CIBTech Journal of Zoology ISSN: 2319–3883
Online, International Journal, Available at http://www.cibtech.org/cjz.htm
2024 Vol.13, pp.209-221/Umang and Nikunj
***Research Article** (Open Access)*

FEEDING CENTERS DETERMINE THE DENSITY AND DISTRIBUTION OF THE FERAL PIGEONS *COLUMBA LIVIA* IN URBAN ENVIRONMENTS

Umang Sutariya and *Nikunj Bhatt
Vitthalbhai Patel & Rajratna P.T. Patel Science College,
Vallabh Vidyanagar, 388120, India
[*]Author for Correspondence: drnikunjbhatt@vpscience.org

ABSTRACT
Most studies on the density and distribution of feral pigeons are based in Western countries. Conversely, no scholarly attention has been directed towards the status and dynamics of feral pigeons in India. In our study, feral pigeons were censused in the urban agglomeration city of Anand, India from 2022 to 2023. Our objective was to gain insights into the preferential locations of feral pigeons and compare their relative abundances. We observed 17 major feeding stations for pigeons, where large flocks would gather to forage on food offered by routine pigeon feeders and passersby. Across these locations, we recorded 3813 pigeons with an average of 48 counts. We divided the 17 feeding stations into three categories of feeding hotspots (designated sites, religious sites, and public sites) based on their spatial characteristics. All three feeding hotspots had significantly different mean pigeon populations. Overall, pigeon density was highest at designated sites (mean: 2214.9), followed by religious sites (mean: 1192.8), and the least pigeon population was observed at public sites (mean: 405.7). We also examined the variation in feeding time intervals, of which pigeons demonstrated the longest uninterrupted feeding intervals at designated sites, with a significant decrease observed at religious sites and the shortest durations recorded within public sites. The feed offered to the pigeons did not vary significantly, as Triticum aestivum (wheat), Sorghum bicolor (sorghum), Oryza sativa (rice grain), and Vigna radiata (green gram) were the most frequent grains offered at all three feeding hotspots. Our results suggest that providing supplementary food to pigeons, and the type of feeding hotspots present in a city can contribute to their abundance. Conversely, the presented results point to a noticeable pattern in pigeon behavior, which appears finely attuned to the environmental features of urban habitat and its surroundings.

Keywords: *Feral pigeon, Abundance, distribution, ecology, India, urbanization*

INTRODUCTION
Considering the use of natural resources, agriculture or land for human settlement, it is evident that nearly all terrestrial expanses on Earth have experienced anthropogenic influence. (Donnelly & Marzluff, 2006; Meyer & Turner, 1992). Therefore, unpopulated wildlands are transformed into metropolitan areas, leading to urbanization. Despite the effects of urbanization, specific avian species, such as the feral pigeons, have proficiently adapted to urban settings, establishing dense and enduring populations within the transformed habitat (Jhonston & Janiga, 1995). Among these birds mentioned above, feral pigeon stands out prominently as the most universally acknowledged bird worldwide. It is well established that feral pigeons originated from domesticated pigeon breeds, while some also descended from wild rock pigeons (Jhonston & Janiga, 1995). Following their release from captivity, domestic pigeons went feral and established a flourishing population in the urban landscape.
Presently, the feral pigeon population has undergone exponential growth, and few large cities worldwide lack feral pigeon populations. The global count of feral pigeons ranges from 100 million to 300 million individuals (Haag-Wackernagel & Bircher, 2010). The absence of natural predators (Shochat, 2004), extended breeding periods (Dimitri Giunchi *et al.*, 2007), and abundant availability of feeding resources

in close proximity (Jhonston & Janiga, 1995) have been identified as key contributors to feral pigeon population explosion. Among these factors, the predominant driver fostering the increase in the feral pigeon population was the ad libitum availability of food.

Post-world wars, feeding garden birds began as a wintering activity across the world to provide birds with nutrition in harsh climates (Fuller *et al.*, 2008). Presently, urban birds such as feral pigeons have become completely dependent on this supplementary feeding (Umang & Nikunj, 2023). From their original granivore diet, the feral pigeons have taken on an omnivores diet including grain, cakes, fried snacks, garbage, and food spillage as their source of food, which is readily available in the urban strata (Murton & Westwood, 1966; Ryan, 2011).

Although feral pigeons are equipped to undertake foraging flights from urban areas to nearby agricultural fields, they tend to rely greatly on the public feed provided to them in parks, squares and gardens (Haag-Wackernagel & Geigenfeind, 2008; Hetmański *et al.*, 2011; Sacchi *et al.*, 2002). Previous studies have highlighted how only a few individuals from pigeon flocks take daily foraging flights, and in some cases, this is extremely rare (Murton & Westwood, 1966; Rose *et al.*, 2006; D. Sol & Senar, 1995). Ryan (2011) has shown how pigeons in Wellington, New Zealand had a very limited activity area, with the average activity being less than 1.87 ha. A similar study in Barcelona, Spain, showed that pigeons had a home range size of less than 1.67 ha with very less movement between foraging sites (D. Sol & Senar, 1995). The site loyalty of feral pigeons suggests that artificial food resources are locally available in abundance in cities and towns; therefore, they need not take foraging flights to find food.

Historically, rock pigeons inhabited mountain cliffs as their natural habitat (Goodwin, 1983). However, their successors, feral pigeons, have a modified ecological niche. They utilize balconies, window ledges, bridges, and gaps in monumental structures as their nesting site (Haag-Wackernagel & Geigenfeind, 2008; Hetmański *et al.*, 2011; Sacchi *et al.*, 2002). Today, millions of feral pigeons live in close association of humans which can lead to human-pigeon conflict (Weber *et al.*, 1994). They are known to produce about 12 kg of excrement per bird annually, posing a sanitation challenge in urban areas where it can degrade architectural monuments, buildings, and public spaces (Haag-Wackernagel & Geigenfeind, 2008). Along with this, fungus that can grow in pigeon feces can damage the structures made up of cement and concrete (Bassi & Chiatante, 1976). Damages done to buildings are insignificant when compared to human health. Pigeon feces and feather dust are known to carry various pathogens which can be transmitted to humans via aerosol route, without any physical contact (Haag-Wackernagel *et al.*, 2006). Out of those pathogens, *Chlamydophila psittaci* and *Histoplasma capsulatum* are bacteria's of most concern, as they can turn out to be lethal when infected to humans (Haag-Wackernagel & Moch, 2004). Ectoparasites attached to pigeons such as bedbug *Cimex lectularius*, the pigeon tick *Argas reflexus* and the red mite *Dermanyssus gallinae*, are also reported to infect humans(Haag-Wackernagel & Bircher, 2010). Considering such large epidemiological significance of pigeons to humans it is necessary to regard the risk with necessary concern. Therefore, it is of importance to study the ecology of bird such as feral pigeons that are closely associated with humans.

In Anand, as in numerous Indian cities, residents engage in the common practice of feeding pigeons. This cultural norm involves offering food to these birds, observed throughout the country's urban environment. The implication of this urban feeding on pigeon populations, much like in other Indian cities, remains uncertain. By systematically gathering data on the distribution and abundance of pigeons, it is possible to ascertain the key resources that are essential to them. This approach also facilitates the evaluation of the degree to which pigeons depend on human resources.

Previous investigations into the abundance of feral pigeons in western countries have highlighted several key factors that influence their distribution. Noteworthy among these determinants are food resources (Przybylska *et al.*, 2012; Soldatini *et al.*, 2006), scale of the urban landscape (Hetmański *et al.*, 2011), human population density (Jokimäki & Suhonen, 1998), age architectural structures (Sacchi *et al.*, 2002), amount of organic waste (Buijs, 2003), landscape type (Przybylska *et al.*, 2012), and distance from the city center (Jhonston & Janiga, 1995).

Our objective was to determine the abundance and distribution of feral pigeons in an urban setting in India. In addition, we attempted to determine the type of food provided to pigeons and if there was a difference in pigeon populations at different feeding stations. Pigeons are social birds that tend to feed on flocks of various sizes. One of the major advantages of foraging in flocks is the better chance of avoiding predators due to increased vigilance and risk dilution (Hamilton, 1971; Pulliam, 1973). If any pigeon among the flock observes a possible threat or any noise, they are startled and the whole flock flies off. However, if it had to be a false alarm, they tend to resettle again once they figured out that there was no danger. Therefore, we hypothesized that the routine occurrence of humans at feeding stations have led to a certain degree of desensitization among pigeons for any human-related disturbance. This potential desensitization could manifest in variation in feeding time intervals (continuous time spent by pigeons feeding in a single sitting) among pigeons across different feeding hotspots.

MATERIALS AND METHODS

Study area

The density and abundance of feral pigeons were examined in the urban areas of Anand, India. Anand city is an urban agglomeration with continuous urban spread constituting towns and its adjoining urban outgrowths. The study area is depicted in Fig. 1. The city of Anand serves as the government headquarters of Anand District in Gujarat, India. The study was conducted from January 2021 to March 2022, pertaining to all three Indian seasons (Summer, Monsoon, post-monsoon & Winter). The Geographical coordinates of the city are 22.57° North (latitude) and 72.93°East (longitude), with an area of 22.7 km2 (8.8 sq. mi). Anand is famous all over India and Asia continent as the milk-cityof India and Asia; for it has the privilege to accommodate and establish The Amul Dairy ', which holds the record to be the biggest co -operative milk-society.

Pigeon survey

No previous records are available for feral pigeon surveys conducted in Indian cities. Therefore, as first-time research we were dependent on our own primary data collection method for pigeon surveys. To determine the distribution and abundance of pigeons, a preliminary survey of the city was conducted using a moped to identify preferential areas of pigeons. The survey established that pigeons had a clumped distribution throughout the city. Flocks are concentrated in areas with constant food availability and human inhabitants. A simple method was employed to estimate pigeon abundance by counting the number of pigeons visiting these feeding stations. It has been documented in western cities that pigeons are engaged in public feeding in public squares and are also dependent on organic waste within the city (Buijs, 2003; Sacchi *et al.*, 2002). However, contradictory to that in the Indian subcontinent, there are specifically established pigeon towers and plots for pigeon feeding. During the survey, we identified 17 major feeding stations (Figure 1.) within the city, where a flock of pigeons would gather to forage for food items provided by pigeon feeders. These feeding stations had at least more than 20 pigeons visiting the sites daily. The major sites were further divided into three main categories of Feeding Hotspots accounting for their specificity. The feeding stations are listed below (table 1).

Counts of pigeons were performed from March 2022 to February 2023. This survey method helped to consider the variation in pigeon populations visiting these feeding stations during different seasons of the year. A modified point-count method was used to monitor bird populations visiting the feeding stations. At least four censuses were conducted at each feeding station every month of the year between 6:00 AM and 12:00 PM. The time of the survey coincided with the peak feeding hours (personal observation). It is at this time that people from the surroundings visit this site with various food offerings. A canon mirrorless camera (M50 mark II) and mobile phone (Apple 14 pro max) were used to click photos of the flocks of pigeons arriving at feeding stations. The photograph was then manipulated on a computer, and individual birds were marked off as they were counted. To avoid double counts, feeding spots less than 100 m away were counted simultaneously.

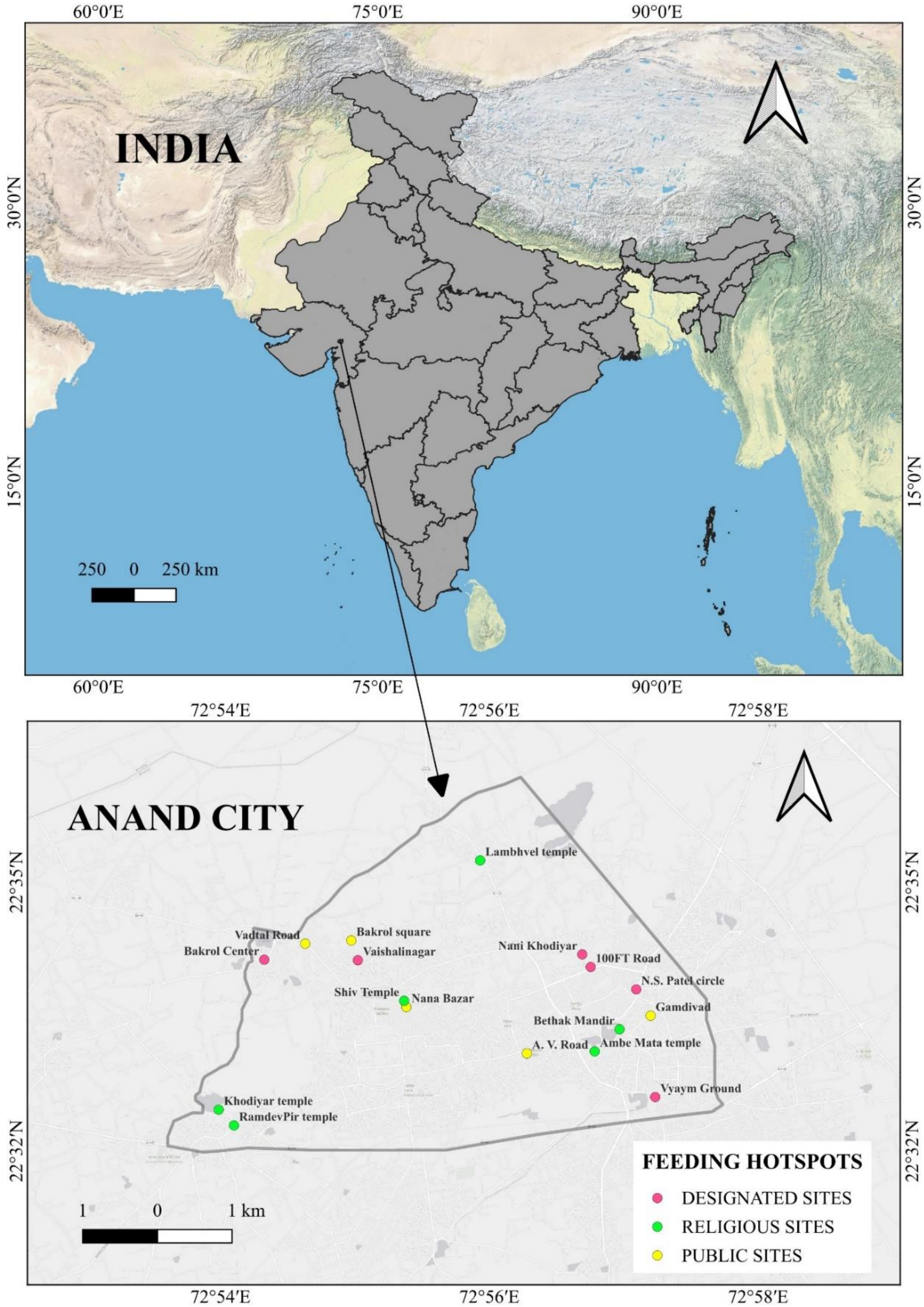

Figure 1: Map of the study area showing the territory of Anand city, along with the position of major feeding stations (preferential sites).

To analyze the variance in feeding time intervals, we examined the feeding hotspots listed in table 1. Our observation method involved selecting a random pigeon from the flock as the flock approach to feed on provisioned food at the feeding hotspots. For the present study, we considered the flock as homogenous group without differentiating sex or age of the individuals. We recorded the duration of uninterrupted feeding by the selected pigeon using a timer (in seconds) and noted the moment when the pigeon flocks away due to any disturbance or alarm made by the neighboring pigeon. We took 69 observations (n=69) from each feeding hotspot and subsequently analyzed the variance in feeding time intervals among these observations.

Statistical analysis:

Variation in the number of pigeons visiting each feeding hotspot were analysed using a non-parametric Kruskal-Wallis [K-W] test. Also, the same procedure was followed to analyse the difference in feeding time intervals among the feeding hotspots. To further investigate the differences between feeding hotspots, we performed post-hoc pairwise comparisons using Dunn's test. Dunn's test allows for multiple pairwise comparisons following a significant Kruskal-Wallis test. The significance level for the coefficients was set at $\alpha = 0.05$. All statistical analysis were performed using the free statistical software R (version 4.3.3, RStudio Team, 2022).

RESULTS

The present study was extended for 12 months (From February 2022 to March 2023) to urban areas and outgrowths of the Anand. We recorded data from approximately 17 feeding stations (Figure 1), where pigeons were fed daily. These sites saw large flocks of pigeons arriving to feed on the offered grains, and fried snacks were provided to them in some instances. No supplementary food provision was undertaken from our team. Table 1. summarizes the mean and maximum number of feral pigeons encountered at each

Table 1. No. of feral pigeons was counted at different Feeding Hotspots throughout the city.

Type of Feeding Hotspot	(Feeding stations with <20 feral pigeons, n = 48 counting) **Names of Feedings stations**	**Mean (SD)**	**Max**
Public sites	Gamdivad	81.60 (19.34)	154
	Nana bazar	95.08 (27.61)	141
	A.V. Road	79.27 (21.78)	124
	Bakrol square	54.54 (13.07)	88
	Vadtal Road	95.25 (24.69)	145
Religious sites	Bethak Mandir	93.33 (21.58)	134
	Amba Mata temple	280.79 (74.80)	436
	Shiv temple	101.29 (34.75)	208
	Ramdevpir temple	112.12 (33.78)	173
	Lambhvel temple	283.33 (47.93)	371
	Khodiyar temple	321.95 (82.70)	441
Designated sites	Bakrol central	97.52 (17.16)	126
	Vaishalinagar	98.60 (20.05)	131
	100Ft Road	778.97 (189.34)	1189
	Nani Khodiyar	440.45 (70.55)	612
	N.S. Patel Circle	426.56 (75.16)	578
	Vyaym Ground	372.83 (75.31)	451

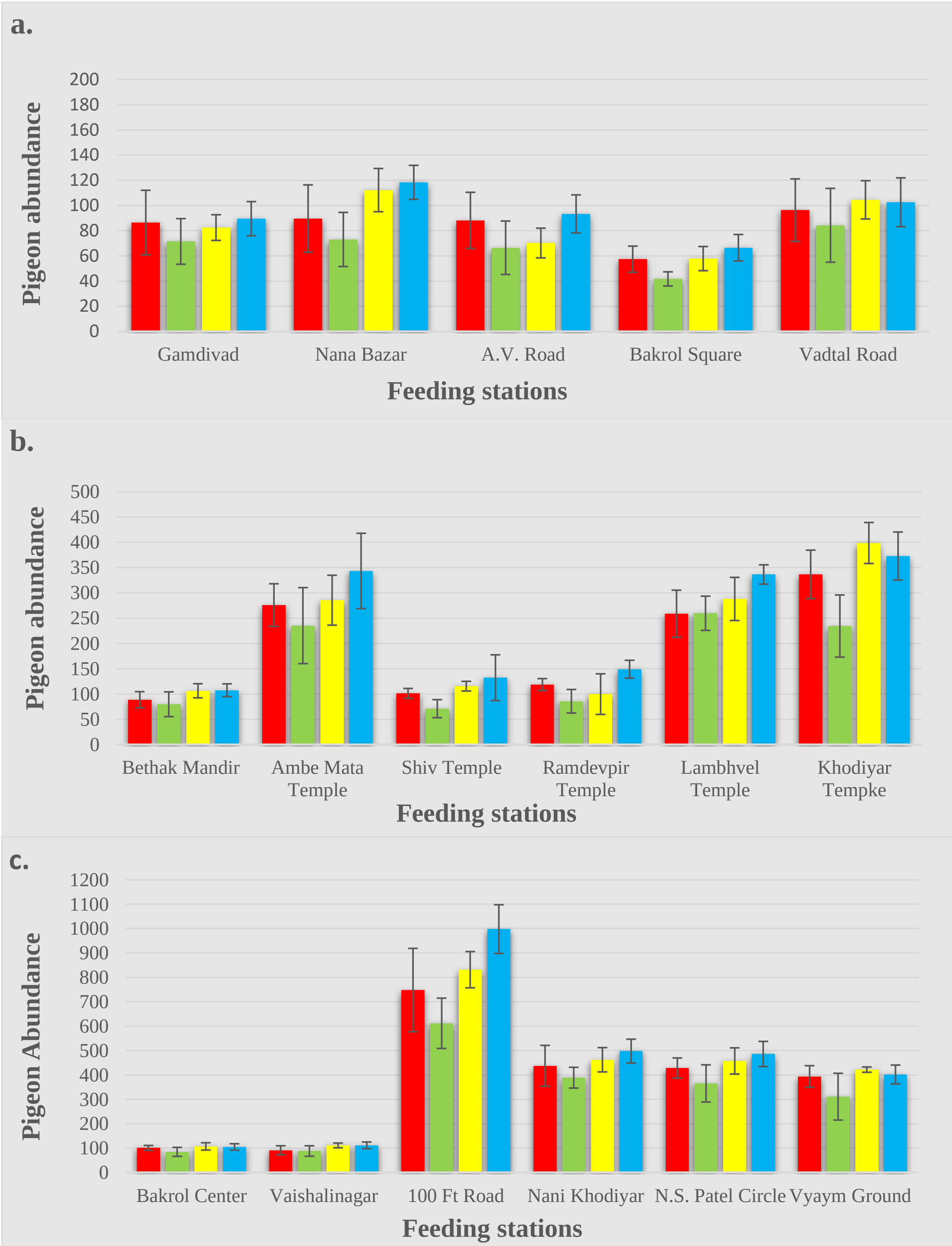

Figure 2. Pigeon abundance during the summer, monsoon, post-monsoon, and winter in a. Public sites, b. Religious sites, c. Designated sites.

feeding stations throughout our survey in the city of Anand. The identified feeding stations, wherein pigeon feeding behaviors were observed, were subsequently categorized into three discrete clusters representing distinct groupings of feeding hotspots i.e. designated sites, religious sites, and public sites. Feeding stations categorized as designated sites are characterized by enclosed perimeter, specifically designed to facilitate bird feeding, often accompanied by provisions such as water tubs for avian hydration. In contrast, feeding stations classified under religious sites are situated within temple corridors, where food offering is traditionally extended to pigeons. Public sites, on the other hand, encompass random feeding stations scattered throughout the town, attracting dedicated pigeon feeders and passerbys. Figure 2 a, b, c provides an estimate of seasonal pigeon abundance at each feeding station among the feeding hotspots.

Population Abundance and Distribution:

Among the three feeding hotspots, Designated sites had the highest number of pigeon abundance (mean ± SE: 2214.9 ± 53.64, n = 48), In comparison, religious sites had a relatively lesser abundance (mean ± SE: 1192.8 ± 34.20, n = 48), while the least number of pigeons were encountered in public sites (mean ± SE: 405.7 ± 11.30, n = 48). At Designated sites, a significant number of individuals were consistently observed to provide grain to the pigeons, with quantities ranging from 100 gm to 15 kg. Throughout the study, it was observed that pigeons visiting various feeding stations left a certain portion of feed unconsumed after their feeding regime, indicating satiation among pigeons. In religious sites, the temple priest and occasional temple visitors provide grains to pigeons during morning hours. While at public sites, casual feeders and passersby’s provided grains and fried snacks to pigeons as feed.

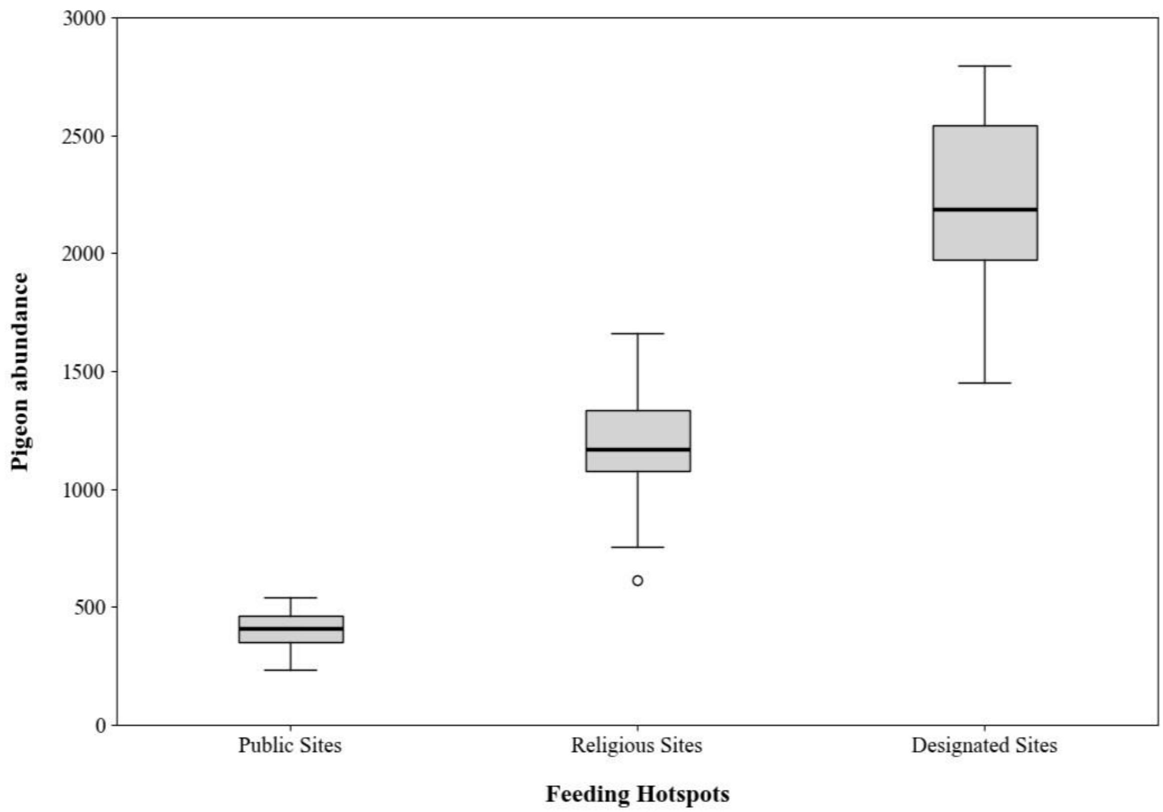

Figure 3. Box-and-whiskers plot depicting relative abundance of feral pigeons at different feeding hotspots from February 2022 to March 2023. Median (thick bar), interquartile range (box), range to the highest and lowest values within 1.5 interquartile ranges (whiskers), and an outlier are shown for each feeding hotspot.

Figure 3. visually demonstrates distinct medians for daily pigeon abundance across the three feeding hotspots throughout the 12-month study period. We employed the K-W test to assess the differences in pigeon abundance among the three feeding hotspots. The test yielded a significant result (chi-square = 126.296, df = 2, p < .001), indicating statistically significant differences in daily pigeon abundance among the feeding hotspots. Dunn's post-hoc test was utilized for pairwise comparisons across three spatial categories, namely public sites, religious sites, and designated sites. The adjusted p-values were computed using Dunn-Bonferroni correction. The analysis revealed statistically significant differences in pigeon abundance among all feeding hotspots (p < .0001 for all comparisons), indicating varying levels of attractiveness or suitability for pigeons across these environments. Specifically, public sites exhibited substantial deviations in pigeon abundance compared to both religious sites (Z = -5.674, p < 0.001) and designated sites (Z = 11.238, p < 0.001). Similarly, religious sites displayed a significant difference in pigeon abundance compared to designated sites (Z = 5.564, p < 0.001). These results suggest that the number of pigeons differed significantly among these space types, as indicated by the standardized rank differences (Z) between the groups. Figure 4. Gives us insight into the types of feed provided to the pigeons.

Table 2. Pairwise comparisons among feeding hotspots with Dunn-Bonferroni correction

Comparison	Test Statistic	Std. Test Statistic	p-value	Adjusted p-value
Public sites vs Religious sites	-48.312	-5.674	< .0001	< .0001
Public sites vs Designated sites	95.688	11.238	< .0001	< .0001
Religious sites vs Designated sites	47.375	5.564	< .0001	< .0001

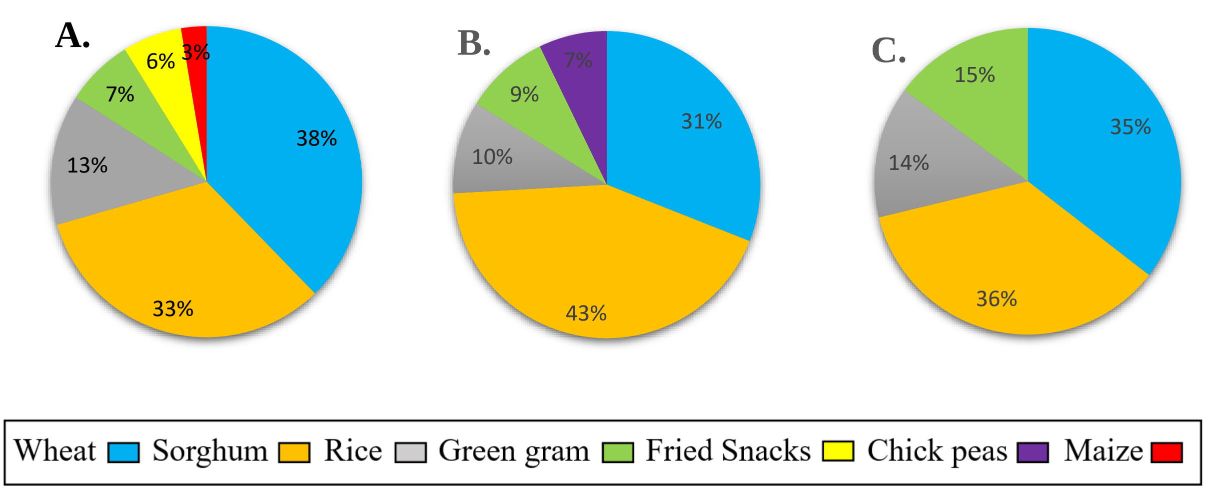

Figure 4. Frequency of different types of feed offered to pigeons at feeding hotspots A. Public sites, B. Religious sites, and C. Designated sites.

3.2 *Temporal feeding patterns of pigeons across feeding hotspots*

Pigeons tend to feed in flocks, which provide a sense of security against any perceived threat. However, pigeons that have been feeding at these feeding hotspots have become habituated to daily encounters with humans. Therefore, they tend to focus more on feeding and take more time to feed than flocking away. It was hypothesized that, to a certain degree, pigeons feeding at different feeding stations around the city would resist human presence or sudden noise while feeding.

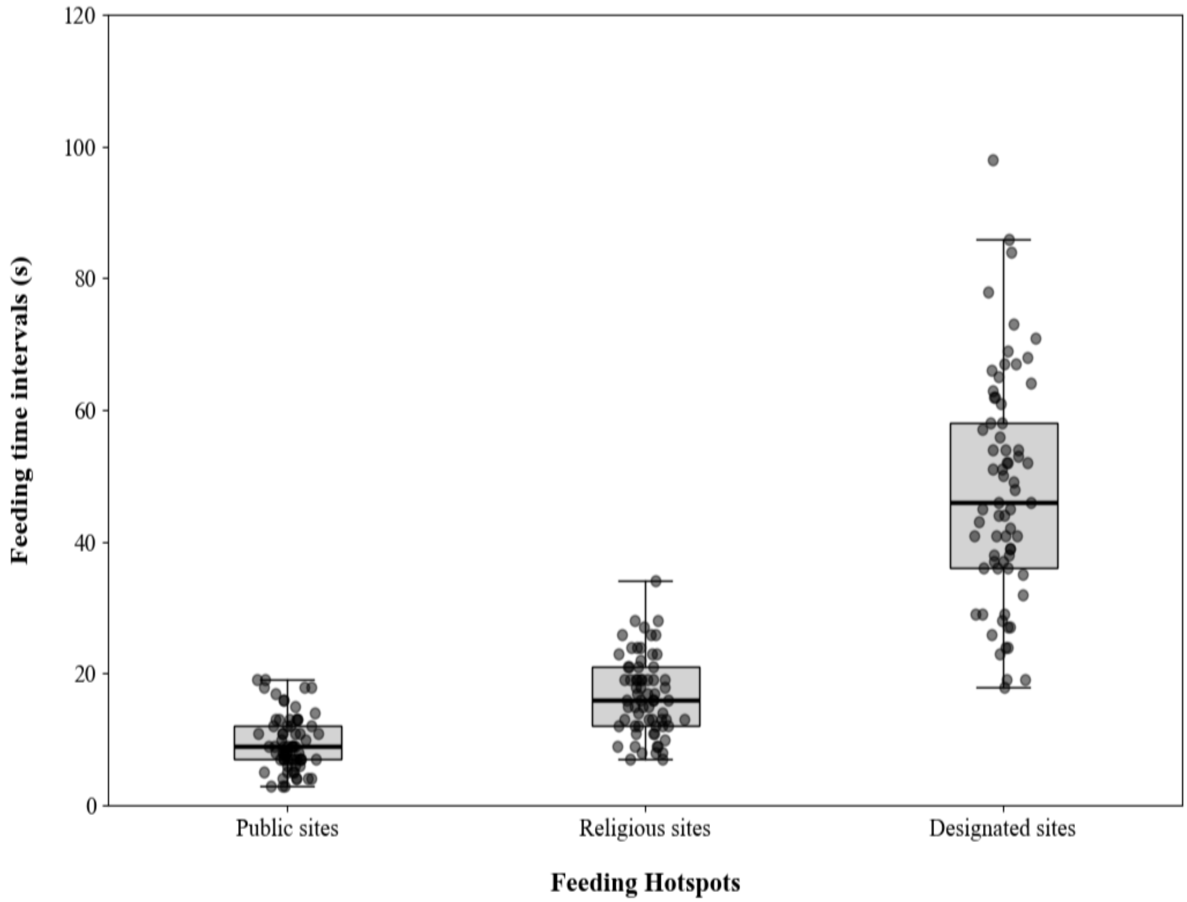

Figure 5. Box-and-whiskers plot suggesting variation in feeding time intervals among different feeding hotspots. Data points, median (thick bar), interquartile range (box), range to the highest and lowest values within 1.5 interquartile ranges (whiskers), and outlier are shown for each feeding hotspots.

The continuous feeding time interval (in seconds) was evaluated for the three distinct feeding hotspots. Designated sites saw the highest continuous feeding time interval (mean ± SE: 47.78 ± 2.06 seconds, n = 69), among the three feeding hotspots, followed by religious sites (mean ± SE: 16.71 ± 0.71 seconds, n = 69). The pigeons feeding at public sites (mean ± SE: 9.47 ± 0.50 seconds, n = 69), took the least time in feeding, and flock away readily encountering any disturbance. The K-W test was conducted to compare the median feeding time intervals among the feeding hotspots. The analysis revealed a statistically significant difference in feeding time intervals among the three groups (chi-square = 153.406, df = 2, $p < 0.001$), indicating that the choice of feeding location significantly affected the feeding behavior of pigeons. Figure 5. provides us a visual depiction of the variation in median feeding time intervals across the three feeding hotspots. Furthermore, post-hoc analysis was implemented for pairwise comparison of the three feeding hotspots. The analysis revealed a significant difference among all feeding hotspots. A comparison of public feeding sites with religious spaces ($Z = -4.802$, $p < 0.001$) indicated a significant difference. Similarly, a comparison of Public Feeding sites to designated sites ($Z = 12.288$, $p < 0.001$) also indicated a significant difference. Finally, comparing religious spaces to designated sites, the ($Z = 7.486$, $p < 0.001$), also indicated a significant difference. These results indicate that the feeding behavior of pigeons is influenced by the type of feeding hotspots they visit. It also suggests that continuous habituation and a sense of protection have led pigeons to take more time to feed.

DISCUSSION

To the best of our knowledge, this is the first attempt to investigate the abundance and distribution of feral pigeons in an Indian city, thereby offering insight into the broader context of the Indian subcontinent. Although pigeons were observed throughout the city, their distribution was notably concentrated in areas with abundant food resources, evidenced by the annual flock size trends at different feeding hotspots (table 1.). A steady influx of pigeons to feeding stations on a daily basis indicates the presence of abundant local food resources (Soldatini *et al.,* 2006). During our study, we observed a noteworthy contrast in the dietary habits of pigeons compared to Western norms. Unlike the prevalent provision of cakes, bacon, bread crumbs, and organic waste documented in Western studies (Buijs, 2003; Ryan, 2011; Daniel Sol & Lefebvre, 2000), the pigeons in our study were predominantly offered grains. Only feeding stations at public sites had the scenario of food provision in the form of fried snacks. Of the varied food resources *Triticum aestivum* (wheat), *Sorghum bicolor* (sorghum), *Oryza sativa* (rice grain) and *Vigna radiata* (green gram) were predominantly offered to the pigeons. No significant difference in supplementary feed was observed among the feeding hotspots, all the three sites had wheat, sorghum, rice grain and green gram as the top four frequently (Figure 3.) offered food grains. While *Zea mays* (maize) and split *Cicer arietinum* (chickpeas) were offered seldom.

These findings shed light on the extent to which feral pigeons have become dependent on human-provided food, with this supplementary feed becoming as their primary food source. These results are similar to studies conducted by European counterparts that put public feeding as one of the most important factors for the rise in the feral pigeon population (D. Giunchi *et al.*, 2007; Haag-Wackernagel, 1995; Przybylska *et al.*, 2012; Stock & Haag-Wackernagel, 2013). It is also interesting to note that different spatial regions of pigeon feeding vary in the number of pigeons arriving there. The designated sites with a fenced perimeter provided the most suitable spot for the pigeon foraging regime as it had reported the highest mean pigeon population (mean ± SE: 2214.9 ± 53.64) throughout the year. It was also observed that a significant number of individuals who feed pigeons, routinely visited this feeding hotspot. The pigeon feeders consistently provide an ample supply of grains to nourish the large congregations of pigeons. This is a prevalent activity in urban areas seen in major parts of the world, where residents intentionally offer food to birds (Fuller *et al.*, 2008; Johnston, 2001). The strong effect of these ecological factors on the foraging behavior of pigeons is evident in the significantly longer mean feeding time interval (mean ± SE: 47.78 ± 2.06 seconds) observed at designated sites among the three feeding hotspots. The provisions of designated sites with fenced perimeters serves to impart a protective environment for pigeons shielding them from potential predatory threats such as stray dogs. As a result, this heightened level of protection has been observed to correlate with a notable increase in the duration of feeding sessions in comparison to alternative feeding hotspots. Although there were some limitations to the data, this outcome highlights the concept of habituation in human-pigeon interaction as they exhibit a reduced propensity to react to human involved disturbances. Religious sites also consistently attract a large number of pigeons throughout the year. As observed during our study, temple terraces and courtyards in the vicinity of the temple have become places for offering food to pigeons, with a significant contribution from both temple priests and visitors. This has now become a cultural practice throughout the country. Also, the predominant religions of the Indian sub-continent, Hinduism, and Islam, consider pigeons as sacred animals, and they associate feeding pigeons with the themes of transformation and redemption (Wilde, 2021). The least abundance of pigeons was recorded at public sites, with irregular quantity of food these sites are not ideal for large pigeon gatherings. Another reason for their low abundance is that the feeding stations categorized as public sites are predominantly positioned along streets, which could potentially evoke negative behavior in pigeons due to the associated commotion and high noise levels (Kociolek *et al.,* 2011). This aspect is notably reflected in the foraging behavior of pigeons in public spaces, as indicated by the shortest mean feeding time interval (mean ± SE: 9.47 ± 0.50 seconds), among the three identified feeding hotspots.

Our findings hold notable significance, as they indicate that the influence of ad-libitum food sources in the form of feeding stations throughout the city contributes to the distribution patterns of feral pigeon populations. Furthermore, the results elucidate the distinct variations in pigeon population dynamics across various feeding hotspots. With only six designated feeding stations catering to more than half of the observed pigeon population, the potential for population growth is apparent. Increasing the number of such sites would likely lead to a corresponding rise in the pigeon population, given that these locations offer sufficient food resources and a sheltered habitat conducive to population expansion. Obviously, we did not include another factor potentially affecting abundance and distribution in an urban area. One such factor is the building features of the town. However, the pigeons are equipped to be flexible in selecting nest site (Hetmański *et al.,* 2011) and a lot of buildings and houses can provide with suitable opportunity. Other reason that might add to the increase in pigeon population is the attitude of people in the city towards pigeon. As seen throughout the study, 'pigeon lovers' are empathetic towards pigeons and offer large quantity of food to them, without due consideration to its consequences.

REFERENCES

Bassi, M., & Chiatante, D. (1976). The Role of Pigeon Excrement in Stone Biodeterioration. *International Biodeterioration & Biodegredation*, **12**(3), 73–79.

Buijs, J. A. N. A. (2003). *Survey of feral rock doves (Columba livia) in Amsterdam , a bird-human association*. 1995, 235–241.

Donnelly, R., & Marzluff, J. M. (2006). Relative importance of habitat quantity, structure, and spatial pattern to birds in urbanizing environments. *Urban Ecosystems*, **9**(2), 99–117. *https://doi.org/10.1007/s11252-006-7904-2*

Fuller, R. A., Warren, P. H., Armsworth, P. R., Barbosa, O., & Gaston, K. J. (2008). Garden bird feeding predicts the structure of urban avian assemblages. *Diversity and Distributions*, **14**(1), 131–137. *https://doi.org/10.1111/j.1472-4642.2007.00439.x*

Giunchi, D., Baldaccini, N. E., Sbragia, G., & Soldatini, C. (2007). On the use of pharmacological sterilisation to control feral pigeon populations. *Wildlife Research*, **34**(4), 306–318. *https://doi.org/10.1071/WR06153*

Giunchi, Dimitri, Gaggini, V., & Baldaccini, N. E. (2007). Distance sampling as an effective method for monitoring feral pigeon (Columba livia f. domestica) urban populations. *Urban Ecosystems*, **10**(4), 397–412. *https://doi.org/10.1007/s11252-007-0032-9*

Haag-Wackernagel, D. (1995). Regulation of the Street Pigeon in Basel. *Wildlife Society Bulletin (1973-2006)*, *23*(2), 256–260. *http://www.jstor.org/stable/3782800*

Haag-Wackernagel, D., & Bircher, A. J. (2010). Ectoparasites from feral pigeons affecting humans. *Dermatology*, *220*(1), 82–92. https://doi.org/10.1159/000266039

Haag-Wackernagel, D., Feare, C., & Cowan, D. P. (2006). Human diseases caused by feral pigeons. *Advances in Vertebrate Pest Management*, **4**(February), 31–58.

Haag-Wackernagel, D., & Geigenfeind, I. (2008). Protecting buildings against feral pigeons. *European Journal of Wildlife Research*, **54**(4), 715–721. *https://doi.org/10.1007/s10344-008-0201-z*

Haag-Wackernagel, D., & Moch, H. (2004). Health hazards posed by feral pigeons. *Journal of Infection*, **48**(4), 307–313. *https://doi.org/10.1016/j.jinf.2003.11.001*

Hamilton, W. D. (1971). Geometry for the selfish herd. *Journal of Theoretical Biology*, **31**(2), 295–311. *https://doi.org/10.1016/0022-5193(71)90189-5*

Hetmański, T., Bocheński, M., Tryjanowski, P., & Skórka, P. (2011). The effect of habitat and number of inhabitants on the population sizes of feral pigeons around towns in northern Poland. *European Journal of Wildlife Research*, **57**(3), 421–428. *https://doi.org/10.1007/s10344-010-0448-z*

Johnston, R. F. (2001). *Synanthropic birds of North America BT - Avian Ecology and Conservation in an Urbanizing World* (J. M. Marzluff, R. Bowman, & R. Donnelly (eds.); pp. 49–67). Springer US. https://doi.org/10.1007/978-1-4615-1531-9_3

Jokimäki, J., & Suhonen, J. (1998). Distribution and habitat selection of wintering birds in urban environments. *Landscape and Urban Planning*, **39**(4), 253–263. *https://doi.org/https://doi.org/10.1016/S0169-2046(97)00089-3*

Kociolek, A. V., Clevenger, A. P., St. Clair, C. C., & Proppe, D. S. (2011). Efectos de las Redes de Caminos sobre Poblaciones de Aves. *Conservation Biology*, **25**(2), 241–249. *https://doi.org/10.1111/j.1523-1739.2010.01635.x*

Meyer, W. B., & Turner, B. L. (1992). Human Population Growth and Global Land-Use/Cover Change. *Annual Review of Ecology and Systematics*, **23**(1), 39–61. https://doi.org/10.1146/annurev.es.23.110192.000351

Murton, R. K., & Westwood, N. J. (1966). The foods of the rock dove and feral pigeon. *Bird Study*, **13**(2), 130–146. *https://doi.org/10.1080/00063656609476116*

Przybylska, K., Haidt, A., Myczko, Ł., Ekner-Grzyb, A., Rosin, Z. M., Kwieciński, Z., Tryjanowski, P., Suchodolska, J., Takacs, V., Jankowiak, Ł., Tobółka, M., Wasielewski, O., Graclik, A., Krawczyk, A. J., Kasprzak, A., Szwajkowski, P., Wylegała, P., Malecha, A. W., Mizera, T., & Skórka, P. (2012). Local and landscape-level factors affecting the density and distribution of the Feral Pigeon Columba livia var. domestica in an urban environment. *Acta Ornithologica*, **47**(1), 37–45. *https://doi.org/10.3161/000164512X653908*

Pulliam, H. R. (1973). On the advantages of flocking. *Journal of Theoretical Biology*, *38*(2), 419–422. *https://doi.org/10.1016/0022-5193(73)90184-7*

Rose, E., Haag-Wackernagel, D., & Nagel, P. (2006). Practical use of GPS-localization of Feral Pigeons Columba livia in the urban environment. *Ibis*, **148**(2), 231–239. *https://doi.org/10.1111/j.1474-919X.2006.00499.x*

Ryan, Alice C. (2011). The Distribution, Density and Movements of Feral Pigeons Columba livia and their Relationship with People. Open Access Te Herenga Waka-Victoria University of Wellington. Thesis. *https://doi.org/10.26686/wgtn.16993483.v1*

Sacchi, R., Gentilli, A., Razzetti, E., & Barbieri, F. (2002). Effects of building features on density and flock distribution of feral pigeons Columba livia var. domestica in an urban environment. *Canadian Journal of Zoology*, **80**(1), 48–54. *https://doi.org/10.1139/z01-202*

Shochat, E. (2004). Credit or debit? Resource input changes population dynamics of city-slicker birds. *Oikos*, **106**(3), 622–626. *https://doi.org/10.1111/j.0030-1299.2004.13159.x*

Sol, D., & Senar, J. C. (1995). Urban pigeon populations: Stability, home range, and the effect of removing individuals. *Canadian Journal of Zoology*, **73**(6), 1154–1160. *https://doi.org/10.1139/z95-137*

Sol, Daniel, & Lefebvre, L. (2000). Behavioural flexibility predicts invasion success in birds introduced to New Zealand. *Oikos*, **90**(3), 599–605. *https://doi.org/10.1034/j.1600-0706.2000.900317.x*

Soldatini, C., Mainardi, D., Baldaccini, N. E., & Giunchi, D. (2006). A temporal analysis of the foraging flights of feral pigeons (Columba livia f. domestica) from three Italian cities. *Italian Journal of Zoology*, **73**(1), 83–92. *https://doi.org/10.1080/11250000500502210*

Stock, B., & Haag-Wackernagel, D. (2013). Effectiveness of gel repellents on feral pigeons. *Animals*, **4**(1), 1–15. https://doi.org/10.3390/ani4010001

Umang, S., & Nikunj, B. (2023). International Journal of Zoological Impact of Supplementary Feeding on Feral Pigeon Abundance : A Brief Review. *International Journal of Zoological Investigations*, **9**(2), 86–91. *https://doi.org/10.33745/ijzi.2023.v09i02.009*

Weber, J., Haag, D., & Durrer, H. (1994). Interaction Between Humans and Pigeons. *Anthrozoös*, **7**(1),

55–59. *https://doi.org/10.2752/089279394787002023*
Wilde, K. (2021). Pigeon symbolism and meaning (totem, spirit, and omens). Sonoma Birding. February 2. *Available at:* https://www.sonomabirding.com/pigeon-symbolism/ (accessed 11 March 2023).