR	0.3	0.33	0.36	0.42	0.33	0.36	0.51	0.63	
CA	0.23	0.32	0.28	0.35	0.26	0.25	0.43		
IA	0.4	0.52	0.65	0.62	0.56	0.58			
UC	0.6	0.59	0.65	0.6	0.62				
SG	0.65	0.52	0.59	0.55					
AG	0.5	0.57	0.63						
RA	0.53	0.49							
MF	0.62								
PTCC									

Table 1.4 Species abundance and the density of birds common as well as those which are under the threat of Urbanization in Vadodara city (n = 24, from 2005 to 2007).

Common species	Species abundance (%)	Density / Km ²
Blue rock Pigeon	58.64 ± 1.4	2305 ± 85.05
House Swift	5.82 ± 1.33	10.09 ± 2.98
Rose-ringed Parakeet	5.65 ± 0.33	219.6 ± 12.84
Common Myna	4.62 ± 0.19	180.6 ± 8.27
House Crow	2.41 ± 0.21	91.68 ± 6.39
House Sparrow	1.46 ± 0.1	56.80 ± 4.07
Large-billed Crow	1.14 ± 0.13	45.44 ± 5.64
Bank Myna	0.80 ± 0.07	31.27 ± 2.77
Black Kite	0.69 ± 0.06	27.09 ± 2.47
Brahminy Starling	0.08 ± 0.02	3.99 ± 0.88
Total %	81.31 %	
Other birds %	18.69 %	

DISCUSSIONS

Species richness and Density

All over the world urbanization has been considered as one of the major threats to biodiversity that has different magnitudes in different regions. When there is a change in the vegetation it changes the fauna that depends on it. Birds are known to respond to vegetation composition and structure, hence avian fecundity in urban area is a reflection of species specific adaptability of birds to the resources as well as to levels of nest predation and nest parasitism (Chace and Walsh, 2004). Distribution of the bird species in urban areas have been related to the urban- rural gradients as well as different anthropogenic activities (Reynaud and Thioulouse, 2000).

In the present study about 82 species of birds were observed in the terrestrial habitats of Vadodara city. These areas have different level of vegetation cover and human activities. The influence of vegetation cover is very clear as minimum species were recorded at disturbed area CA (16) while maximum at undisturbed area PTCC (58). Among all the areas surveyed PTCC is the most undisturbed area with minimum human activities. However, when mean species richness is considered the areas with moderate disturbance as well as moderate human activities were found to be supporting more species at a time than other areas. Moderately disturbed areas are inhabited by the most common as well as rare species of the region. Common species were less common in undisturbed areas and vice versa, whereas indigenous species were almost totally absent from disturbed urban areas. Urban areas with minimum

vegetation are known to support low species richness compared to areas with dense vegetation (Clergeau *et al.*, 1998). The distribution of common birds was also uneven among the study areas.

The **Disturbed areas, CA** has 95% of concrete structures and 5% vegetation cover. The concrete structures include old patterned residential buildings interspersed with few modern commercial buildings. This habitat is preferred by very few species. Only 16 species (mean average 10 ± 0.3), minimum among all the areas were observed during the two years of study period. These mainly include few hardy species called urban exploiter by *Kark et al.* (2007), the species that are known to adapt to human presence. However, the high density of birds at CA was mainly because of the presence of Blue Rock Pigeon, House Swift, Bank Myna, House Crow, House Sparrow and Black Kite. Among all the nine study areas maximum densities of House Swift, House Crow, House Sparrow and Bank Myna were observed in this region. However the density of Black Kite was second highest among nine sites. All these species mainly depend on shelter and highly protected nesting sites provided by man in the form of concrete jungle as well as additional food supplies. A recreational site with famous lake “Sursagar” is also present in this area where additional food supplies are available for birds. This indicates that old housing pattern with sparse vegetation and water supplies support some hardy bird species for their basic needs.

At **RCDR** with 25% vegetation and 75% concrete jungle, only 20 species of birds were observed. Species richness is usually reported to be lower in urban

areas, where the avian community is dominated by a few species (Lancaster and Rees, 1979). Large number of buildings reduces the food availability and hence number of bird species (Tilghman, 1987). However the birds like pigeon, that use these concrete structures for shelter and are fed by animal lovers, increase in density. Thus, the density of total birds was highest due to presence of common urban birds mainly the Blue Rock Pigeon with density of $(9305 \pm 756.9 \text{ birds/Km}^2)$ and also Rose ringed Parakeet $(206.1 \pm 37.39 \text{ birds/Km}^2)$ and Common Myna $(278.9 \pm 32.64 \text{ birds/Km}^2)$. Pigeons are well adapted to the man made environments and are considered the most troublesome bird pests of cities and suburbs (Marsh and Howard, 1982). Commercial buildings constructed with exposed I-beam are used by pigeons for nesting (Geis, 1976). Warmer urban climate, where many patches of congregation of trees are present, provide roosting sites for many species of birds. One such area is present behind Vadodara railway station from where RCDR starts. These trees are used mainly by Rose- ringed Parakeets where approximately 17,000 Rose- ringed Parakeets were counted during evening hours (Unpublished report, Chapter III). Such roosting sites with 62,945 Rose- ringed parakeets have also been reported in Vallabh Vidhyanagar (Parasharya, 2005). In present study, Rose- ringed Parakeets ranks third in the abundance (Table 1.4). As they leave the roost long before sunrise their presence at the start of transect (Sunrise) was low.

IA: Among the three disturbed areas at IA, which has about 50% of vegetation cover, highest 33 (16 ± 0.4) species of birds were observed but with minimum

density. Industrial area is supposed to be a disturbed area. However, the modern industrial policies put emphasis of developing green patches around the industrial development. The IA studied in present study, with 50% vegetation cover, is an example where the secondary vegetation grown supports better species richness. Padate *et al.* (1998; 2001) have also reported good diversity of birds in an experimental ecofarm developed by a major industry around its premises in Vadodara. Compared to other two disturbed areas, density of common birds was low at IA. Surprisingly, Brahminy Starling the species that is believed to be declining under urban development was observed frequently in this area. The vegetation at IA also provides roosting sites for House Sparrow and both the species of crows. The density of pigeon was also high in the area as they could get secured nesting sites under the long shades of industries and food from the feeding spots.

Moderately disturbed areas:

Urban parks are usually the most heterogeneous green spaces in the urban ecosystem that are important habitats for bird communities (Shwartz *et al.*, 2007). Such parks are expected to have a greater availability of escape covers and higher tolerance levels of birds to visitors (Knight and Temple, 1995). The amount of shrub cover is also principal microhabitat characteristic that increases bird's tolerance to people in urban parks (Fernandez-J *et al.*, 2001).

Sayaji Garden SG is one such big garden in the Vadodara city with zoo, toy train, planetarium and museum. Thaker and Jasrai (2005) have reported that .95% of vegetation cover at SG includes 97 species of trees, 42 species of herbs,

22 species of shrubs and 5 species of climbers. SG being a public park, composition of its plant species changes every season/year making it more complex habitat. SG has only about 5% of building cover. River Vishwamitri cuts the park into two parts adding to variations in the habitat. 56 (25.3 ± 0.8) species of birds were noted at SG during study period. Moderate levels of development are reported to increase bird species richness (Tilgham, 1987; Shwartz *et al.*, 2007). Trees at SG provide roosting sites for variety of the urban exploiters. A heronry for native wetland species like Cattle egret, Little egret, Median egret, Pond heron, Night heron and Little cormorant is also present further influencing species richness and density. Several other species are also observed nesting here. At couple of points in SG grains are fed to pigeons where alongwith with pigeons other birds like Jungle babblers and Parakeets are also observed, increasing density of birds. Such gardens with good vegetation, availability of water and food provide breeding, roosting as well as feeding grounds for diversity of avifauna.

UC has about 60% of vegetation cover and 40% of building cover that includes a small botanical garden and a small tributary that adds to the diversity of habitat. UC is separated from SG by a highway with heavy traffic. The birds, because of their flying habits, are not much influenced by the traffic on the ground and hence 62% of the species are shared by the two regions. However, the difference is mainly due to water birds which use some of the trees for nesting as well as are found in the Vishwamitri River that crosses through the garden. Mean species richness was insignificantly lower at UC compared to

SG. SG is having less concrete structures compared to UC too. However the urban exploiters have not yet invaded this moderately disturbed area to their maximum, hence the density of birds is low. The University Campus is flooded with students, thus no feeding grounds are available. Here, the density of Common Myna, Brahminy Starling, Large-billed Crow, Rose-ringed Parakeet and House Swift were high. UC has a lush green cricket ground surrounded by large trees which are preferred by most of these species and old buildings are preferred by birds like House Swift. The habitat also provides nesting sites for several species. Nests of Black kite, House swift, Parakeet, Golden backed woodpecker and Jungle babbler are common at UC.

AG is comparatively a smaller garden with only 5% building and 95% vegetation cover. However, the park is surrounded by residential buildings and like SG occupied by the morning walkers and joggers. These visitors to urban parks are a relatively benign source of disturbance as the birds are not killed or pursued by them (Cooke, 1980). Therefore, it is likely that the birds in garden learn to tolerate human intrusions (Rodgers and Smith, 1995; Riffel *et al.*, 1996). Though it is a smaller park 37 species of birds with 1 migratory species the Red Throated Flycatcher (*Ficedula superciliaris*) were observed here. AG shares 50% to 60% species with other undisturbed areas and moderately disturbed areas respectively. However the density of birds was lower at AG.

RA the fourth moderately disturbed area has 60% vegetation cover and 40% residential buildings. 43 species of birds were observed here during two years of study period but the density of birds was minimum. According to Clergeau

et al., (1998) the bird abundance is high in residential area with good vegetation. Residential area has minimum density.

Undisturbed areas include MF and PTCC. At MF, which is situated in the center of the Vadodara city and is having agricultural land as well as vegetation surrounded by large trees (95%), 51 species of birds were noted. In modern world, men tend to build urban centers in highly productive ecosystems that also support high levels of biodiversity (Huston, 1993; Balmford *et al.*, 2001). They may develop farms away from urban centers. Such mosaic habitat with urban and agriculture patches presents both direct problems of habitat conversion and indirect effects of chemical pollution disturbing water and nutrient cycle (Pimentel *et al.*, 1992). Further, agriculture provides a concentrated and highly predictable source of food to birds (Dhindsa and Saini, 1994) whereas urbanization can provide diverse unpredictable food supply in the form of human leftovers. Hence in such heterogenous habitats both “urban exploiters” as well as “native species” are found. Here at MF rare birds of the area *i.e.*, Red throated flycatcher (*Ficedula parva*) and Grey-headed Flycatcher (*Culicicapa ceylonensis*) were observed during the migratory season, winter. The low density of birds in general, as compared to other study areas, can be attributed to agricultural practices that provide high concentration of any one type of food that favours only particular groups of birds.

PTCC, the second undisturbed area, is present at the outskirts of the Vadodara city. It has dense vegetation (95%) and low (5%) building cover that provide serene habitat where highest species richness, *i.e.* 58 species, were observed.

As the diversity of native species increases the density of birds and the diversity of common birds decrease. This indicates that undisturbed areas support good diversity of birds with less density. The Grey-headed flycatcher was also observed here. PTCC campus has a ground which is surrounded by large trees. This ground provides feeding habitat for some species of birds like Cattle egret, Common myna and Red-wattled Lapwing (*Vanellus indicus*).

Shannon-Wiener index (H') and evenness.

According to Krebs (1985) the heterogeneity is higher in a community when there are more species and also when the species are equally abundant. In present study, this was true for undisturbed area (PTCC) and moderately disturbed areas (UC and SG). Shannon-Wiener index (H') and evenness are always high where vegetation cover is also high. Several species of birds that were common in Vadodara few decades ago are either reduced in number or are found in these few pockets (Padate, personal communication). They were not observed in some disturbed areas during present study. Thus it can be noted that species diversity and evenness were low at disturbed highly urbanized habitats (RCDR, CA and IA). These habitats are dominated by few species of birds, the so called "urban exploiters" Kark *et al.*, (2007).

A marked decline in species diversity is known to occur over the time if the degree of urbanization increases (Batten, 1972). The lower species diversity at disturbed areas indicates absence of vegetation as well as increase in human disturbances like heavy vehicular traffic and development of commercial and industrial premises humming with various activities. This is a totally opposite

condition compared to undisturbed areas which have high vegetation cover and less human disturbances supporting good diversity as well as equitability of birds.

Abundance and density:

Common birds

Blue rock pigeon, Rose-ringed Parakeet, Common Myna, House swift and Black Kite are very common and abundant species of bird at all the 9 areas surveyed (Table 1.4). According to the present study one can consider these species as “urban exploiters” as described by Kark *et al.* (2007). These are the native species which are habituated to the urban conditions and exploit the urban environment, often reaching their greatest densities in highly urbanized areas. The feeding spots in most urbanized area, RCDR, supported maximum density of pigeon whereas most undisturbed area, PTCC, supported minimum density of the same. When freely-available supplementary food is exploited by urban dwelling species, there are several readily predictable outcomes including significant advancement of breeding dates of seasonally breeding birds (Boal and Mannan, 1999). Such advancement of breeding, leading to a sort of continuous breeding when at least few pairs are nesting every month and majority breeding during 2 annual peaks has been reported for pigeons in Vadodara (Kotak, 1979). In addition, pigeons nest in concrete buildings where their nests are highly secured. These two factors help in an increased population of pigeons in urban areas.

Similarly, the density of House Swift was maximum again in most disturbed areas but with old housing patterns (CA) where swift could get secured nesting sites. Swifts prefer nesting in colonies under the domes of old building and such heritage type of buildings are present at CA which is the old main city area. In all other areas swifts were present with very low density comparatively. Next in abundance was Rose-ringed Parakeet which was also found in all the areas. As said earlier a roosting site for parakeet is present on the eastern end of RCDR. However, at the time of transect their maximum density was found in SG followed by UC, the areas with moderate disturbance and good vegetation cover near the communal roost on eastern side of RCDR. About 17000 Rose-ringed Parakeet leave the roost at the break of the day hence at the time of sunrise when transect was started they settle down in their respective feeding grounds. The flowering and fruiting trees in the sayaji garden as well as campus area provide important feeding guild for the parakeets. Common myna was next in abundance. It is also a common species of these two moderately disturbed areas with large patches of lawns and open ground. Common Myna mainly feeds on the ground in morning and evening hours and perches on higher elevation when the sun is high. The lawns of gardens are one of the favourite feeding niche of common myna. Large areas of SG and UC have open ground with lawns favoured by common myna. Common Myna and Rose-ringed Parakeet are capable of covering large areas (Shwartz, unpublished data). They move long distance from their roosting area

to their feeding areas. Large roosts of common myna supporting 200-300 individuals are found in some parts of the city (Chapter III).

Black Kite (*Milvus migrans*) is mainly an urban bird. Large populations have been observed in several metro cities in western India (Personal observations) including Vadodara (Padate and Sapna, 2002-2003; Rathod and Padate, 2004). They were found in all the areas but with maximum density in areas which had a source of water (SG with Vishwamitri river and CA with Sursagar lake). A huge roosting site is present at SG. They disperse to other areas in the morning; hence in almost all the areas surveyed kites were present. Minimum kites were observed in undisturbed areas (PTCC and MF). Kite is one of the bird of prey whose population was noted high during monsoon. It has changed its feeding habits with the urban development (Rathod and Padate, 2004).

Common birds considered as under the threat of decline under urban conditions

Coming to the species that are thought to be under the threat of urbanization, the abundance of House crows and Large-billed Crows were low as compared to some of the urban exploiter but high as compared to other species like Bank Myna and Brahminy Starling. As per the terminology of Kark *et al.* (2007) House Crow and Large-billed Crow may be called “urban adapters” the species that can exploit some of the urban resources such as ornamental vegetation characteristic of intermediate levels of urbanization. Both the species of crow were observed at all the areas but with varying densities.

House sparrow, Bank Myna and Brahminy Starling are three other species of concern that are trying to adapt to the urbanization. House Sparrows are seen

only in the areas with old housing patterns and/ or vegetation with heavy to moderate human activities. Both, the Pigeon and the House Sparrow are known to be ubiquitous in urbanized areas worldwide (Clergeau *et al.*, 1998). However, pigeons have adapted to urban conditions and have achieved the status of top “urban exploiter” the House Sparrow is probably fighting for its existence and has moved to certain pockets of urban areas with old type of houses that can provide nesting sites. If care is not taken they may vanish from the urban map. House sparrow and Pigeon have been reported to have more restricted home ranges (Shochat *et al.* 2004). However, there is great concern among naturalist and conservationist about decline in House Sparrow population in many cities of India (Dilwar, 2006). The density of House Sparrow was highest in the city area (CA) (Fig 1.2) where old houses are present providing suitable nesting sites as well as food grains. Industrial area (IA) also showed good density of House Sparrow compared to other areas. The large industries with low human activities during morning and evening hours are also preferred by House Sparrow compared to modern houses providing less nesting sites (RA). Garden surrounded by residential area (AG) is also providing good habitat for House Sparrow. In some moderately disturbed areas as well as undisturbed area sparrows were not recorded. This indicates that House Sparrow, as the name suggests, prefer human presence where nesting sites are available. According to Geis (1976) House sparrow and Pigeon are concentrated to specific areas which have buildings having design or quality features that are favorable to these species. During study period nest of house

sparrow were observed in street light boxes, net of old mosque and roofs of the old houses at CA. House sparrow frequently use designed features that leave nooks and crannies in to which nest material could be lodged (Geis, 1976).

Urban areas with its gardens, road side vegetation, open grounds with and without lawns, ponds, tributaries and rivers support large number as well as species of birds. There are few additional species which have been observed in such areas but not during transect or point count. These are nocturnal birds like Eurasian Eagle-Owl (*Bubo bubo*), Eurasian Scoups owl (*Otus scops*), Barn owl (*Tyto alba*), bird of prey Red-headed Falcon (*Falco chicquera*) and local migratory bird, Indian Pitta (*Pitta brachyura*).

CONCLUSION

Urban areas with good vegetation, parks, water bodies and old type of buildings support good diversity of birds. Some species of birds are totally adapted to the urban conditions, whereas, some sensitive species of birds like House Sparrow that could not adapt to the urban conditions have declined in number or totally vanished from the urban areas. Even some migratory species of birds have been observed visiting the undisturbed areas amidst disturbed habitats. In present study a gradation in the urban exploiter is noted.