Research Article

Application of Structural Equation Modeling (SEM) for Free-Roaming Dog Population Management

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Abstract | Dogs are a ubiquitous species, and their ecology is closely linked with human activities. Catch-neuter-vaccinate-release is the intervention employed to manage the free-roaming or stray dog population in the Sri Lankan context after imposing a "no kill" policy in 2006. However, sustainable and effective management is still not visible in urban areas and rural areas of the country as well. Therefore, this study aimed to investigate dog owners' dog-keeping practices, and behaviours for dogs' undesirable behaviours, and veterinary services (VS) to determine whether those affect free-roaming dog (SDP) population management. Simple random sampling was employed to select participants. The data was collected through in-person interviews adapting a closed-ended, structured questionnaire from 287 participants (dog owners who have local or native dogs). The measure was five point rating likert scale. RDO and SDP management were higher-order constructs, and dog-keeping practice, behaviour, veterinary services, abandonment, and owned stray dogs were first-order constructs of the model. Structural equation modeling with maximum likelihood estimation via AMOS 21 software was employed. The study showed that RDO and VS were significant and positive predictors of SDP population management. This model can be used to better understand the insights of dog-keeping practices and behaviours of dog owners for planning and implementing cost-effective and sustainable SDP population management interventions in a area.

Keywords | Responsible dog ownership, Free-roaming dogs, Veterinary services, Abandonment

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INTRODUCTION

The term responsible dog ownership (RDO) has a broad meaning. Responsible dog ownership means the situation whereby a person accepts and commits to perform various duties in accordance with the legislation in place and focused on the satisfaction of the behavioural, environmental, and physical needs of a dog and the prevention of risks (aggression, disease transmission, or injuries) that the dog may pose to the community, other animals, or the environment according to OIE definitions (OIE, 2023).

The free-roaming dogs (FRD) population is also known as the stray dogs population (SDP) in some countries. Free-roaming dogs pose negative consequences in terms of social, economic, environmental, and wildlife conservation (Bhalla *et al*., 2021; Cetkovic *et al*., 2022; Gills *et al*., 2022; Papavasili *et al*., 2023; Smith *et al*., 2019). The negative social consequences are social risks and social disturbances. The social risks are disease transmission, especially rabies, biting incidents, and motor traffic accidents. Some reported

social disturbances are excessive barking and howling. The faeces and urine of stray dogs cause environmental pollution (Abdulkarim *et al*., 2021; Zhang, 2022). Stray dogs are a threat to wildlife conservation because they attack endangered species in some countries and contribute to the extinction of wild birds and animal species (Khadka, 2019; Smith *et al*., 2019). Economically, stray dogs are a financial burden on countries: Disease prevention, especially rabies; dog population management through catch-neuter-vaccination-release (CNVR) intervention; post-operative prophylaxis treatments for dog bite victims; wound treatments for dog bite and motor traffic accidents; economic losses due to injuries or killing of livestock animals.

Effective stray dog population management is important to minimize human health risks and stray dogs' health and welfare as well (Gills *et al*., 2022; Smith *et al*., 2019).

Culling was the strategy employed to mitigate the FRD population until 2006 in Sri Lanka. In 2006, a "no kill" policy was imposed in the country (Harischandra *et al*., 2017), and the humane intervention of fertility control in FRD through sterilization was introduced. Initially, both hormonal contraception and surgical sterilization were practiced in the country, and subsequently, priority was given to surgical sterilization through CNVR intervention. CNVR intervention has been employed for fertility control of the ownerless FRD in Dehiwala divisional secretariat area, Sri Lanka, with systematic biannual ownerless FRD estimates since 2013. Today, ownerless FRD estimates in this divisional secretariat area revealed a marked reduction in the ownerless FRD sub-population during the period from 2013 to 2020 (Jayasundara *et al*., 2023). However, the ownerless FRD sub-population is being managed, and a reduction in FRD population is not visible in the Dehiwala divisional secretariat area (present study area).

RDO is an important factor in the context of FRD population management because the FRD population consists of sub-populations: owned FRD and ownerless FRD (Smith *et al*., 2022). Unrestricted-owned dogs (free-roaming-owned dogs) and abandoned dogs are the sources of the dog population increase (Smith *et al*., 2022). Thus, dog owners' knowledge, attitudes, and practices are vital for effective management of sub-populations that are free-roaming (Tiwari *et al*., 2019). CNVR is the intervention applied for fertility control of the abandoned dogs in the FRD population in the present study area. However, the dog owners' perceptions of their dog-keeping practices and their behaviours to overcome certain problematic behaviours of their dogs are under-explored in the present study area. Thus, the present study was designed to determine the potential factors in the domain of RDO and veterinary services that affect FRD population management.

MATERIALS AND METHODS

There were two hypotheses, H1 (There is a relationship between responsible dog ownership and stray dog population management) and H2 (There is a relationship between availability of veterinary facilities and stray dog population management) suggested to be tested in the model according to the conceptual framework of the study (Figure 1).

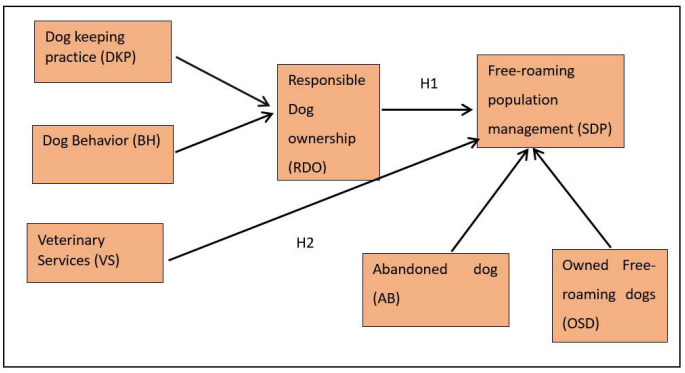

Figure 1: Illustration of the conceptual framework of the study.

Target population and study area

The population of interest was dog owners who have local or mixed-breed dogs in the Dehiwala divisional secretariat area, Sri Lanka. The land area is 871.03 hectares (8 Km^2).

Sample

A simple random sampling technique was employed for the selection of study participants. The dog register prepared by the local authority of the area, Dehiwala Mt. Lavinia Municipal Council, according to the 2019 survey, was the sample frame. This dog register contains mixed records of dog owners who have local or native dogs and high-pedigree dogs. Therefore, the respective record numbers of dog owners with local or native dogs were selected and written on pieces of paper (1021 pieces). According to records in the register, the total number of dog owners who have local or native dogs is 1021. The actual sample size was 287, and it was determined according to Yamane's sample size formula (Adam, 2020), and the sample size with a 57% response rate was 450. Out of 1021 pieces of paper, 450 pieces were randomly selected by flipping a hat. The record numbers on the selected 450 pieces of paper were checked to find the dog owners' information on name, address, and contact details to get their consent for recruitment. Of the 450 participants, 311 granted verbal consent for recruitment. Out of the 311 recruited participants, 24 did not participate in interviews due to migration, hospitalization, ignoring, loss of interest, etc. However, they were not forced due to ethical considerations of the study. The simple random sampling technique was adapted in this study to obtain an unbiased study sample.

Measurement instrument

The measurement instrument was a close-ended structured questionnaire. It consisted of two sections: Section one contained questions about demographic data of participants, ownership practices, and the participants' dogs and, section two contained questions relevant to inferential analysis. The ordinal scale, Likert scale (five point rating) was adapted to measure the variables for inferential analysis. The variables were conceptualized by employing a series of items tailored to the scope of the research with five point response options. Each option of response was detailed (1= Strongly disagree, 2= Disagree, 3= Neither disagree nor agree, 4= Agree, 5 = Strongly agree).

Pilot study

The pilot study was conducted and the rules of thumb, the general flat rule was applied to decide the sample size for pilot study (Whitehead *et al*., 2016). The sample size was 30 and the participants were selected from the aforesaid dog register applying a simple random sampling technique. The face-to-face interviews were carried out with selected participants for data collection. Subsequently, Cronbach's alpha test was employed to assess the reliability (internal consistency) of the questionnaire. 0.902, 0.821, 0.862, 0.915, and 0.881 were the Cronbach's alpha values for the constructs, dog keeping practice, dog owner behaviour, veterinary service, owned stray dogs, and abandonment, respectively. The items of the constructs were not excluded or modified since all the constructs' coefficient alpha value was above the threshold value of 0.7 (Hair *et al*., 2010). Therefore, Cronbach's alpha test results established the internal consistency of items in each latent variable of the questionnaire.

Data collection and preparation

The quantitative primary data was collected through face-to face structured interviews with the participants from February 2023 to April 2023 for this cross-sectional study. The screening of the data was carried out to prepare the data for analysis.

The two statistical measures, skewness and kurtosis, were chosen to check the distribution of the data. The results of this study revealed that the data is normally distributed and the statistics of skewness and kurtosis were within the recommended threshold level (±2, ±7) as suggested by Brown (2015), Bryne (2010), Hair *et al.* (2010), Kim (2013), and Kline (2016). Collinearity statistics, tolerance, and variance inflation factor (VIF) were tested and all the VIF and tolerance values of predictor variables in the model were less than 10 and above 0.1, respectively (Allision, 1999).

Analysis

The statistical package SPSS version 25 and the AMOS software package were employed for factor analysis and structural equation modelling (SEM) respectively. The statistical technique, SEM was employed to test the relationship between the variables in the model and the proposed hypotheses.

RESULTS AND DISCUSSION

Demographic analysis

Demographics of respondents and their dog ownership practices

In this study, of 287 respondents who reported their gender, 162 (56.4%) were female and 125 (43.6%) were male; 73 (23.4%), 40 (13.9%), 90 (31.4%), 48 (16.7%), and 36 (12.5%) respondents were government employees, private sector employees, self-employed persons, retired persons, and non-employees, respectively. Of them, most respondents were self-employed. The age distribution variables and their frequencies in the sample were between 20 and 30, between 31 and 40, between 41 and 50, between 51 and 60 and over 60, and 22 (7.7%), 40 (13.9%), 125 (43.6%), 66 (23.0%), and 34 (11.8%), respectively. The frequency distribution of respondents' educational level and their categories were 11.8% (n= 34), 32.8% (n= 94), 11.1% (n= 32), 15.3% (n= 44), 27.5% (n= 79), and 1.4% (n= 4) for primary education, secondary education (junior), secondary education (senior), diploma, bachelors, and others, respectively. The four respondents in the category of others were PhD holders. The majority of the respondents' educational level was in the variable secondary education (junior). Participants' domestic environment: Apartment and no compound 12 (4.2%), detached house with an enclosed small domestic compound and close to roads 72 (25.1%), detached house with an opened domestic compound and close to roads 80 (27.9%), detached house in an isolated area with an enclosed domestic compound 31 (10.8%), detached house in an isolated area with an opened domestic compound 50 (17.4%), attached house with no compound and close to roads 34 (11.8%), and an attached house with a small compound and close to roads 8 (2.8%). In this study, 112 (39%) respondents stated their reason for having a dog was as a pet. Apart from that, other reasons for having a dog and its related frequencies were security purposes, to avoid loneliness, stress, and depression, and 108 (37.6%), 42 (14.6%), and 25 (8.7%), respectively. Regarding the responsibility of providing physical exercise, 33.8% (n= 97) of participants did not accept it as a responsibility.98 out of 287 participants' mode of providing physical exercise to their dog was allowing for free- roaming. Out of 287 participants, 103 (35.9%) did not hope to control their dogs fertility either surgically or chemically. However, out of the aforesaid 103 participants, 99 participants had male dogs.

Table 1: Constructs, items, and percent (%) for responses.

Construct	Item (Code)	SD	D	N	A	SA
Dog keeping practice	My dog is allowed to free-roam in the morning (DKP1)	16.7	9.8	0.7	23.7	49.1
	My dog is allowed to free- roam in the night (DKP2)	19.5	7	9.8	9.8	63.8
	My dog is allowed to free- roam as he or she cannot be kept long hours in one place (DKP3)	19.5	15.3	0.7	16.4	48.1
	My dog is allowed to free-roam for urination and defecation (DKP4)	15.3	8.4	0.7	4.2	71.4
	My dog is allowed to free-roam as my house is closed to roads (DKP5).	30.7	11.8	4.9	8.7	43.9
Dog behaviour	My dog is allowed to stay in a free- roaming state throughout the day to avoid barking disturbances (BH1)	45.3	9.1	1.4	1.4	42.9
	My dog is allowed to free- roam because of his /her aggression (BH2)	36.2	37.6	2.8	8.4	15.0
	My dog is allowed to free-roam because of his/ her dislike to being on a leash or in the kennel (BH3)	30	23.7	7.3	13.2	25.8
	My dog is allowed to free-roam because of his/ her disobedient (BH4)	39	23.7	14.6	9.4	13.2
	My dog is allowed to free- roam because he/ she soils my house (BH5).	25.4	36.2	4.9	2.1	31.4
Veterinary services	Govt. and private veterinary services are available in my area (VS1).	1.7	5.6	15.3	61.3	16
	Govt. Veterinary services carry on stray dog population management activities (VS2)	2.1	9.4	4.9	38.3	45.3
	Govt. Veterinary services vaccinate stray dogs in my area (VS3)	2.8	8.7	4.9	4.6	37.6
	Govt. Veterinary services carry on fertility control of female dogs (CNVR) in my area (VS4)	3.5	8.7	4.9	35.5	47.4
	Govt. Veterinary services in my area are affordable (VS5)	1.4	1.4	26.5	39.4	31.4
Abandonment	More abandoned dogs are in my area (AB1)	3.8	11.5	7.3	26.8	50.5
	Abandoned dogs are adults (AB2)	0.3	13.6	21.3	41.1	23.7
	Abandoned dogs are mostly juveniles (AB3)	3.4	6.3	7.6	39	43.6
	Abandoned dogs are mostly puppies (AB4)	4.1	3.5	19.1	35.9	37.3
	Abandoned female dogs in my area are fertility controlled (AB5).	6.9	0.3	21.2	25.1	46.3
Owned free-roaming dogs	We see more owned free-roaming dogs in the morning (OSD1)	2.8	5.6	7.7	23	61
	We see more owned free- roaming dogs in the night (OSD2)	2.8	4.9	2.1	9.1	81.2
	We see more owned free-roaming dogs during the daytime (OSD3)	7.7	5.9	71.1	11.8	3.5
	We see more owned free-roaming dogs during the evening time (OSD4)	1.4	6.3	32.1	32.1	28.2
	We see more owned free-roaming dogs (OSD5)	0.7	7.0	0.7	24	67.6

SD: strongly disagree; D: Disagree; N: Neither disagree nor agree; A: Agree; SA: Strongly agree.

Demographic of the respondents' dogs

Out of 287 participants, 34.5% and 65.5% participants had male and female dogs respectively. Moreover, 14 (4.9%), 74 (25.6%), and 199 (69.5%) were in the age categories of puppy (between 1 month and 3 months), juvenile (between 4 months and 12 months), and adult (over 12 months), respectively.

Structural equation modeling

The KMO value for sample adequacy is > 0.5 (Hair *et al*., 2006), and the Bartlett's spherificity test statistic for the significance of the null hypothesis was <0.05 (Hair *et al*., 2006). Therefore, factor analysis was performed using the principle component extraction method and the varimex rotation method. The five factors greater than Eigenvalue 1 were identified. The identified factors were dog-keeping practice, dog owner behaviour, veterinary services, abandonment, and owned stray dogs.

Reliability and validity of first-order constructs

The reliability of constructs were assessed with Cronbach's alpha coefficient ≥ 0.70 (Hair *et al*., 2010) and composite reliability (CR) ≥ 0.70 (Fornell and Larcker, 1981) The validity of first-order constructs was assessed with convergent validity. The value of the average variance extract (AVE) > 0.50 was considered the threshold value for convergent validity (Fornell and Larcker, 1981). The factor loading of ≥ 0.5 was considered for further evidence of convergent validity (Steenkamp and van Trijp, 1991). All the items' factor loadings with respective constructs were ≥ 0.5 and provided evidence of convergent validity. In this study, all the first order constructs achieved reliability and validity (Illustrated in Table 2).

Table 2: Composite reliability, Cronbach's alpha and average variance extract (AVE) values.

Construct	Composite reliability values (CR)	Cronbach's Alpha	Average variance extract (AVE)
DKP	0.88	0.89	0.69
BH	0.89	0.87	0.57
VS	0.89	0.88	0.63
AB	0.85	0.83	0.63
OSD	0.87	0.87	0.58

Reliability and validity of higher order constructs

The repeated-indicator approach was employed to evaluate the reliability and validity of the higher-order constructs. According to the conceptual framework, DKP and BH were modeled as higher-order constructs of RDO, while AB and OSD were modeled as higher-order constructs of SDP (FRD population). The CR of RDO and SDP were 0.95 and 0.91, respectively, which were well above the required threshold value of 0.70 (Fonnel and Larcker, 1981; Wetzels *et al*., 2009). The AVE of RDO and SDP were 0.63 and 0.56, respectively, which were within an acceptable threshold value of 0.50 (Fonnel and Larcker, 1981; Wetzels *et al*., 2009). RDO and SDP established the requirement of reliability and convergent validity. The discriminant validity of RDO and SDP was evaluated by comparing the square root of AVE and inter-construct correlations (Fonnel and Larcker, 1981).The Square root of AVE values of RDO, VS and SDP were greater than all the inter-constructs correlations. Therefore, RDO, VS, and SDP established discriminant validity (Table 3).

Table 3: Composite reliability (CR), Average variance extracted (AVE), square root of average variance extracted (*in bold*) and correlations between constructs (off-*diagonal*).

Construct	CR	AVE	RDO	VS	SDP
RDO	0.95	0.63	0.793		
VS	0.89	0.63	0.082	0.793	
SDP	0.91	0.56	0.324	0.654	0.748

SDP: Free-roaming dog population; RDO: responsible dog ownership; VS: Veterinary services.

Overall measurement model

The model fit estimates of the measurement model were in an acceptable range. The software suggested modifications to the overall measurement model were not performed for further modification because the suggested modifications were not compatible with the real world situation. The acceptable thresholds are RMSEA≤0.08 (Awang, 2012; MacCallum *et al*., 1996; Hu and Bentler, 1998),CFI ≥0.90 (Fan *et al*., 1999) and CMIN/DF ≤5 (Marsh and Hoceva, 1985; Schumacker and Lomax, 2004).

Overall structural model

The results showed that the structural model has a good fit with the observed data: CMIN/DF= 2.195, CFI = 0.931, and RMSEA= 0.065 were at the acceptable range.

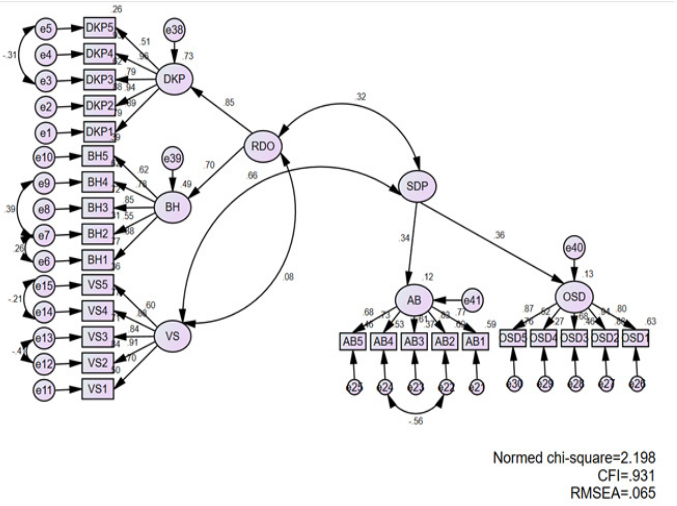

Figure 2: Illustration of the overall measurement model.

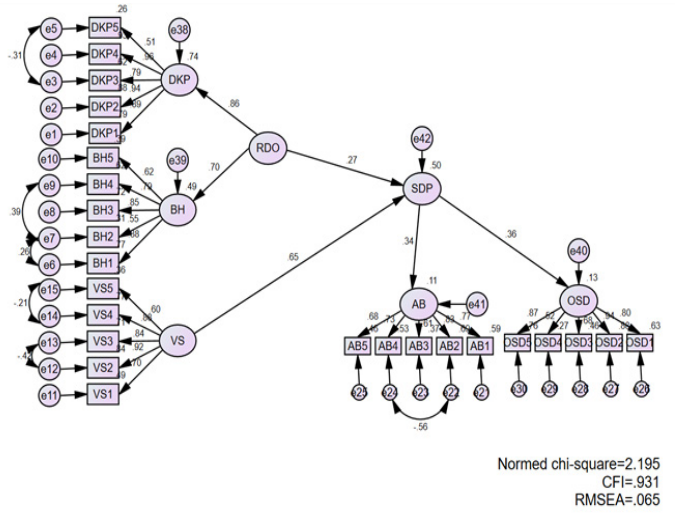

Figure 3: Illustration of structural model.

Hypothesis testing

The hypothesis testing is based on the results of the path analysis in the structural model. The criterion, regression weight estimate and its critical ratio (CR>1.96), and the p value (0.05 and 0.001 levels) were applied to decide the significance level (Byrne, 2016; Awang, 2015). The standardized regression weight (SRW) was also applied to assess the strength of the relationship. The strength of the association should be greater than 0.2 (20%) to accept the hypothesis (Ramayah *et al*., 2012). Therefore, the hypotheses H1 and H2 are significant (Tables 4 and 5) These results suggest that every single unit of change in responsible dog ownership could affect the stray dog population by 0.259 units and for every single unit increase in available veterinary facilities, stray dog population management is increased by 0.587 units.

Table 4: The results of the hypothesis testing. (Maximum likelihood estimates) standard error (SE), Critical ratio (CR), p-value and significance.

Hypotheses		Path		Estimate	S.E.	C.R.	P	Result
H1	SDP	<---	RDO	0.073	0.037	1.972	0.050	Significant
H2	SDP	<---	VS	0.365	0.079	4.604	0.001	Significant

Table 5: Standardized regression weights (SRW).

Hypothesis	Construct	Path	Construct	Estimate	Remarks	Supported/ not supported
H1	SDP	<---	RDO	0.259	SRW>0.2	Supported
H2	SDP	<---	VS	0.587	SRW>0.2	Supported

Evaluation of limitations and assumptions of SEM

Normal distribution: All the variables have a normal distribution.

Outliers: The data set was tested for outliers with IBM SPSS version 25. Outliers were not detected.

Adequate sample size: The sample size of this study was 287. Kline (2016) stated that a typical sample size for studies employing SEM is 200. Thus, this study has fulfilled the adequacy of the sample size.

Simplicity of model structure: SEM allows us to estimate complex relationships simultaneously rather than piece-wise. This model is also a complex one, and simultaneously, estimates of relationships between RDO and SDP and VS and SDP were produced.

Observable variables: SEM can measure latent variables. SEM relies on observed variables of the latent construct. If latent constructs are not measured well, the model relationships may be biased. All the latent variables of the model were conceptualized and operationalized to measurable variables.

Measurement error (ME)

Structural equation modelling assumes all the variables are measured without errors. However, measurement errors occur in items of the questionnaire while measuring the latent variable. In a survey study, measurement errors could happen through four sources: Respondent, interviewer, survey questionnaire, and mode of data collection. Therefore, uncertainties in the variable measurements were examined to enhance the credibility of the results. The measurement error is the standard error of the mean (SEM), and it shows how much the sample mean varies from the true population mean when multiple samples are drawn from the same population. In this study, the SEM values of variables (predictors) BH1 and BH2 were 0.105 and 0.112, respectively, and all the other variables SEM were less than those two values. (The SEM value of other predictors vary from 0.039 to 0.097).

One of the previous studies conducted in the Sri Lankan context revealed 34 % of owned dogs are in free- roaming state (Piburage *et al*., 2017). However, the aforesaid study was not designed to reveal the reasons for this regard. The present study explored the insights of dog owners: Why do dog owners allow their dogs to be in a free- roaming state, at what time most dog owners send their dogs out of the house and how the sub-population of owned SDP is formed in an area. This study revealed the significance of the relationship between responsible ownership and stray dog population management. This finding is important to the national programme authorities of the country. Therefore, the national programme authorities in the country have to consider the practical essence of this finding because it is practically important to assess the status of responsible dog ownership and address their key concern areas of irresponsible behaviour and practices in any area in order to achieve effective and sustainable management of the stray dog population.

The present study and the previous study (Jayasundara *et al*., 2023) revealed abandonment of dogs in the study area as well. The non-regulation of the free-roaming state of owned dogs and dog abandonment have a potential impact on the SDP (FRD) population. Hence, the improvement of responsible dog ownership (RDO) is very essential, as it is the core factor in this regard. Smith *et al*. (2022) stated that RDO is a cost-effective strategy for stray dog population management. Taylor *et al*. (2017) stated that enforcement of legislation related to dog ownership has reduced the proportion of owned free-roaming dogs in the SDP (FRD) in the Philippines. In the Sri Lankan context, the existing legislation (the dog registration ordinance) has not been amended for 61 years (Jayasundara *et al*., 2023). The existing legislation lacks legal codes to prevent dog abandonment and to regulate the practices and behaviours of dog owners in a responsible way. In addition, the penalties imposed by the existing legislation are outdated and do not match the currency value of the present. Therefore, it is the sole responsibility of the legislative bodies at the provincial and national levels to initiate forum discussions to share the current experiences and expertise involved in this field and accordingly amend the legal codes of the existing dog registration ordinance.

Rabies control is integrated with stray dog population management by the health authorities in the country. Therefore, the national programme of rabies control has targeted the fertility control of dogs through CNVR intervention with the intention of population management. This study revealed a significant relationship between the veterinary service and SDP (FRD) management. Thus, the availability of veterinary services at a substantial level is a prerequisite for carrying out CNVR intervention continuously in any area that has a high density of SDP (FRD). The longitudinal study carried out in this study area revealed evidence-based results in reducing the ownerless sub-population of stray dogs (Jayasundara *et al*., 2023). In this study area, the CNVR intervention was carried out by the veterinary department of the respective municipal council with systematic biannual estimations of the sub-population, ownerless stray dogs, and continuous monitoring of the ownerless sub-population for fertility control of abandoned female dogs. The difference in the national programme is the lack of surveillance for SDP (FRD), continuous monitoring of the population, systematic evaluation of the data on CNVR, and haphazard way of carrying out fertility control surgeries compared with the CNVR intervention carried out in this study area. It is prudent to take policy decisions by the policy and decision makers to establish veterinary units at the local government institution level to upgrade the availability of government veterinary services in order to enhance the CNVR intervention activities.

RDO is a cost-effective strategy for stray dog population management (Smith *et al*., 2022). Even though stray dog population size and turnover management are carried out through CNVR in this study area, results revealed the presence of free-roaming owned dogs. Thus, similar situations may practically occur in other parts of the country where the national programme is being carried out. It is prudent to couple measures with the CNVR national programme to improve RDO island-wide through legal codes rather than carry out CNVR intervention in a haphazard way.

Limitations

There were a few limitations to this study in terms of sampling biases. This study was designed to target dog owners who have local or native dogs since highly pedigreed dogs were not seen in the study area during the visits made at the point of study design. Therefore, dog owners who rear purebreds and the general public's perceptions were not assessed in this study.

The SDP density was not equal throughout the study area. There were high population density areas and low population density areas in this study area. Therefore, some of the of the selected participants were in areas with high population density. The sampling bias was minimized by employing a simple random sampling technique with the intention of giving everyone an equal chance of being selected from the target population. However, the participants' responses may vary depending on the degree of SDP (FRD) density in the participants' living area.

SDP management is a multi-factorial phenomenon. Animal shelter management and garbage management in the environment may also affect SDP (FRD) management. The standard of garbage management was observed to be satisfactory in this study area. Therefore, garbage management was not included as a factor in this model. There are few animal shelters in Sri Lanka, and those shelters are run by non-government organizations and welfare organizations. There is no government involvement in running animal shelters in order to mitigate SDP (FRD). This study area does not have an animal shelter run either by a non-government organization or an animal welfare organization. Therefore, this model was limited to testing the relevance of RDO and VS on SDP. Thus, these study findings can be limited to regions that maintain satisfactory standards of garbage management and do not have animal shelters.

CONCLUSIONS AND RECOMMENDATIONS

It is better to apply a regression model similar to the present study before implementation of the CNVR intervention to manage the SDP population since the aforesaid model helps to gain insights into other factors that affect SDP population management. In garbage mismanagement and animal shelter operating areas, garbage mismanagement and "animal shelter management could be included as independent variables of the model to determine their impact in this regard. Sometimes, the implementation of CNVR intervention without exploring the current scenario of other potential factors becomes ineffective and unsustainable for the area.

There may be practical constraints in terms of the insufficiency of staff for survey activities at the point of implementing the suggested regression modelling. A temporary staff comprising at least two members, depending on the area, could be recruited and attached to each MOH (medical officer of health) office for a short period of time (three years) since the existing island-wide national programme is conducted at the MOH office level in the country. Subsequently, newly recruited staff could be trained for survey activities and close monitoring and evaluation activities relating to SDP (FRD) and CNVR. In addition, volunteer groups that help with animal welfare activities could be encouraged to actively participate in this regard.

This study has certain limitations, as per the explanations under the limitations. Accordingly, there are possibilities for directly immeasurable concepts (factors: animal shelter management, garbage management in the area etc.) that affect SDP (FRD) management. The relationships between those concepts and SDP (FRD) could be investigated in future studies relating to SDP. The factors affecting SDP may vary from rural settings to urban settings. However, this regression model explains a fundamental idea: how to estimate factors that affect the SDP (FRD) in a particular area and how to test the relationships between those factors and the SDP (FRD). Therefore, this model could be employed in areas similar to the present study. Furthermore, this model could be modified with other conceptualised and operationalized independent variables that influence SDP (FRD) in different settings to determine the relationships in future SDP (FRD) investigations.

The general public's perceptions are not assessed in this present study. However, their perceptions of owned free-roaming dogs, dog abandonment, veterinary services, and CNVR intervention in the study area are important in finding sustainable solutions. Therefore, findings relating to general public perceptions in the aforesaid areas need to be investigated by researchers in this study area in the future.

This study's findings revealed a relationship between RDO and SDP (FRD). Descriptive analysis revealed that dog owners purposely send their dogs for free-roaming and dog abandonment. Therefore, an amendment to the existing dog registration ordinance to regulate the free-roaming state of owned dogs and dog abandonment is one of the vital needs in order to find an effective and sustainable solution with CNVR intervention for SDP (FRD) management in the Sri Lankan context.

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NOVELTY STATEMENT

This study has introduced a novel model for how to find the factors relating to the practices and behaviours of dog owners and veterinary services that affect the stray (free-roaming) dog population in an area. It is worthwhile to develop effective and sustainable stray dog (free-roaming) population management strategies.

AUTHOR'S CONTRIBUTION

The study design, data collection, data analysis, and drafting of the manuscript were done by Viranga Kumudini Jayasundara. The study was supervised by Ali Khabiti and Jacquline Tham.

Conflict of interest

The authors have declared no conflict of interest.

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