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 Mahanagara Palike, Karnataka, India

.

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 Mahanagara Palike (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 279335. It indicates a significant 10% reduction in the street dog population since 2019 which had estimated it at 309898, suggesting effective interventions. There is also a commendable 20% increase in neutering rates from an estimated 51.16% in 2019 to 71.85% in the present study, 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: Street Dogs, Single-Sight and Sight–Resight survey, Lincoln–Petersen's Formula, Chapman's Correction, Population Control

1. INTRODUCTION

Dogs, renowned for their loyalty, wide range of breeds, and innate ability to form connections, have become an integral part of urban life [1]. Whether they are free-ranging street dogs or owned pets, it's essential to approach them with compassion and ensure that their population is managed to prevent issues for their human companions. Current estimates indicate that there are over 700 million dogs worldwide, with 75% of them roaming freely, without human supervision. Regrettably, almost 99% of human rabies cases stem from dog bites, and the presence of free-roaming dogs exacerbates the spread of the disease in many countries [2].

In this context, the Bruhat Bengaluru Mahanagara Palike (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.

BBMP is carrying out an Animal Birth Control-Anti Rabies Vaccination (ABC-ARV) program in all of its 08 zones. 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 a survey estimation of the street dog 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 population, 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(SS) and Sight–Resight surveys(SRS), authorities can gather essential data on the size, distribution, and health status of the street 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 street dog population, thereby limiting the potential for rabies transmission. Concurrently, ARV campaigns ensure that a significant proportion of the roaming dog community is immunized against rabies[6], 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 such as BBMP, the significant presence of street dogs significantly escalates the risk of rabies transmission. According to the World Health Organization (WHO), rabies claims the lives of approximately 20,000 individuals in India each year, with around 98% of these cases linked to dog bites [28]. This statistic underscores the critical role that street dogs play in the transmission of rabies within the community. [17,18]. 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 street 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

$$m1 = \left(\frac{200}{Q}\right)^2 \left(\frac{s}{\overline{N}}\right)^2$$

where Q 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 each stratum 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.

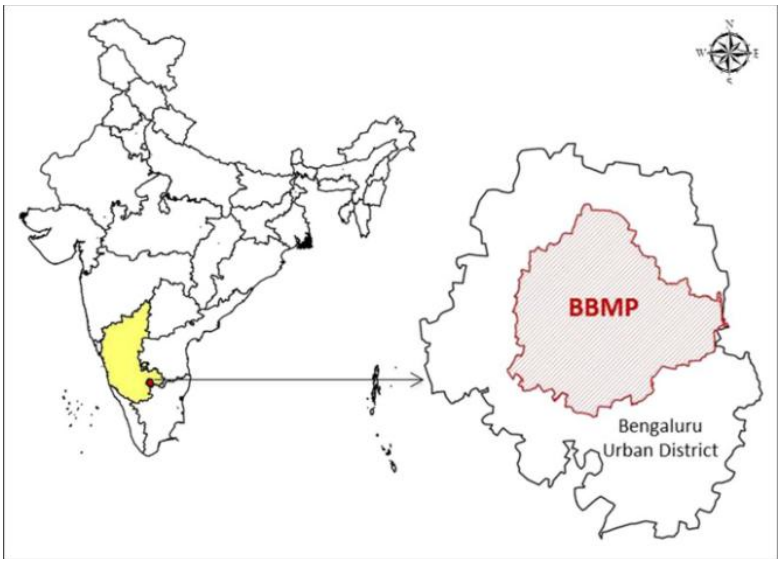

Fig. 1. Study area showing BBMP in Bengaluru Urban district of Karnataka State

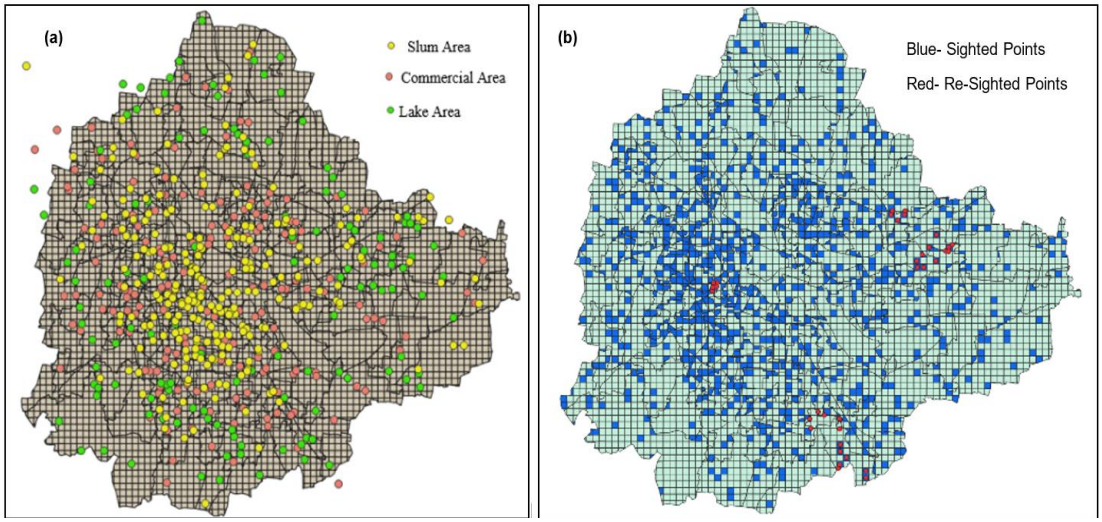

Fig. 2. Study area showing BBMP gridded map demarcated with lakes, slums & commercial area (a), sampling area (b)

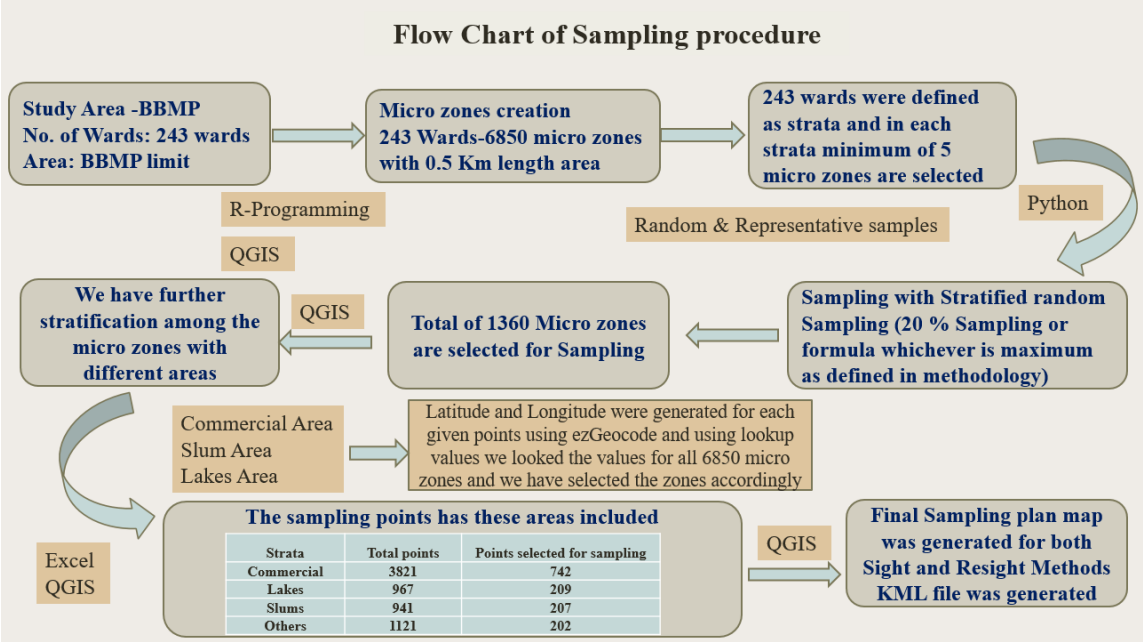

Fig. 3. Flow chart of Sampling (Stratified Random Sampling) procedure

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, a 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 [17] 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 size of the Street Dog populationwere 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-sightedduring Sight–Resight survey. An approximate unbiased variance of N was estimated by using Seber's formula [13] (equation 2). The 95% confidence interval for N was estimated according to equation 3

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

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

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

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 The Worldwide Veterinary Service – Mission Rabies played a crucial role in ensuring the successful execution of the survey and data collection using a mobile application. They provided valuable technical assistance and guided field surveyors to meticulously conduct the survey. 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

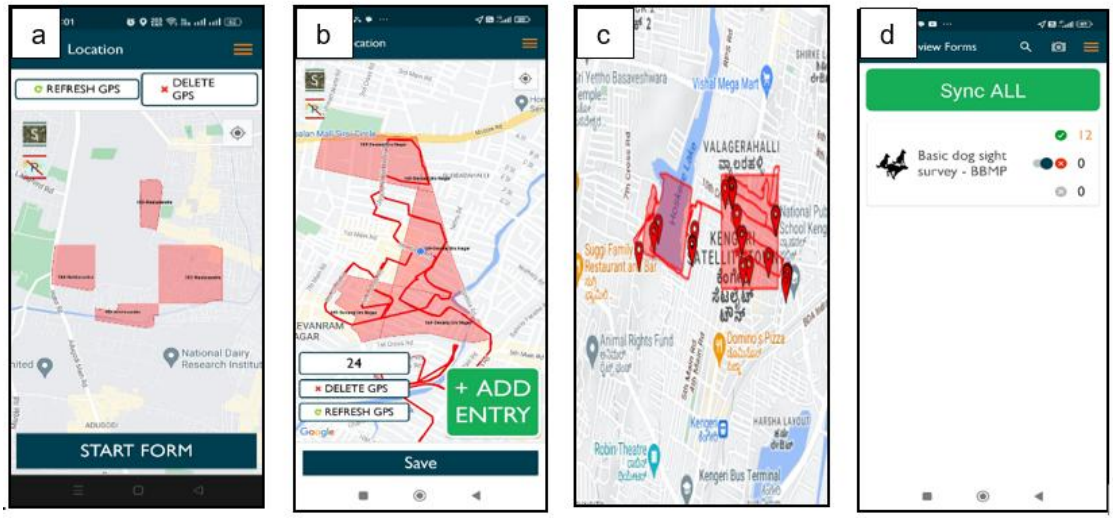

Fig. 4. Operational Perspective of the Survey: a. Allocated Grids, b. & c. GPS Mapping of Survey Zone and d. Image Upload to the Application (WVS)

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 population, it is 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:

$$CAGR = \left(\frac{\textbf{Current Year Population}}{\textbf{Previous Year Population}}\right)^{\frac{1}{\textbf{Number of Years}}} - 1$$

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	19395	20008	6996	55465	54625-56305
6850 Micro zones	97674	100760	35232	279335	277450-281220

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 exhibit relatively higher total population, with 58371 street dogs, respectively. 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.

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

The total population estimates for 6850 micro zones provide insight into the BBMP limits. The overall citywide analysis underscores a total street dog population of 279335, with a gender distribution of 165341 males, 82757 females, and 31237 of unknown gender with overall neutering percentage of 71.85%.

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 population in relation to specific urban contexts. Commercial areas emerge as hubs of Street Dog activity, highlighting the complex interplay between human activities and canine habitation. The prevalence of Street Dogs in commercial areas can be attributed to multiple factors like the presence of food establishments, food traffic, and the availability of potential resources [20].

Table 3. Street Dog Population by Categories

Categories	Total Population	95% CI	Total points	Sample points	Total Points (%)
Commercial	155684	154286-157082	3821	742	55.78
Lakes	21408	20933-21883	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

The heat map [22] 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. 6). 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 offers a nuanced understanding of street dog activity within BBMP by highlighting the heterogeneous distribution of dog density across different areas of the city. Through detailed analysis and mapping, it reveals variations in the concentration of street dogs, allowing for a more tailored approach to urban management strategies. By utilizing the results, decision-makers can discern specific patterns and trends in dog density, enabling targeted interventions in areas with higher concentrations of street dogs. This granularity in information empowers BBMP to allocate resources more efficiently, prioritize interventions effectively, and mitigate risks associated with street dog-human interactions in areas where density is particularly high. Thus, the visual depiction not only identifies hotspots but also leverages the results to inform strategic decision-making processes aimed at promoting responsible urban management and safeguarding the welfare of both human residents and street animals within BBMP's jurisdiction.

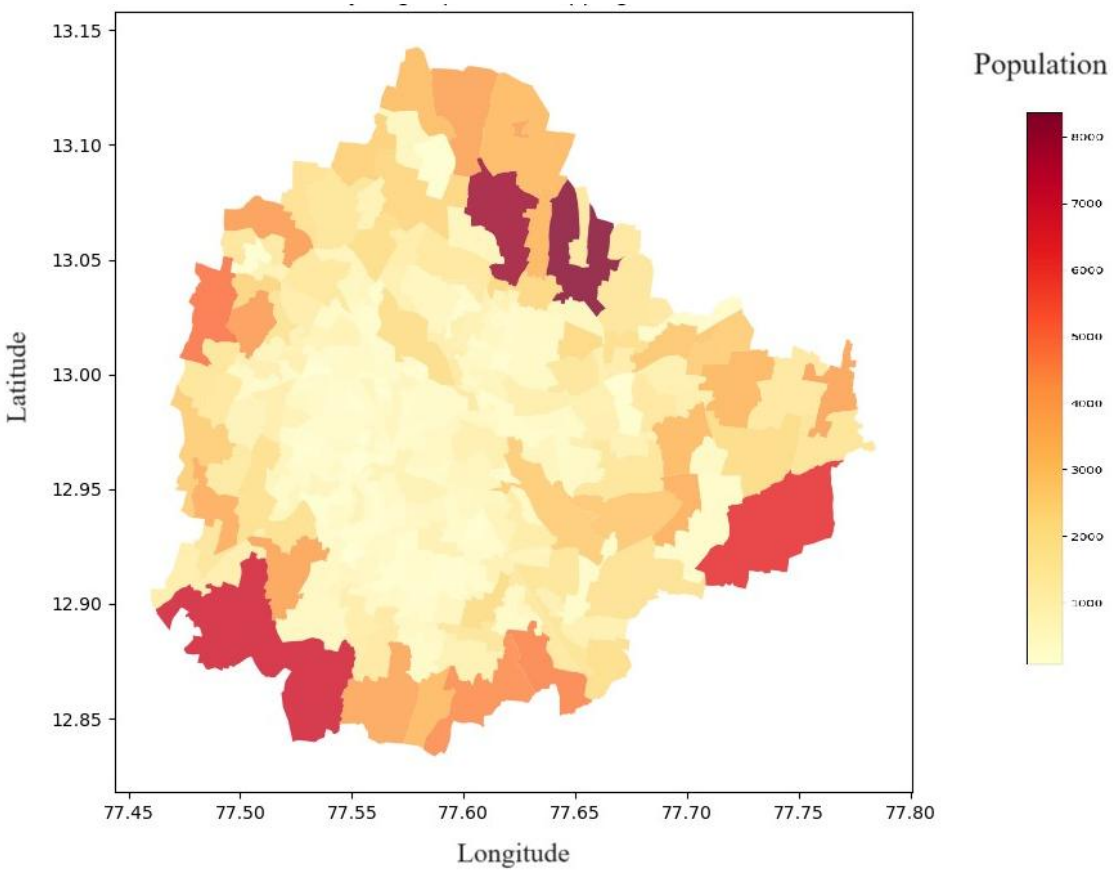

Fig. 6. Street dog population density map in BBMP Wards

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 population in Bengaluru.

The dominance of male Street Dogs [23], as indicated by the higher percentage, points to a distinct gender imbalance within the population[2]. This observation raises questions about factors influencing the gender ratio [17] and the potential implications for population dynamics

and the prevalence of adult Street Dogs among the sampled population underscores the established presence of mature canines within the urban landscape. This trend hints at the stability and effective execution of ABC program over time.The larger percentage of neutered Street Dogs highlights the impact of ongoing sterilization programs. A higher neutering percentage suggests a proactive approach to curbing overpopulation and controlling the spread of diseases.

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

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

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	24.36	68.94	6.70
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 population, 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.

From the Table 6 it is evident from the data that the total Street Dog population has experienced a decrease in its growth rate. Both male and female Street Dog populationalso exhibit a decrease in their growth rates. In contrast, the growth rate of neutered Street Dogs shows an increase. This is a positive indicator, reflecting the impact of neutering and spaying campaigns. These trends highlight the effectiveness of population management strategies and initiatives focused on neutering and spaying.

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

Categories	2019	2023	CAGR (%)*
Total Population	309898	279335	-5.41
Male population	205660	165341	-5.31
Female Population	104238	82757	-5.62
Total Neutered	158588	200608	6.05

*Unknown population is removed for the CAGR calculation

The estimation of a Street Dog population of approximately 279335 within the surveyed area serves as a pivotal benchmark. This all-encompassing figure not only highlights the magnitude of canine habitation but also underscores the need for evidence-based urban management strategies. The inclusion of Confidence Intervals further bolsters the credibility of this estimation, acknowledging the inherent variability in survey data.The categorization of Street Dog populationinto Slums, Lakes, Commercial, and Other Areas provides a contextual lens through which to view their dynamics. The insights drawn from these categories reveal the influence of diverse urban environments on canine habitation. The dominance of Street Dogs in Commercial area and the nuances within Slums and Other Areas enrich our understanding of canine behaviour and coexistence in different contexts.

The observed male dominance [14], prevalence of adult dogs, and significant neutering efforts have far-reaching implications for urban management. These insights guide the formulation of gender-sensitive strategies, age-specific interventions, and the continuation of successful neutering initiatives.The synthesis of total dog population estimates, zonal dynamics, ward wise insights, categorized dynamics, and sample output insights presents a panoramic view of Street Dog dynamics in Bengaluru. The collective findings underscore the complexity of canine habitation in urban spaces, encapsulating nuances, disparities, and trends that resonate across wards and zones [24].

Notable aspect in comparison with previous surveys, the present study reveals a decrease in the overall street dog population. There is a 10% reduction in the street-dog population as compared to previous survey [16] which had estimated the Street Dog Population as 310000. At the same time overall Neutering percentage has increased by 20% from the estimated 51.16% in 2019 to 71.85% in the present study. This decline in population points to the effectiveness of intervention efforts aimed at population control and responsible management. The success of initiatives such as neutering campaigns and community-driven strategies highlights the collective dedication to ensuring a harmonious balance between street dogs and city residents.

The comprehensive synthesis of population estimates, gender distribution, age composition, and neutering status provides a holistic understanding of street dog dynamics in Bengaluru. This detailed examination lays the groundwork for evidence-based urban management strategies tailored to the unique context of the city and its administration by the BBMP. Bengaluru's specific characteristics, such as its rapid urbanization, diverse socioeconomic landscape, and cultural attitudes toward street animals, shape the dynamics of its street dog population in distinct ways. Integrating these local nuances with broader regional and global perspectives enhances our understanding of urban animal management challenges and facilitates the development of targeted interventions that address the specific needs of Bengaluru while also contributing to broader discussions on urban animal welfare and public health[25]. By acknowledging the multifaceted nuances within zonal and ward wise dynamics, stakeholders are empowered to tailor interventions and strategies that align with specific needs. This holistic approach encompasses gender imbalances, age-specific healthcare, and

targeted neutering campaigns, ushering in an era of harmonious coexistence and welfare for both humans and Street Dog [26,27].

4. CONCLUSION

In conclusion, the BBMP Street Dog Survey encapsulates a steadfast commitment to responsible urban stewardship and the cultivation of compassionate cohabitation between Bengaluru's residents and its street dog population. Through meticulous research and analysis, the survey has unearthed invaluable insights into the city's canine demographics, categorizations, and distribution within its diverse urban fabric. Key findings underscore the efficacy of ongoing neutering initiatives, evidenced by a notable 20% increase in neutering rates compared to previous assessments, thus significantly contributing to rabies control and public health. Additionally, the survey sheds light on a noteworthy decrease in the street dog population, indicating the positive impact of population management strategies. Moreover, the survey illuminates the significance of gender distribution, age composition, and neutering status in shaping street dog dynamics, highlighting the need for targeted interventions and community-driven solutions.These discoveries underscore the indispensable role of evidence-based policymaking and collaborative action in ensuring the safety, welfare, and harmonious coexistence of both human and canine population.

ACKNOWLEDGEMENTS

We express our gratitude to the entire Street Dog Estimation Survey 2023 Committee for their unwavering support and guidance throughout the survey. Additionally, we extend our thanks to all the AH BBMP/AHVS Officers, WVS team and Staff who actively participated in the Dog Estimate Survey Program - 2023. Special appreciation goes to the Director of ICAR-NIVEDI for constant support.

AUTHORS CONTRIBUTIONS

Raaga R designing the methodology, performed the statistical analysis finalization of the results, wrote the first draft of the manuscript and edited the manuscript. Suresh K. P.conceptualization, supervised the activity, designing the methodology and revised the manuscript. Divakar Hemadri, Baldev Raj Gulati, Chandraiah T, Ravi Kumar K. P., Manjunath Shinde. S. M., Shrikrishna Isloor, Balaji Chandrashekar, Balaji R, Asha G. K., revised the manuscript.Chandraiah T, Balaji Chandrashekar, Ravi Kumar K. P., Manjunath Shinde. S. M., Asha G. K., Rudresh Kumar K. L., Balaji R conducted the survey operation and data collection. Balaji Chandrashekar and Balaji R conducted capacity-building training for all surveyors in two phases to ensure the effective execution of the survey. They also supervised the meticulous implementation of the survey, facilitated data collection through a mobile application, and addressed any operational challenges encountered in the field.All authors read and approved the final manuscript.

CONSENT

Written 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.

COMPETING INTERESTS

Authors have declared that they have no known competing financial interests or non-financial interests or personal relationships that could have appeared to influence the work reported in this paper.

REFERENCES

1. Christian HE, Westgarth C, Bauman A, Richards EA, Rhodes R, Evenson KR. Dog ownership and physical activity. A review of the evidence. J. Phys. Act. Health. 2013;10:750–759.doi: 10.1123/jpah.10.5.750.
2. Stepping up dog population management to achieve rabies elimination. *https://www.woah.org/en/article/stepping-up-dog-population-management-to achieve-rabies-elimination/*
3. Totton SC, Wandeler AI, Zinsstag J, Bauch CT, Ribble CS, Rosatte RC, et al. Stray dog population demographics in jodhpur, India following a population control/rabies vaccination program. Prev Vet Med. 2010;97(1):51–57. doi: 10.1016/j.prevetmed.2010.07.009.
4. National Action Plan for Dog Mediated Rabies Elimination from India by 2030. https://rr-asia.woah.org/wp-content/uploads/2022/12/india-napre-rabies.pdf
5. Reece JF. Rabies in India: an ABC approach to combating the disease in street dogs. Vet Rec. 2007;161:292-3.doi: 10.1136/vr.161.9.292.

6. Haydon DT, Randall DA, Matthews L, Knobel DL, Tallents LA. Low coverage vaccination strategies for the conservation of endangered species. Nature. 2006;443: 692-95.doi: 10.1038/nature05177.
7. Cleaveland S, Fèvre EM, Kaare M, Coleman PG. Estimating human rabies mortality in the United Republic of Tanzania from dog bite injuries. Bull World Health Organ. 2002;80:304-10.PMCID: PMC2567765
8. Gill GS, Singh BB, Dhand NK, Aulakh RS, Ward MP, Brookes VJ. Stray dogs and public health. Population Estimation in Punjab, India. Vet. Sci. 2022;9:75.doi: 10.3390/vetsci9020075.
9. Dias RA, Guilloux AG, Borba MR, Guarnieri MC, Prist R, Ferreira F, et al. Size and spatial distribution of stray dog population in the University of São Paulo campus, Brazil. Prev Vet Med. 2013;110:263-73.doi: 10.1016/j.prevetmed.2012.12.002.
10. Thanapongtharm W, Kasemsuwan S, Wongphruksasoong V, Boonyo K, Pinyopummintr T, Wiratsudakul A, et al. Spatial distribution and population estimation of dogs in Thailand. Implications for Rabies Prevention and Control. Front. Vet. Sci. 2021;8.doi: 10.3389/fvets.2021.790701.
11. Tegegne D ,Mengesha A. Estimation of Owned and Street Dog Population by Quesionnire Surveyand Mark-Recapture Method in Three Urban Areas: Bishoftu, Dukem and Modjo Towns. Austin J Vet Sci & AnimHusb. 2022;9(5):1105.
12. Hiby LR, Reece JF, Wright R, Jaisinghani R, Singh B, Hiby EF. A mark-resight survey method to estimate the roaming dog population in three cities in rajasthan, India. BMC Vet Res. 2011;7:46. doi: 10.1186/1746-6148-7-46.
13. Chapman DG. Some properties of the hypergeometric distribution with applications to zoological sample censuses. University of California Press. Berkeley, CA, USA, 1951;131–160.
14. Conan A, Akerele O, Simpson G, Reininghaus B, van Rooyen J, Knobel D. Population Dynamics of Owned, Free-Roaming Dogs: Implications for Rabies Control. PLoSNegl Trop Dis.2015;9(11): e0004177. https://doi.org/10.1371/journal.pntd.0004177
15. Srikrishna Isloor. BBMP-Street dog survey report 2019.
16. Tiwari HK, Vanak AT, O'Dea M, Gogoi-Tiwari J and Robertson ID. A Comparative Study of Enumeration Techniques for Free-Roaming Dogs in Rural Baramati, District Pune, India.Front. Vet. Sci. 2018;5:104.doi: 10.3389/fvets.2018.00104.
17. Knobel DL, Cleaveland S, Coleman PG, Fèvre EM, Meltzer MI, Miranda ME, et al. Re-evaluating the burden of rabies in Africa and Asia. Bull. World Health Organ. 2005; 83(5):360–8. doi: /S0042-96862005000500012
18. Meslin FX ,Briggs DJ. Eliminating canine rabies, the principal source of human infection: what will it take? Antiviral Res.2013;98(2):291–6. doi: 10.1016/j.antiviral.2013.03.011.
19. Raymond TN, Roland ME, Francoise KM, Francis Z, Livo EF, Clovis ST. Do open garbage dumps play a role in canine rabies transmission in Biyem-Assi health district in Cameroon? Infect Ecol Epidemiol.2015;5:26055. doi:10.3402/iee.v5.26055
20. Tenzin T, McKenzie JS, Vanderstichel R, Rai BD, Rinzin K, Tshering Y, et al. Comparison of mark-resight methods to estimate abundance and rabies vaccination coverage of free-roaming dogs in two urban areas of south Bhutan. Prev Vet Med. 2015; 118(4):436–48. doi:10.1016/j.prevetmed.2015.01.008.
21. Ricardo AD, Aline GAG, Mauro RB, Maria CLG, Ricardo P, Fernando F, et al. Size and spatial distribution of stray dog population in the University of São Paulo campus, Brazil,Preventive Veterinary Medicine.2013;110(2):263-273.https://doi.org/10.1016/j.prevetmed.2012.12.002.
22. Moazzem H, Kamruddin A, Aung SPM, Sohrab H, Mohammad AA, Abul KMS, et al. A survey of the dog population in rural Bangladesh,Preventive Veterinary Medicine.2013;111(1):134-138.https://doi.org/10.1016/j.prevetmed.2013.03.008.

23. Acosta-Jamett G, Cleaveland S, Cunningham AA, Bronsvoort BM. Demography of domestic dogs in rural and urban areas of the Coquimbo region of Chile and implications for disease transmission. Prev Vet Med. 2010 May 1;94(3-4):272-81. doi: 10.1016/j.prevetmed.2010.01.002. Epub 2010 Jan 22. PMID: 20096943.
24. Belo VS, Werneck GL, Silva ES, Barbosa DS, Struchiner CJ. Population Estimation Methods for Free-Ranging Dogs: A Systematic Review. PLoS ONE. 2015;10(12):e0144830.
25. Butler JRA, Bingham J. Demography and dog-human relationships of the dog population in Zimbabwean communal lands. The Veterinary Record. 2004;147:442-446.
26. Dalla Villa P, Kahn S, Stuardo L, Iannetti L, Di Nardo A, Serpell JA. Free-roaming dog control among OIE countries which are members. Prev Vet Med. 2010; 97: 58–63. pmid:20709415.
27. Rabies in India. https://www.who.int/india/health-topics/rabies.
28. Czupryna AM, Brown JS, Bigambo MA,Whelan CJ, Mehta SD, Santymire RM, et al. Ecology and Demography of Free-RoamingDomestic Dogs in Rural Villages near SerengetiNational Park in Tanzania. PLoS ONE. 2016;11(11):e0167092. doi:10.1371/journal.pone.0167092.