Original Research Article

Unveiling Urban Canines: Leveraging Single-Sight and Sight–Resight Survey for Street Dog Population Estimation and Enhanced Rabies Surveillance in Metropolitan City of Bruhat Bengaluru MahanagaraPalike, Karnataka, India

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ABSTRACT

Aim: The aim of the study is to estimate Bengaluru's street dog population and evaluate the effectiveness of interventions for population control and public health, particularly in rabies control. It also aims to develop a blueprint for responsible urban management that prioritizes compassion and safety for both humans and street dogs.

Study design and Methodology: The study utilizes the Bruhat Bengaluru MahanagaraPalike (BBMP) Street Dog Survey to estimate the street dog population in Bengaluru. It employs Single-Sight and Sight–Resight methods with Lincoln–Petersen's Formula and Chapman's Correction for estimation. The population is categorized into zones to provide nuanced insights, guiding targeted interventions based on gender, age composition, and neutering status.During the initial six days, a single-sight survey was conducted by a pair of surveyors traveling on a 2-wheeler down every road in an allocated zone, photographing and recording details of dogs observed. Subsequently, on the following six days, all dogs sighted during the initial survey period were documented, regardless of whether they were previously recorded.

Results: The study estimates Bengaluru's street dog population at approximately 279,335. It indicates a significant 10% reduction in the street dog population since 2019, suggesting effective interventions. There is also a commendable 20% increase in neutering rates, highlighting the importance of ongoing efforts in population control and public health, particularly in rabies control.

Conclusion: The reduction in the street dog population is deemed pivotal for curtailing disease transmission and ensuring public safety. The study positions itself to develop a blueprint for responsible urban management, prioritizing compassion and safety for both humans and street dogs. By exemplifying the effectiveness of evidence-driven policies and collective action, the aim is to pave the way for sustainable urban management practices that foster harmonious coexistence between communities and street dogs. Through continued collaboration and informed decision-making, the study suggests striving towards creating a safer and more compassionate environment for all inhabitants of Bengaluru.

Keywords: Single-Sight and Sight–Resight survey, Lincoln–Petersen's Formula, Chapman's Correction

1. INTRODUCTION

Dogs, renowned for their loyalty, diversity of breeds, and innate ability to forge connections, have made them a permanent part of the urban ecosystem [1]. The free ranging Street Dogs or the street dogs which are owned, need to be looked upon with compassion and seen that they are not overgrown in population to cause problems to their human companions.

In this context, the Bruhat Bengaluru MahanagaraPalike (BBMP), embarked on a significant endeavor that extends well beyond its typical municipal duties. As the custodian of Bengaluru's civic amenities and Stray Animals, BBMP's mandate extends far beyond the

realm of roadways and waste management. In a bid to comprehensively address the dynamic relationship between the city's human and canine inhabitants, BBMP conducted a street dog survey. This survey, a testament to BBMP's commitment to effective civic management, holds immense importance in shaping policies, fostering harmonious coexistence, and ensuring the well-being of both the city's residents and its four-legged companions.

Bruhat Bengaluru MahanagaraPalike (BBMP) is carrying out Animal Birth Control-Anti Rabies Vaccination (ABC-ARV) program in all of its 08 zones. In order to study the impact of the ongoing ABC-ARV program [2] on the Street Dog population in Bengaluru, it is necessary to carry out systematic survey estimation of the street dog's population using National Action Plan for dog Mediated Rabies Elimination (NAPRE) [3]recommended method (single sight and sight-resight surveys) in Bengaluru city (BBMP) with the following objectives which include estimating the current neutering percentage among street dogs, analyzing the geographical distribution and zone-wise density of the street dog population, formulating a ward-wise micro plan, setting reliable ABC-ARV targets based on estimated street dog populations, and intensifying systematic Anti Rabies Vaccination (ARV) drives to achieve a 70% vaccination rate among street dogs.

Accurate population estimation in BBMP enables targeted and efficient public health interventions. By employing methods such as Single-Sight and Sight–Resight surveys, authorities can gather essential data on the size, distribution, and health status of the stray dog population[2]. This information forms the foundation for strategic implementation of Animal Birth Control (ABC) programs[4] and Anti-Rabies Vaccination (ARV) campaigns[5]. ABC programs, which involve spaying and neutering, help manage and reduce the stray dog population, thereby limiting the potential for rabies transmission[6]. Concurrently, ARV campaigns ensure that a significant proportion of the roaming dog community is immunized against rabies, acting as a barrier to the virus's spread.

Rabies, a lethal viral disease, poses a significant public health threat globally. Transmitted through the saliva of infected animals, particularly through bites, the rabies virus targets the nervous system, leading to severe neurological symptoms. The disease is almost universally fatal once clinical signs appear, making prevention crucial. In urban settings like BBMP, the presence of a substantial stray dog population amplifies the risk of rabies transmission. Understanding the magnitude of the roaming dog population through accurate population estimation becomes a critical tool in rabies control[7]. In essence, an accurate estimation of the stray dog population in BBMP is instrumental in designing and implementing targeted measures for rabies control. This proactive approach not only protects the health and well-being of the community but also fosters a more harmonious coexistence between the human and animal populations in urban environments. Through responsible and data-driven management strategies, BBMP can significantly contribute to the reduction of rabies risk and enhance the overall health and safety of its residents[8].

2. METHODOLOGY

2.1. Study Area

The study was conducted in the wards of BBMP (Fig. 1) in Bengaluru Urban district located in the southern part of India with coordinates of 12° 58' 17.7564" N and 77° 35' 40.4376" E between 11th July 2023 and 2nd August 2023. BBMP jurisdiction has 243 wards. These 243 wards are divided into 6850 grids (micro zones) for Survey purpose[9][10].

2.2 Selection of the Micro-zones

The micro zones (n=6850) each having an area of 0.5 Sq.km, were created within the 243 wards for more detailed and precise analysis of data. It is assumed that this level of granularity allows for a better understanding of localized trends and variations with reducing the risk of missing important data points and ensures a comprehensive assessment. Challenges or opportunities identified in specific zones can be addressed with tailored solutions, optimizing resource allocation and efforts.

The methodology employed (Fig. 3) for the selection of wards involved the utilization of Stratified Random Sampling. With a total of 243 wards and 6850 micro zones, the aim was to ensure a representative sample. To achieve this, the Sample size formula $m1 = \left(\frac{200}{Q}\right)^2 \left(\frac{s}{N}\right)^2$ Where Q is PRP (10),is the estimated mean number of dogs per sample,s is the estimated sample standard deviation, N is the total estimated population size, or 20% of the sampling results, whichever is higher was used [15]. A total of 1360 micro zones, were required to be chosen for analysis (Fig. 2(b)).

The initial step involved the subdivision/stratification of the 6850 micro zones into four distinct categories, carefully aligned with the unique facets of the urban environment. These categories encompassed micro zones surrounding lakes, in slum areas, in commercial areas, and other general areas (Fig. 2(a)). By categorizing the micro zones into these four strata, the methodology acknowledged and embraced the diversity inherent in the city's fabric. The micro zones within eachstratum were meticulously chosen for inclusion in the survey. This methodical selection process was driven by the aim to capture a cross-section of the city's various dynamics and characteristics, thereby enhancing the validity and reliability of the survey outcomes.

To uphold the integrity of the sample, the selection process involved picking minimum five micro zones from each ward. This systematic approach of selecting micro zones from different wards while maintaining the prescribed quantity within each ward adheres to the principles of Stratified Random Sampling. This technique was chosen to provide an accurate and well-rounded understanding of the city's diverse dynamics. By embracing a systematic and balanced approach to selecting wards and micro zones, the survey outcomes are poised to provide a robust foundation for decision-making, policy formulation, and the harmonious coexistence of both humans and their canine companions within the urban landscape.

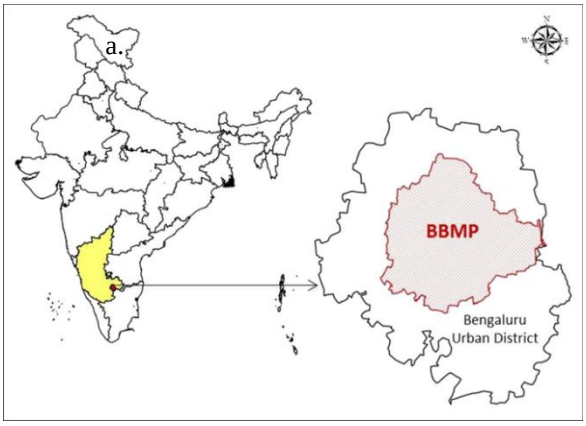


Fig. 1. Study area showing BBMP in Bengaluru Urban district of Karnataka State

(b)

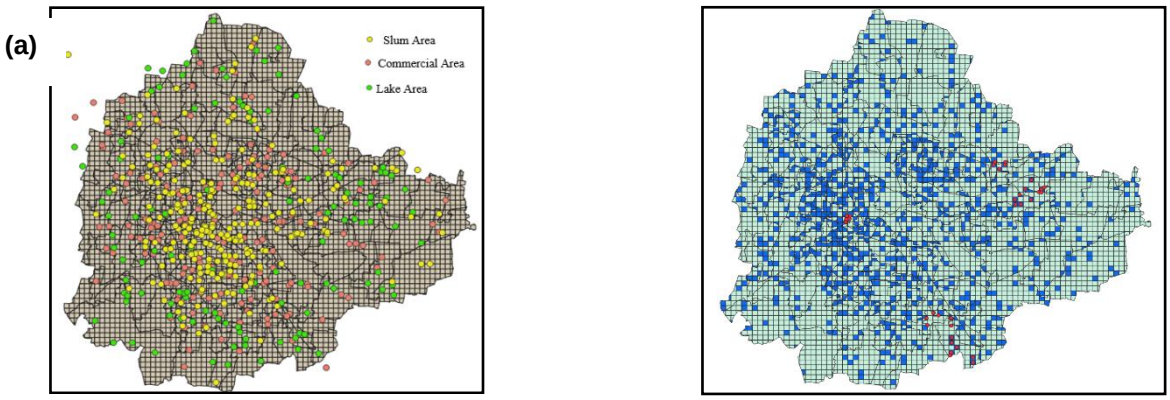


Fig. 2. Study area showing BBMP gridded map demarcated with lakes, slums & commercial area (a), sampling area (b)

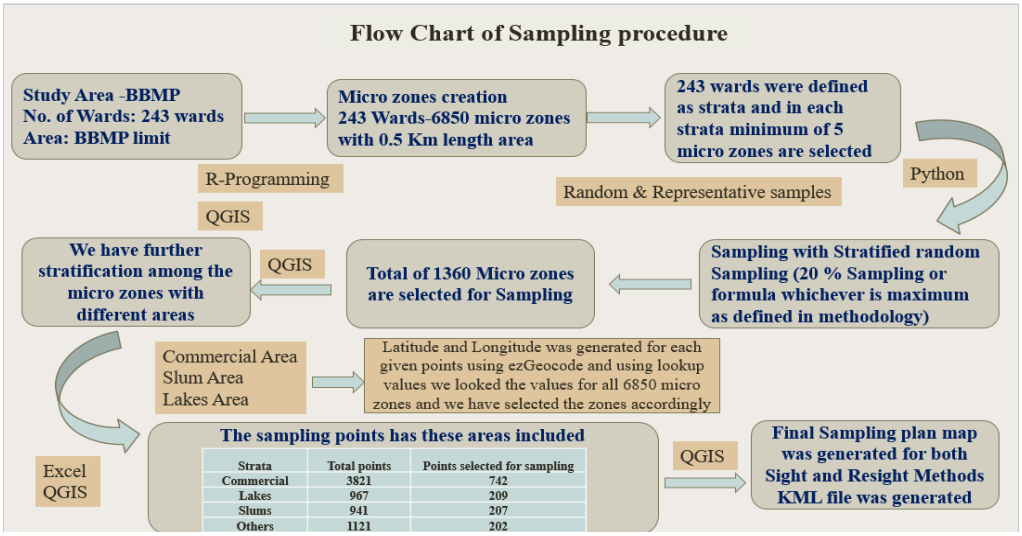


Fig. 3. Flow chart of Sampling (Stratified Random Sampling) procedure

2.3. Mode of Survey

2.3.1 Single-Sight and Sight –Resight survey

The Single-Sight and Sight-Resight Survey [11] was conducted within the BBMP limits over twelve days. For the first six days, single-sight survey was carried out for gathering information about the number of dogs in a particular area by a pair of surveyors by travelling down every road on a 2-wheeler, taking photographs and recording information about dogs seen in all parts of an allocated zone and also recording details of every dog they saw. On the next six days, all of the dogs seen on the first six days are recorded, whether or not, they were captured as seen on the first six days. This proportion makes it possible to estimate the total dog population for the region using Lincoln–Petersen's formula given below.

Unlike the Single-Sight Survey method, the SRS Survey method provides an estimate of the total population in the surveyed area, however, they require more staff expertise and time to implement, limiting the area, which can be covered. Therefore, a combination of both SS and SRS surveys makes it possible to benefit from both scale and intensity of method.

2.3.2.Lincoln–Petersen's Formula with Chapman's Correction for population estimation

The sizes of the Street Dog populations were estimated using the Lincoln–Petersen formula with Chapman's correction[12][13] according to equation 1 in which N is the estimate of the total population size, n1 is the total number of dogs sighted during single sight survey, n2 is the total number of dogs sighted during Sight–Resight survey, and m is the number of sighted dogs re-sighted Sight–Resight survey. An approximate unbiased variance of N was estimated by using Seber's formula [14][13](equation 2). The 95% confidence interval for N was estimated according to equation 3

$$\boldsymbol{N} = \left[\frac{(\boldsymbol{n1}+\boldsymbol{1})(\boldsymbol{n2}+\boldsymbol{1})}{\boldsymbol{m}+\boldsymbol{1}} - \boldsymbol{1}\right] \quad (1)$$

$$\boldsymbol{var}(\boldsymbol{N}) = \left[\frac{(\boldsymbol{n1}+\boldsymbol{1})(\boldsymbol{n2}+\boldsymbol{1})(\boldsymbol{n1}-\boldsymbol{m})(\boldsymbol{n2}-\boldsymbol{m})}{(\boldsymbol{m}+\boldsymbol{1})^{\boldsymbol{2}}(\boldsymbol{m}+\boldsymbol{2})}\right] (2)$$

$$\boldsymbol{95\%\ confidence\ interval\ (CI)} = \boldsymbol{N} \pm \boldsymbol{1.965}\sqrt{\boldsymbol{var}(\boldsymbol{N})} (3)$$

2.4. Survey Execution and Data Collection

The BBMP Street Dog Survey was executed with a carefully planned methodology to ensure accuracy. Covering 1360 micro zones in Bengaluru, the survey enlisted 79 para-veterinarians from AHVS, Bengaluru Urban District, and 30 from BBMP (AH). Supervised by 15 Veterinary Officers, ICAR-NIVEDI designed the sampling plan, and Worldwide Veterinary Service (Mission Rabies) provided technical support through their mobile application. A dedicated committee oversaw logistics for transparency. The survey employed the Single-Sight and Sight-Resight Survey methods, with 50 teams covering 1360 micro zones [10]over 12 days (Fig. 4). Each team, assigned to 5 wards, conducted surveys on 2-wheelers from 6:00 AM to 8:30 AM. The resight survey involved 12 teams meticulously revisiting locations over two days to capture photographs for calculating the crucial "m value" (Fig. 5). The careful cross-referencing and calculation of "m values" for a subset of micro zones, followed by extrapolation to the entire dataset, underscored the survey's commitment to accuracy and reliability in estimating the street dog population

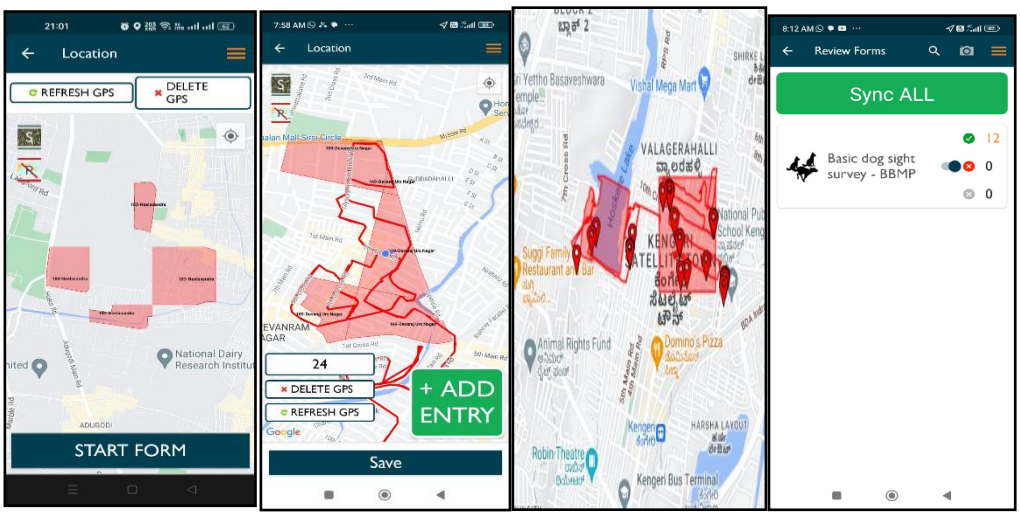


Fig. 4. Operational Perspective of the Survey: Allocated Grids, GPS Mapping of Survey Zone and Image Upload to the Application (WVS)

Fig. 5. Few Images of Canines Documented Throughout the Survey

2.5. Methodology for Analyzing Population Changes

To gain a comprehensive understanding of the changes in Street Dog populations, it's essential to delve into the data from the previous year and the current year. One effective tool for this analysis is the Compound Annual Growth Rate (CAGR). It offers a dynamic lens through which we can assess the average annual growth or decline in the Street Dog population over a specified period. It helps us discern the trajectory of change by considering both past and current figures. CAGR is calculated as follows.

CAGR = [(Current Year Population / Previous Year Population) ^ (1 / Number of Years) - 1] × 100

Here, "Current Year Population" represents the Street Dog population in the present survey, "Previous Years Population" denotes the population in the previous survey, and "Number of Years" signifies the time elapsed between the two data points.

3. RESULTS AND DISCUSSION

The implementation of the BBMP Street Dog Survey involved a systematic sampling strategy that encompassed the division of the survey area into wards, the introduction of micro zones, and the careful selection of specific blocks for analysis. This section sheds light on the details of this strategic approach and its implications for the survey outcomes.

3.1. Population estimation insights

The population estimation results for micro zones, as summarized in the Table1 below, offer a comprehensive overview of the Street Dog population dynamics in the surveyed area. The data reflects the calculated population estimates for both 1360 and 6850 micro zones, shedding light on the distribution and magnitude of the Street Dog population.

Table 1. Population estimation for Micro zones with confidence interval (CI)

Number of Zones	No of dogs Sighted on Single Sight survey	No of dogs Sighted on Sight-Resight survey	m value	Total Population	95% CI
1360 Micro zones	19,395	20,008	6,996	55,465	54625-56305
6850 Micro zones	97,674	1,00,760	35,232	2,79,335	277450-281220

Table 2. Zone wise Total Population estimates with Confidence Interval CI, Gender population estimates and percentage status of neutered

Zones	Total Population	95% (CI)	Gender population			Neutered (%)
			Male	Female	Unknown	
Bengaluru East	37685	36993-38377	21584	11228	4873	71.75
Bommanahalli	39183	38475-39891	23860	9299	6024	72.18
Bengaluru South	23241	22692-23790	13116	7066	3059	77.32
Bengaluru West	22025	21493-22557	13870	6261	1894	79.48
Dasarahalli	21221	20700-21742	14580	4850	1791	77.46
Mahadevpura	58371	57513-59229	32528	18872	6971	59.34
R R Nagar	41266	40541-41991	24638	11899	4729	67.64
Yelahanka	36343	35679-37007	21165	13282	1896	66.50
Total	279335	277450-281220	165341	82757	31237	71.85

From the Table 2, the results reveal significant variations in the street dog population across different zones of Bengaluru, shedding light on the diverse challenges and characteristics of these communities. Mahadevpura and R R Nagar exhibit relatively higher total populations, with 58,371 and 41,266 street dogs, respectively (Fig. 6). Neutering efforts are notable, with Bengaluru West and Dasarahalli boasting percentages of 79.48% and 77.46%, indicating proactive measures in population control. However, Mahadevpura stands out with a lower neutering percentage of 59.34%, suggesting potential areas for targeted intervention.

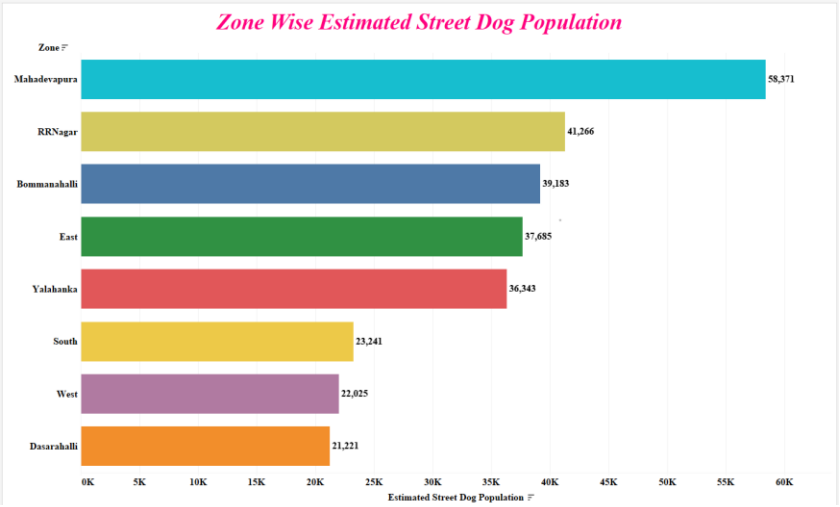


Fig. 6. Zonal Street Dog estimated population distribution

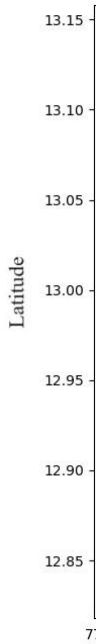
The Table 3 presents a comprehensive breakdown of the Street Dog population estimates in each of the strata such as Commercial Areas, Lakes, Slums and Others. This segmentation provides a deeper insight into the distribution of Street Dog populations in relation to specific urban contexts.

Table 3. Street Dog Population by Categories and Confidence Intervals

Categories	Total Population	95% CI	Total points	Sample points	Total Points (%)
Commercial	155684	154286-157082	3821	742	55.78
Lakes	21408	20933-21882	967	209	14.11
Slums	12783	12429-13137	941	207	13.73
Others	89460	88396-90524	1121	202	16.38
Total	279335	277450-281220	6850	1360	100

Gender (%)			
Categories	1st Sight	2nd Sight	Overall

The heat map was generated on the population map which serves as a valuable tool for understanding the spatial distribution and density of the street dog population in Bengaluru (Fig.7.). The heat map provides a visual representation of population density, with areas of higher concentration indicated by warmer colors (e.g., red or orange) and areas of lower density represented by cooler colors (e.g., yellow or cream). This visual depiction makes it easy to identify hotspots of street dog activity within the city and also aiding in risk assessment, resource allocation, and decision-making processes aimed at promoting responsible urban management and safeguarding both human and animal welfare.



Male	61.18	56.83	59.05
Female	29.64	29.22	29.28
Unknown	9.18	13.95	11.565
Age (%)			
Adult	96.49	97.68	97.08
Puppy	3.06	2.32	2.69
NA	0.45	-	0.23
Neutered Status (%)			
Entire	23.69	20.04	21.86
Neutered	69.59	74.11	71.85
Unknown neuter	6.72	5.85	6.28

Fig. 7. Street Dog population mapping in BBMP Wards

3.2. Sample estimation Insights

The sample estimation process within the BBMP Street Dog Survey offers valuable insights into the demographic attributes of the Street Dog population. By delving into the percentages of Gender, neutering status, and age distribution, (Table 4 and Table 5) this aspect of the survey enriches our understanding of the Street Dog ecosystem in Bengaluru.

Table 4. Percentage distribution of dogs based on Age, Gender and Neutered Status

Table 5. Percentage distribution of dogs based on Neutered status and gender

Categories	Entire (%)	Neutered (%)	Unknown neuter (%)
Male	21.88	74.60	3.52
Female	23.91	72.11	3.98
Unknown	16.37	56.94	6.69
Grand Total	21.86	71.85	6.28

3.3 Analysing Street Dog Population Trends: A Perspective through CAGR

A positive CAGR suggests an average annual increase in Street Dog populations, while a negative CAGR indicates a decrease. This metric is valuable in quantifying the rate of change and provides insights into the trends shaping our urban canine landscape.

Application of CAGR to our data, allows us to make informed decisions and tailor interventions to the evolving needs of our city's Street Dog population. It also enables us to gauge the effectiveness of our efforts in managing these vital urban inhabitants. Table 6 gives us the CGAR for various parameters.

Table 6. CAGR for Total population, Male and Female population and Neutered status

	2019	2023	CAGR (%)*
Total Population	3,09,898	2,79,335	-5.41
Male population	205660	165341	-5.31
Female Population	104316	82757	-5.62
Total Neutered	158588	200608	6.05

*Unknown population is removed for the CAGR calculation

The total population estimates for 6850 micro zones within the BBMP limits offer valuable insights into the street dog population dynamics in Bengaluru. The citywide analysis reveals a considerable street dog population of 279,335, with a gender distribution indicating 165,341 males, 82,757 females, and 31,237 of unknown gender, alongside an overall neutering percentage of 71.85%. This synthesis of data provides a comprehensive understanding of street dog habitation in Bengaluru, shedding light on localized tendencies, overarching trends, and variations in population density across different urban landscapes.

Commercial areas emerge as significant hubs of street dog activity, reflecting the intricate interplay between human activities and canine habitation. Factors such as the presence of food establishments, high human foot traffic, and the availability of resources contribute to the prevalence of street dogs in these areas. However, the dominance of male street dogs [10], as indicated by the higher percentage, suggests a distinct gender imbalance within the population, warranting further exploration into the factors influencing this ratio and its potential implications for population dynamics.

The prevalence of adult street dogs among the sampled population underscores the established presence of mature canines within the urban landscape, hinting at the stability and effectiveness of Animal Birth Control (ABC) programs over time. Moreover, the larger percentage of neutered street dogs highlights the impact of ongoing sterilization programs, indicating a proactive approach to curbing overpopulation and controlling the spread of

diseases. This positive trend underscores the efficacy of community initiatives and their significant contribution to responsible street dog management efforts in Bengaluru.

Notably, compared to prior surveys, there is a discernible 10% reduction in the overall street dog population and a commendable 20% increase in the neutering percentage, indicating the effectiveness of intervention efforts. Overall, the synthesis of population estimates, gender distribution, age composition, and neutering status offers a panoramic view of street dog dynamics in Bengaluru, forming the foundation for evidence-based urban management strategies.

4. CONCLUSION

In conclusion, the BBMP Street Dog Survey epitomizes a dedicated commitment to responsible urban management and the promotion of compassionate coexistence between humans and street dogs. The comprehensive study offers nuanced insights into street dog populations, categorizations, and demographic attributes within Bengaluru's diverse urban landscape.These findings emphasize the importance of continued collective action and evidence-driven policies for ensuring the safety and well-being of both humans and street dogs in the city.

CONSENT

Informed consent was obtained from all participants involved in the sampling process. Prior to selection, potential participants were provided with detailed information regarding their inclusion in the study, the purpose of the sampling, and their rights as participants. This included explanations of voluntary participation, confidentiality assurances, and the option to decline participation without consequence.

ETHICAL APPROVAL

Ethical approval was not required for the animal study because this research is on spatial modeling and population estimation of dogs, that cannot link to individual animal subjects.

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