Full title: Public attitudes towards free-roaming dogs and dog ownership practices in Bulgaria, Italy, and Ukraine

Short title: Public attitudes towards free-roaming dogs and dog ownership practices in three European countries

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Abstract

Overabundant, free-roaming dog populations are associated with risks to public health, livestock losses, wildlife conservation, and dog health and welfare. Dog population management is conducted to mitigate these issues. Assessing dog population management strategies is important to determine their effectiveness, efficiency, and long-term impact. It is essential to also determine how the behaviour and outlook of local communities may influence the efficacy of dog population management. This study aimed to determine public attitudes towards free-roaming dogs and their management and describe dog ownership practices in three European countries using an online questionnaire survey. This study found that most surveyed respondents wanted to see a reduction in free-roaming dog numbers, and felt that this should be achieved through sheltering, catch-neuter-release, and by controlling the breeding of owned dogs. This questionnaire also identified significant associations between public attitudes and dog ownership practices with gender, religious beliefs, age, education level, reason for dog ownership, previous experience with free-roaming dogs, and country of residence. Respondents who identified as: (i) being male, (ii) holding religious beliefs, (iii) owning dogs for practical reasons, (iv) being young, and (v) having no schooling or primary education had a lower probability of neutering and a higher probability of allowing dogs to roam. Respondents who identified as: (i) being female, (ii) feeling threatened by free-roaming dogs, (iii) being older, and (iv) having more education had a higher probability of answering that an increase in free-roaming dog numbers should be prevented. These findings can help to inform future dog population management interventions in these countries and highlight the importance of considering local public attitudes and dog ownership practices in the development of effective dog population management approaches. Including these social factors will ensure that both the community and organisations involved in dog population management work cohesively towards a shared goal.

Introduction

Domestic dogs (*Canis familiaris*) are one of the most abundant species of canids in the world, with total population estimates between 700 million to 1 billion (1,2). Around 75% of this population are classified as “free-roaming”, indicating their ability to roam and reproduce freely (1). Where free-roaming dogs exist in high densities, there are important implications for public health (3–5), livestock losses (6–10) and wildlife conservation (11–13), in addition to issues for the welfare of the dogs themselves (14–17). The management methods applied to control population sizes involve culling, reproductive control, and the use of shelters to house unowned or unwanted dogs (18). Assessing dog population management is important to determine whether these methods are effective and efficient, and to evaluate their long-term impact.

Human behaviour can shape the success of a population management programme. This includes actions of local communities, the teams involved in dog population management and the governments imposing management strategies. Indeed, the World Organisation for Animal Health (OIE) has identified that understanding public attitudes is important for developing effective dog population control (19). In order for interventions to be successful, there must be public support for both the management method and its aims (e.g. reducing or stabilising the number of free-roaming dogs). Different communities may have different attitudes towards free-roaming dogs and management methods due to culture, religion, and the specific risks to humans, wildlife, livestock, and other companion animals in the area. Organisations involved in dog population management should consider these factors to ensure interventions are effective. For example, free-roaming dog populations can be an important part of a community, providing protection to people and livestock (17). Where management methods aim to reduce free-roaming dog numbers, there may still be demand for dogs in a community. Reduction in numbers could result in increased movement of dogs from neighbouring areas, which has

important implications for disease control (20–22). Prior to implementing management strategies, the level of acceptance of free-roaming dogs in the area should be gauged (i.e. determine whether the public prefer to have fewer free-roaming dogs in the community) so that those involved in dog population management can work towards a goal that benefits the community.

Dog ownership practices can also influence the success of population management. Encouraging responsible ownership practices is included as an objective in Chapter 7.7 of the OIE Terrestrial Animal Health Code on stray dog population control (19). The OIE defines responsible ownership as: "*When a person takes on the ownership of a dog, there should be an immediate acceptance of responsibility for the dog, and for any offspring it may produce, for the duration of its life or until a subsequent owner is found*" (19). Unrestricted owned dogs (free-roaming owned) and abandoned dogs are sources of free-roaming dog population increase (19). Dog ownership practices that allow owned dogs to roam and do not prevent reproduction can hinder efforts to control free-roaming dog populations. Those involved in dog population management must determine the extent to which owned dogs contribute to the free-roaming dog population so that management strategies can be tailored appropriately (e.g. by encouraging responsible ownership through legislation and education programmes).

Questionnaire surveys are frequently used to gain insight into public attitudes, opinions, behaviours, and the demographic and sociological factors associated with these. In terms of dog population management, different attitudes, opinions and behaviours about and towards dogs have been associated with responder gender (23–27), age (23,25,28), education (24,25,29), and previous life experiences (e.g. experience of keeping dogs in childhood) (30). Questionnaires aiming to describe dog ownership, public attitudes, and knowledge have been

conducted in many countries around the world, but few published studies have been carried out in European countries.

This study assesses how the behaviour and outlook of local communities may influence the efficacy of dog population management, by gauging attitudes towards the presence of free-roaming dogs and of dog ownership practices in three European countries – Bulgaria, Italy, and Ukraine. The objectives of this study are to: (i) determine public attitudes towards the presence of free-roaming dogs; (ii) determine local ownership practices, including whether owned dogs were free-roaming or neutered, the level of dog abandonment, and the reasons for dog abandonment; and (iii) investigate whether demographic and other factors (including age, gender, education level, religious beliefs, and previous experience with dogs) influence ownership practices and attitudes towards free-roaming dogs. This information can inform interventions so that education campaigns can target groups who are at-risk of irresponsible dog ownership behaviours (23,29), as well as provide a baseline for evaluating the impact of interventions on human behaviour and attitudes (29).

Materials and methods

Study design

This was a cross-sectional study, with target populations of Bulgaria, Italy, and Ukraine. The study populations were residents who used social media. Subjects were recruited through social media using an online questionnaire (Online Surveys (31)) that was open between the 8th of March 2019 and the 21st of December 2019, available in four languages: Bulgarian, Italian, Ukrainian, and Russian. The social media outlets used to distribute the questionnaire included Facebook (32) and Twitter (33). Facebook advertising was used to increase the

visibility of the questionnaire to the study population and increase the number of respondents. Facebook advertising targeted Facebook users who: (i) were recorded in their online profile as living in Bulgaria, Italy, or Ukraine; and (ii) were over the age of 18. The Facebook adverts invited participants to provide their opinion on free-roaming dogs and dog ownership practices (see S1 file for English translation of adverts). Sample sizes were calculated for the three study areas, using Equation 1. A sample size of 385 respondents per study country was necessary to provide estimates with a 5% error margin and 95% confidence interval. Subjects under the age of 18 were filtered in the first page of the online questionnaire.

Equation 1. Sample size calculation

$$Sample\ size = \frac{\frac{z^2 \times p(1-p)}{e^2}}{1 + (\frac{z^2 \times p(1-p)}{e^2 N})}$$

Where N = population size, e = margin of error, z = z-score, p = population proportion.

Ethical approval

Prior to completing the questionnaire, all participants were asked to consent to their responses being collected, stored, and analysed in an anonymised form for the purpose of reports and publication. No directly identifiable information was collected; all data obtained remains anonymous. Participants were able to withdraw from the questionnaire prior to completion, but as the data was collected anonymously, participants could not withdraw after the questionnaire was submitted. The study was approved by the University of Leeds Ethical Committee (reference BIOSCI 17-003).

Questionnaire design

The questionnaire was developed in English and translated into Bulgarian, Italian, Ukrainian, and Russian. The questionnaire comprised closed questions regarding the subjects' attitudes and practices towards dog ownership and free-roaming dog population control. Likert-type scales were used to estimate the level of agreement with specific questions. The questionnaire consisted of three sections: (1) socio-demographic information of the respondent; (2) ownership practices; and (3) attitudes towards the presence of free-roaming dogs and the management of the free-roaming dog population. A copy of the questionnaire in English can be found in S2 File.

Statistical analyses

All predictor and response variables are described in Table 1. Bernoulli logistic regression models were used to test the effect of demographic parameters and respondent experience on the response variables: (i) *Neutering status of owned dogs*; and (ii) respondents' answers to the question *"Do you think an increase in dogs on the street should be prevented?"*. Ordinal probit models (34) were used to test the effect of demographic parameters and respondent experience on: (i) *Roaming status of owned dogs*; (ii) *I do not like the presence of stray dogs around my home or work*; and (iii) respondents' answers to the question "*Would you prefer to see: no stray dogs, fewer stray dogs, do not mind stray dogs, more stray dogs"*.

Table 1. Response and predictor variables (self-reported responses to questions) included in the statistical analyses and their levels.

Variables	Levels
Age	** 18-24, 25-34, 35-44, 45-54, 55-64, 65-74 and 75 and above*

Variables	Levels
Children in household	*Children in household, no children in household*
Country	*Bulgaria, Italy, Ukraine*
Dog ownership	*Dog owner, non-dog owner*
Education status	** No education, primary, secondary, tertiary*
Gender	*Male*, *Female*, NA (including option *Other*)
Neutering status of owned dogs	*Neutered, not neutered*
Owning a dog for practical reasons	*Practical, not practical*
Religious belief	*Religious, non-religious*
Feeling physically threatened by dogs on the street	** Strongly disagree, disagree, neither agree nor disagree, agree, strongly agree*
Been attacked by dogs on the street	*Been attacked, not been attacked*
Respondent or family members have been bitten by dogs on the street in last 12 months	*Been bitten, not been bitten*
Roaming status of owned dogs	*Never, Sometimes, Always*
I do not like the presence of stray dogs around my home or work	*Strongly disagree, disagree, neither agree nor disagree, agree, strongly agree*
Should an increase in dogs on the street be prevented?	*Yes, No*
Would you prefer to see dogs on the street?	*No stray dogs, fewer stray dogs, do not mind stray dogs, more stray dogs*

* Ordinal predictor variables analysed as continuous variables in statistical models.

Effect of parameters on dog ownership practices

Model 1 tested the effects of demographic parameters and respondent experience on neutering of owned dogs using a Bayesian Bernoulli logistic regression model. The response variable was *neutering status of owned dogs* with fixed effects of *gender*, *age*, *education status*, *religious belief*, *owning a dog for practical reasons* and *country* (Table 1). Model 2 tested the effects of demographic parameters and respondent experience on the roaming status of owned dogs using a Bayesian ordinal probit model. The response variable was *roaming status of owned dogs* and fixed effects were the same as for Model 1.

Effect of parameters on public attitudes

Model 3 tested the effects of demographic parameters and respondent experience on agreement to the statement *I do not like the presence of stray dogs around my home or work* using a Bayesian ordinal probit model. The response variable was *I do not like the presence of stray dogs around my home or work* and fixed effects were *dog ownership*, *gender*, *age*, *education status*, *children in household*, *feeling physically threatened by dogs on the street*, *been attacked by dogs on street*, *respondent or family members have been bitten by dogs on the street in last 12 months,* and *country*.

Model 4 tested the effects of demographic parameters and respondent experience on the question *Do you think an increase in dogs on the street should be prevented?* using a Bayesian Bernoulli logistic regression model. The response variable was *should an increase in dogs on the street be prevented,* with fixed effects the same as in Model 3.

Model 5 tested the effects of demographic parameters and respondent experience on response to the question *Would you prefer to see: no stray dogs, fewer stray dogs, do not mind stray dogs, more stray dogs* using a Bayesian ordinal probit model. The response variable was *Would you prefer to see dogs on the street,* with fixed effects the same as in Model 3.

To fit the statistical models using a Bayesian analysis framework, the package "**brms**" version 2.12.0 (35) was used in R version 3.6.1 (36). All models were run with four chains, each with 2000 iterations (1000 used for warmup and 1000 for sampling). Thinning was set to one. The total number of post-warmup samples was 4000. Where a response was missing (i.e. a respondent did not answer a question), the response was omitted from the statistical analysis (see S1 Table for number of no responses per variable).

Collinearity in the predictor variables was checked using the "vif" function in R package "car" (37) and values lower than three were considered not collinear. Model parameters were summarised by the mean and 95% credible intervals of the posterior distribution (CI; 95% most probable values). A significant effect was determined if the 95% credible intervals of the posterior distribution did not contain zero on the log odds or probit scale. Probabilities were converted from the logit scale to the probability scale by $\exp(x) / 1 + (\exp(x))$, and are converted to odds using $\exp(x)$, where *x* is the posterior value on the logit scale.

Results

Descriptive analyses

Demographics

The numbers of respondents were 5,434 in Bulgaria, 3,468 in Italy, and 19,323 in Ukraine. All demographic information is provided in S2 Table. Respondents were from multiple regions within Bulgaria, Italy, and Ukraine (see S3 to S5 Tables). A broad range of ages between 18 and 64 were represented in all three study countries. Most respondents were female in all three study countries (87.5% in Bulgaria, 83.1% in Italy, and 87.1% Ukraine). In Bulgaria 68.9%, 42.0% in Italy, and in Ukraine 67.3% of the respondents considered themselves to be religious. In Bulgaria 36%, Italy 43% and Ukraine 57% of respondents lived in households with children.

Ownership practices

The main reason for dog ownership in all three study countries was for pleasure and company (Bulgaria 85.5%, Italy 87.7%, Ukraine 70.7%; see Table S6 for detailed responses on ownership practices). In Italy, a higher percentage of respondents acquired their dog from a dog shelter (38.1%), compared to in Bulgaria (9.7%) and Ukraine (9.9%) (Fig 1). In Bulgaria and Ukraine, more respondents found their dog on the street (Bulgaria 35.5% and Ukraine 34.6%) or received their dog from friends/family (Bulgaria 32.6% and Ukraine 27.9%). More respondents in Italy answered that they prevent their dog from breeding through neutering (65.4%), compared to 40.4% in Bulgaria and 35.4% in Ukraine. When asked the reason why respondents did not prevent breeding, 37.6% of respondents in Bulgaria, 34.6% in Italy, and 13.7% in Ukraine answered: "*A dog should reproduce at least once*" (Fig 1). When respondents were asked if they allowed their dog to roam outside unsupervised, 59.0% in Bulgaria, 92.1% in Italy and 79.4% in Ukraine responded *Never*, and 29.5% in Bulgaria, 6.3% in Italy and 16.3% in Ukraine responded *Sometimes*.

Fig 1. Ownership practices of respondents in Bulgaria, Italy, and Ukraine. The percentage of respondents who answered each of the answer options regarding (A) acquisition of dog, (B) reasons for not preventing breeding, (C) the outcome of the dog, and (D) reason for relinquishment. * Multi answer question: Percentage *of respondents who selected each answer option (i.e. 100% would indicate that all respondents chose this option).*

Most respondents in all study countries responded that they had never given up a dog (Bulgaria 98.5%, Italy 92.4%, and Ukraine 92.2%). Those respondents who had given up a dog mostly answered that this was because of an *Animal behavioural problem* (Bulgaria

27.3%, Italy 36.5%, and Ukraine 23.8%), or *Other* reason (Bulgaria 39.4%, Italy 57.5%, and Ukraine 45.3%) (Fig 1).

Attitudes

In Bulgaria and Ukraine, high percentages of respondents had seen a free-roaming dog on the day they filled in the questionnaire (73.3% and 77.3% respectively), compared to only 15.4% of respondents in Italy (Fig 2; see S7 Table for detailed results). A higher percentage of respondents in Bulgaria (21.6%) and Ukraine (26.5%) had been attacked by dogs on the street ever in their lifetime, compared to few (4.2%) in Italy. Higher percentages of respondents in Bulgaria answered that they provided care to free-roaming dogs by giving food (90.6%), water (71.0%), and shelter (34.8%), compared to Italy (53.7% food, 44.2% water, 19.0% shelter) and Ukraine (67.5% food, 29.6% water and 9.7% shelter) (S6 Table).

Fig 2. Attitudes of respondents towards free-roaming dogs in Bulgaria, Italy and Ukraine. The percentage of respondents who answered each of the answer options regarding (A) observation of free-roaming dogs and (B) agreement with statement "*I do not like stray dogs being present around my home or work*".

When respondents were asked their level of agreement with the statement "*I do not like stray dogs being present in the streets around my home or work*", responses were varied across the full range of options between strongly disagree and strongly agree in Bulgaria and Ukraine (varying between 14 and 25% for all answer options) (Fig 2). Most respondents in Italy disagreed with this statement (35.8%). In all three study countries, most respondents disagreed (Bulgaria 20.8%, Italy 19.3%, and Ukraine 25.3%) and strongly disagreed (Bulgaria

42.2%, Italy 56.4%, and Ukraine 31.6%) with the statement "*I feel physically threatened by stray dogs*".

Respondents answered most often that the municipality government and volunteer organisations should be responsible for managing the free-roaming dog population (Fig 3; S6 Table). Respondents most often answered that they would like to see *no* (Bulgaria 52.4%, Italy 70.2%, and Ukraine 45.2%) and *fewer* (Bulgaria 32.8%, Italy 24.3%, and Ukraine 40.6%) free-roaming dogs. Respondents who answered that they would like to see *no* or *fewer* free-roaming dogs answered that this should be achieved through sheltering, CNR, and controlling the breeding of owned dogs (Fig 3). Few answered that the free-roaming dog population should be reduced through culling (Bulgaria 1.7%, Italy 1.6%, and Ukraine 6.3%).

Fig 3. Attitudes of respondents towards dog population management in Bulgaria, Italy, and Ukraine. The percentage of respondents who answered each of the answer options for: (A) who should be responsible for dog population management? and (B) how should free-roaming dogs be reduced?. These were multi answer questions: Percentage of respondents who selected each answer option (i.e. 100% would indicate that all respondents chose this option).

Statistical analyses

All models converged (for all parameters Rhat = 1.00 and effective sample size >1000, see Supplementary information). There was no collinearity in the predictor variables (all values less than three). All raw model results (including the posterior mean values, standard deviations and 95% credible intervals, the 2.5% and 97.5% percentiles of the posterior

287 distribution) are presented in Tables S8 to S12. Estimates for mean and 95% CIs for
288 probabilities are reported for each model and presented in Table 2. Odds ratios (OR) are
289 reported for predictor variables in the Bernoulli logistic regression models (Models 1 and 4).

290

291 **Table 2. Effect of predictor variables on statistical models on the probability scale.**
292 **Significant results are highlighted in bold.** NI = predictor variable not included in the
293 model.

Predictor variable		**Model 1**	**Model 2**	**Model 3**	**Model 4**	**Model 5**
		Probability of neutering (95% CI)	Probability of answering *Never* allow dog to roam (95% CI)	Probability of answering *Strongly agree* (95% CI)	Probability of answering *Yes* to the question "*Should an increase in stray dogs be prevented*" (95% CI)	Probability of answering *No stray dogs* (95% CI)
Gender	Male	**0.38 (0.35-0.41)**	**0.74 (0.71-0.76)**	**0.17 (0.16-0.18)**	**0.97 (0.96-0.97)**	**0.53 (0.51-0.55)**
	Female	**0.48 (0.47-0.49)**	**0.81 (0.80-0.82)**	**0.15 (0.14-0.15)**	**0.98 (0.98-0.99)**	**0.60 (0.59-0.61)**
Religious belief	Religious	**0.44 (0.43-0.45)**	**0.79 (0.78-0.80)**	NI	NI	NI
	Non-religious	**0.54 (0.52-0.56)**	**0.83 (0.82-0.85)**	NI	NI	NI
Reason for dog ownership	Practical	**0.31 (0.28-0.33)**	**0.71 (0.69-0.74)**	NI	NI	NI
	Non-practical	**0.48 (0.47-0.49)**	**0.81 (0.80-0.82)**	NI	NI	NI
Been attacked by dogs on the street	Attacked	NI	NI	**0.16 (0.15-0.17)**	0.98 (0.98-0.99)	**0.61 (0.59-0.62)**
	Not attacked	NI	NI	**0.15 (0.14-0.15)**	0.98 (0.98-0.99)	**0.59 (0.58-0.59)**
Respondent or family members have been bitten by dogs on the street in last 12 months	Bitten	NI	NI	**0.19 (0.18-0.21)**	0.98 (0.98-0.99)	**0.65 (0.63-0.67)**
	Not bitten	NI	NI	**0.15 (0.14-0.15)**	0.98 (0.98-0.99)	**0.58 (0.57-0.59)**
Dog ownership	Yes	NI	NI	0.15 (0.15-0.16)	0.98 (0.98-0.99)	**0.59 (0.59-0.60)**
	No	NI	NI	0.15 (0.14-0.16)	0.98 0.98-0.99)	**0.56 (0.55-0.57)**
Children in household	Yes	NI	NI	0.15 (0.15-0.16)	0.98 (0.98-0.99)	**0.585 (0.58-0.60)**
	No	NI	NI	0.15 (0.14-0.15)	0.98 (0.98-0.99)	**0.593 (0.57-0.59)**

Predictor variable		Model 1	Model 2	Model 3	Model 4	Model 5
Age	18-24	**0.40 (0.39-0.42)**	**0.78 (0.76-0.79)**	**0.14 (0.14-0.15)**	**0.980 (0.977-0.984)**	**0.57 (0.56-0.58)**
	25-34	**0.44 (0.43-0.45)**	**0.79 (0.78-0.80)**	**0.15 (0.14-0.15)**	**0.982 (0.980-0.985)**	**0.58 (0.57-0.59)**
	35-44	**0.47 (0.46-0.48)**	**0.80 (0.80-0.81)**	**0.15 (0.15-0.16)**	**0.984 (0.982-0.986)**	**0.59 (0.58-0.60)**
	45-54	**0.51 (0.49-0.52)**	**0.82 (0.81-0.83)**	**0.16 (0.15-0.16)**	**0.985 (0.983-0.988)**	**0.60 (0.59-0.61)**
	55-64	**0.54 (0.52-0.56)**	**0.83 (0.82-0.84)**	**0.16 (0.15-0.17)**	**0.987 (0.984-0.989)**	**0.61 (0.60-0.63)**
	65-74	**0.57 (0.55-0.59)**	**0.84 (0.83-0.86)**	**0.16 (0.15-0.17)**	**0.988 (0.985-0.991)**	**0.62 (0.61-0.64)**
	75+	**0.61 (0.58-0.63)**	**0.85 (0.84-0.87)**	**0.17 (0.15-0.18)**	**0.989 (0.985-0.993)**	**0.63 (0.61-0.65)**
Education level	None	**0.30 (0.24-0.35)**	**0.73 (0.67-0.78)**	0.14 (0.12-0.16)	**0.95 (0.92-0.97)**	0.55 (0.51-0.60)
	Primary	**0.35 (0.32-0.39)**	**0.75 (0.72-0.79)**	0.14 (0.13-0.16)	**0.96 (0.95-0.98)**	0.57 (0.54-0.60)
	Secondary	**0.41 (0.39-0.43)**	**0.78 (0.77-0.80)**	0.15 (0.14-0.16)	**0.98 (0.97-0.98)**	0.58 (0.56-0.60)
	Tertiary	**0.48 (0.47-0.49)**	**0.81 (0.80-0.82)**	0.15 (0.15-0.16)	**0.98 (0.98-0.99)**	0.60 (0.58-0.60)
Threatened by dogs on the street	Strongly disagree	NI	NI	**0.05 (0.047-0.054)**	**0.973 (0.969-0.977)**	**0.49 (0.48-0.50)**
	Disagree	NI	NI	**0.13 (0.12-0.13)**	**0.982 (0.980-0.984)**	**0.57 (0.56-0.58)**
	Neutral	NI	NI	**0.26 (0.25 t0 0.27)**	**0.988 (0.986-0.990)**	**0.65 (0.64-0.66)**
	Agree	NI	NI	**0.44 (0.43-0.45)**	**0.992 (0.990-0.994)**	**0.73 (0.72-0.74)**
	Strongly agree	NI	NI	**0.64 (0.62-0.65)**	**0.995 (0.993-0.997)**	**0.79 (0.78-0.81)**
Country	Bulgaria	**0.41 (0.39-0.43)**	**0.61 (0.59-0.62)**	**0.20 (0.18-0.21)**	0.987 (0.983-0.990)	**0.55 (0.53-0.56)**
	Italy	**0.62 (0.60-0.64)**	**0.92 (0.91-0.93**	**0.10 (0.10-0.11)**	0.983 (0.979-0.987)	**0.76 (0.74-0.77)**
	Ukraine	**0.37 (0.36-0.38)**	**0.81 (0.81-0.82)**	**0.17 (0.16-0.17)**	0.980 (0.978-0.982)	**0.45 0.44-0.46)**

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Effect of demographic parameters on neutering status of owned dogs

Gender, *age*, e*ducation level*, *owning a dog for practical reasons*, *religious beliefs* and *country* had significant effects on the *neutering status of owned dogs* (Table S8). Probabilities of neutering are presented in Table 2. Male respondents had a lower probability of neutering, compared to females (OR 1.47; 95% CI 1.28-1.64). Holding religious beliefs (OR 0.66, 95% CI 0.61 to 0.72) and owning dogs for practical reasons (i.e. guarding or hunting, compared to for pleasure and company; OR 0.49, 95% CI 0.43 to 0.54) were both negatively associated with neutering. Respondent age (OR 1.15; 95% CI 1.12-1.18) and education level (OR 1.29; 95% CI 1.17-1.41) were both positively associated with neutering (i.e. the older and more educated a participant, the more likely they were to neuter). Respondents from Italy had a higher probability of neutering compared to Bulgaria (OR 2.32; 95% CI 2.05-2.62) and Ukraine (OR 2.73; 95% CI 2.44-3.01). Respondents from Ukraine had a lower probability of neutering compared to Bulgaria (OR 0.37; 95% CI 0.33-0.40).

Effect of demographic parameters on roaming

Gender, *age*, *education level*, *owning a dog for practical reasons*, *religious beliefs*, and *country* had significant effects on the *roaming status of owned dogs* (Table S9). Probabilities of answering *Never* allow dog to roam for predictor variables are presented in Table 2. Females had a higher probability of answering that they *Never* allowed their dog to roam. Respondents who held religious beliefs, and respondents who owned dogs for practical reasons were less likely to answer *Never*. Age of respondent was positively correlated with answering *Never* (i.e. older respondents were less likely to allow their dog to roam). Increased education level of the owner was positively associated with answering *Never* (i.e. respondents with higher levels of education were less likely to allow their dog to roam). Respondents from Italy had the highest

probability of answering *Never*, respondents in Bulgaria had the lowest probability of answering *Never*.

Effect of demographic parameters and respondent experience on answer to "I do not like the presence of stray dogs around home or work"

Predictor variables *gender*, *age*, *owning a dog for practical reasons*, *feeling threatened by dogs on the street*, *having been attacked by dogs on the street, respondent or family members have been bitten by dogs on the street in last 12 months*, and *country* had significant effects on agreement with the statement *I do not like the presence of stray dogs around my home or work* (Table S10). Probabilities for answering *Strongly agree* for predictor variables are presented in Table 2. Female respondents had a lower probability of agreeing with the statement. Respondents who answered *Yes* to the question *Have you ever been attacked by dogs on the street?* had a higher probability of agreeing with the statement. Respondents who answered *Yes* to the question *Have you or your family members been bitten in the last 12 months?* had a higher probability of agreeing with the statement. Respondent age was positively associated with agreement to the statement (i.e. older respondents were more likely to agree). Agreement with the statement *I feel physically threatened by dogs on the street* was positively associated with agreement with the statement *I do not like the presence of stray dogs around my home or work* (i.e. respondents who felt threatened were more likely to agree with the statement that they did not like the presence of dogs around their home or work). Respondents from Italy had the lowest probability of answering *Strongly* agree, and respondents from Bulgaria had the highest probability of answering *Strongly* agree.

There was no evidence of an effect of: *dog ownership*, *education level*, and *children in household* on agreement with the statement *I do not like stray dogs present around my home or work* (Table S10).

Effect of demographic parameters and respondent experience on answering an increase in stray dogs should be prevented.

There were significant effects of *gender*, *age*, *education level*, and *feeling threatened by dogs on the street* on answering *Yes* to the question *Do you think an increase in dogs on the street should be prevented?* (Table S11). Female respondents had a higher probability of answering *Yes* (OR 2.14; 95% CI 1.67-2.65). There was a positive association between answering *Yes* and respondents' agreement with the statement "*I feel physically threatened by dogs on the street*" (OR 1.53; 95% CI 1.37-1.68); their age (OR 1.11; 95% CI 1.03-1.19); and education (OR 1.54; 95% CI 1.24-1.83).

There was no evidence of an effect of *dog ownership*, *children in household*, *having been attacked by dogs on the street, respondent or family members have been bitten by dogs on the street in last 12 months* or *country* (Table S11).

Effects of demographic parameters and respondent experience on the question "Would you prefer to see: no stray dogs, fewer stray dogs, do not mind stray dogs, more stray dogs"

Dog ownership, *gender*, *age*, *feeling threatened by dogs on the street*, *having been attacked by dogs on the street, respondent or family members have been bitten by dogs on the street*

in last 12 months, and *country* had significant effects on response to this question regarding preference for observing stray dogs (Table S12). Probabilities for answering *No stray dogs* for predictor variables are presented in Table 2. Male respondents had a lower probability of answering *No stray dogs* (Table 2). Dog owners had a higher probability of answering *No stray dogs*. Respondents who answered *Yes* to the question "*Have you ever been attacked by dogs on the street?*", or *Yes* to the question "*Have you or your family members been bitten in the last 12 months*" or had children in their household had a higher probability of answering *No stray dogs*. Agreement with the statement "*I feel physically threatened by dogs on the street*" was positively correlated with answering *No stray dogs* (i.e. respondents who feel threatened by dogs on the street are more likely to answer *No stray dogs*). Respondent age was positively correlated with answering *No stray dogs* (i.e. older respondents had an higher probability of preferring to see *No stray dogs*). Respondents in Italy had the highest probability of answering *No stray dogs*, and respondents in Ukraine had the lowest probability of answering *No stray dogs*.

There was no evidence of an effect of children in household and education level on the probability of preference of observing stray dogs (Table S12).

Discussion

This study quantified dog ownership practices and investigated public attitudes towards the management of free-roaming dogs in Bulgaria, Italy, and Ukraine. Risk factors for neutering, roaming and tolerance of free-roaming dog presence have been identified by comparing attitudes and dog ownership practices to demographic factors. This study found evidence for significant effects of gender, religious beliefs, age, education level, reason for dog ownership,

391 previous experience with free-roaming dogs, and country of residence on ownership practices
392 and attitudes.

393

394 Ownership practices

395 Responsible ownership is an important component of dog population management (19). In
396 order to effectively target dog population management interventions, it is important to
397 understand the level of dog ownership, level of care for owned dogs (e.g. feeding and
398 vaccination) and prevalence of abandonment, neutering and roaming practices. This study
399 quantified the prevalence of ownership practices in Bulgaria, Italy, and Ukraine, allowing us to
400 make comparisons between the countries.

401

402 There were differences in dog-acquiring behaviour between the countries. More respondents
403 in Italy acquired their dogs from a shelter, compared to acquiring from friends or by finding a
404 dog in the street in Bulgaria and Ukraine. The differences in dog acquiring behaviour could be
405 due to a lack of public awareness of local shelters, or perceived differences in shelter quality
406 between the study countries. However, there is currently little research to substantiate these
407 explanations and more work on public awareness is needed. In all study countries, many
408 participants had adopted a dog directly from the street, potentially reflecting the prevalence of
409 free-roaming dogs in the study countries. Fewer participants in Italy paid for their dog. Previous
410 studies have suggested that dogs who are received for little cost are at higher risk of
411 relinquishment (38). However, the number of respondents who answered that they had given
412 up a dog was low across the study countries. These numbers are likely to be an underestimate,
413 given the taboo around relinquishing dogs. A study by Hsu, Severinghaus and Serpell (2003)
414 (30) found similar estimates, where only 5.3% of respondents answered that they had given
415 up a dog, however, far more respondents answered that they knew someone who had given

up a dog (31.9%). This indicates that respondents may underreport relinquishment of owned dogs.

Responsible dog ownership requires that an owner provides care for a dog until they are transferred to another owner (19). Most respondents who had relinquished a dog in Italy and Ukraine reported they had given their dog to a friend (Fig 1), complying with responsible ownership (19). In Bulgaria, a higher percentage of respondents answered they had "*Let free*" their dog (Fig 1). Letting a dog free to the street directly increases the free-roaming dog population. Previous studies have found that respondents prefer to let a dog free to the street as it offers the dog an opportunity to live, unrestricted, outside of a shelter and offers the possibility to find another owner through adoption from the street (30). This suggests that some dog owners may perceive letting a dog free to the street as responsible ownership. Further research is required to understand why respondents in Bulgaria chose to let a dog free, instead of giving to a shelter or to another owner.

Preventing the production of unwanted puppies is an important part of responsible ownership (19). Most respondents answered that they prevented their dogs from reproducing; 50.8% respondents in Bulgaria, 65.3% in Italy, and 35.3% in Ukraine answered that they did so through neutering. These results should be interpreted with caution, as the self-selection process of recruiting for questionnaires can result in biased samples of the populations. It is possible that respondents who were more likely to neuter their dogs (such as those with higher levels of education) were more likely to complete the questionnaire. The true proportion of neutered owned dogs in the study countries may therefore be lower. Neutering of owned dogs can prevent unwanted offspring and, if owned dogs are free-roaming, can help to prevent unowned dogs from reproducing. When respondents were asked why they did not neuter their dog, the most common answer (if one was provided) across all countries was that a dog should

reproduce at least once (Fig 1). Few respondents answered that it was for cost reasons. This contrasts with previous findings in Taiwan (30) and Brazil (39), where respondents cite cost and “too much trouble” as primary reasons for not neutering. As cost, in this study, was not found to be a primary reason that owners did not neuter their dogs, this suggests that in Bulgaria, Italy, and Ukraine, whilst low-cost or free neutering interventions may be important (40), interventions should also address owner attitudes towards reproduction, in order for interventions to have a greater impact.

This study found evidence for significant associations between country, gender, religious belief, reason for ownership, age, and education level and the probability of neutering (Table S9). These results reflect those reported in other studies (23–27,29). For example, a study by Fielding (2007) in New Providence, The Bahamas (24) also found that respondents with higher levels of education were more likely to have neutered their dog. Similarly, Costa *et al.,* (2015) (29) found that respondents with higher levels of education were more likely to answer that neutering was the best way to control the overabundance of stray animals in Brazil. Respondents with higher levels of education may have a higher level of awareness of responsible ownership and the benefits of neutering, in addition to potentially having a higher income and ability to pay for neutering. Fielding, Samuels & Mather (2002) (23) also found a significant effect of owner age on neutering probability, suggesting that younger owners may have a greater desire to breed from their dog, compared to older owners.

Owned dogs that are free-roaming contribute to the free-roaming population directly by increasing the population size. Owned free-roaming dogs therefore contribute to the issues, such as the risks to public health (41,42) and wildlife (11,12,43–47). Efforts encouraging responsible ownership may help reduce the number of dogs roaming, and may therefore help to reduce the impacts of the free-roaming dogs on public health and wildlife (19). This study

found evidence for significant effects of gender, religious beliefs, reason for dog ownership, age, education, and country, on the probability of allowing owned dogs to roam (Table S9). It is clear from these results that interventions should be targeted using these demographic risk factors to prevent roaming behaviour, particularly in countries where higher percentages of owned dogs are free-roaming, such as Bulgaria and Ukraine.

Most respondents (59-92%) across all three countries answered that they never allowed their dogs to roam (Table S5). Again, these results might be biased, for example respondents less likely to allow their dogs to roam may have been more likely to complete the questionnaire. The results are higher than those reported in the Bahamas 57% (48), Bhutan 50% (49), Cameroon 37.7% (50), Guatemala 25.7% (51), urban households in Haiti 54% (52), Kenya 19% (53), Mexico 44.9% (54), Ethiopia 15.7% (55), Tanzania 22% (56), and Uganda 21.7% (57), but lower than those reported in semi-urban households in Haiti 62% (52) and Taiwan 79% (30). There was a significant effect of study country on roaming probability (Table S9), with respondents in Bulgaria more likely to allow their dogs to roam, compared to Italy and Ukraine. The significant effect of country may reflect differences in dog ownership behaviour and culture.

Attitudes towards free-roaming dogs

In Bulgaria and Ukraine, almost all respondents answered that they had seen free-roaming dogs on the street, whereas in Italy 18.7% of respondents had never seen a free-roaming dog (Fig 2). These results may indicate that the populations of free-roaming dogs are larger in Bulgaria and Ukraine. Within Italy, there are differences in dog population management: some regions permit CNR and the presence of “community dogs” (free-roaming dogs owned by the municipality), whilst other regions only permit dog population management through sheltering.

493 Respondents living in regions that do not permit community dogs, or in regions with smaller
494 free-roaming dog populations, may be expected to observe fewer free-roaming dogs. Higher
495 percentages of respondents in Bulgaria and Ukraine answered that they felt threatened by
496 free-roaming dogs, and that they or a member of their family had been bitten in the last 12
497 months. These results may also indicate a greater free-roaming dog population size and
498 related problems in Bulgaria and Ukraine.

499

500 A large proportion of respondents across all countries answered that they provided care for
501 free-roaming dogs (Table S6). For example, 90.6% in Bulgaria, 53.7% in Italy, and 67.5% of
502 respondents in Ukraine answered that they provided food for free-roaming dogs. For Bulgaria
503 and Ukraine, these numbers are similar to those reported by Costa *et al.,* (2015) in Brazil,
504 where 61.9% of respondents reported that they or their neighbours fed stray animals, and
505 Massei *et al.,* (2017) (58) in Nepal, where 47% of respondents provided food and care for free-
506 roaming dogs. In a previous study by Slater *et al.,* (2008) (59) in central Italy, only 5% of
507 respondents reported that they provided care for free-roaming dogs. This is much lower than
508 the numbers reported in this study, where 71.5% of Italian respondents answered that they
509 provided care for free-roaming dogs. This may be explained by the potential bias in the
510 recruitment process of this study, respondents who provide care for free-roaming dogs may
511 also have been more motivated to complete the questionnaire. Data was collected by Slater
512 *et al.,* (2008) using an anonymous telephone survey and had a high response rate (74%).
513 Providing care for free-roaming dogs is controversial. Providing food may alleviate welfare
514 issues associated with lack of nutrition in the free-roaming dog population (60–62), but also
515 increases the carrying capacity for the free-roaming dog population.

516

517 Most respondents across all study countries felt that the municipal government and volunteer
518 organisations should be responsible for managing free roaming dog populations, and mostly

519 by methods such as sheltering, CNR, and by controlling the breeding of owned dogs (Fig 3).
520 These results are similar to those found in previous studies (59,63,64). For example, a study
521 by Ortega-Pacheco *et al.,* (2007) (64) in Yucatan, Mexico found that 52.8% of interviewed
522 households supported the neutering of dogs for dog population management, and felt that the
523 government and society were responsible for dog population management. The results in this
524 study suggest there is support for dog population management through sheltering, CNR, and
525 restricted breeding of owned dogs. Few respondents answered that culling should be used to
526 control the free-roaming dog population (Fig 3). These results are similar to those found by
527 Beckman *et al.,* (2014) (63), but are much lower than results by Costa *et al.,* (2017) (29),
528 where culling was supported by 26.8% of respondents.

529

530 As public attitudes can play an important role in determining the success of dog population
531 management, it is important that organisations involved in dog population management gauge
532 the level of support for reducing free-roaming dogs in the area. Across all three countries,
533 most respondents answered that they would prefer to see fewer or no stray dogs, and that an
534 increase in stray dogs should be prevented. With regards to Italy, these responses correspond
535 with previously reported attitudes in the Teramo province in the Abruzzo region of Italy (59).

536

537 Implications for future interventions

538 The results of this study suggest that the public in the three study countries would prefer a
539 reduction in free-roaming dog numbers, and for this to be achieved through sheltering, CNR
540 and responsible ownership, rather than culling. There is therefore support for the management
541 interventions that are taking place in these study countries. Targeted interventions that can
542 influence the behaviour of those less likely to practice responsible ownership may help to
543 improve responsible ownership and reduce free-roaming dog numbers. For example, as there

was evidence for significant effects of gender and age on roaming and neutering, interventions could be adapted to target men and younger people on responsible ownership practices.

Questionnaires are important tools for evaluating the impact of interventions on human attitudes and behaviour. This includes monitoring public attitudes and behaviour (such as responsible ownership) to determine whether education campaigns are having a significant effect. There have been numerous studies on public attitudes towards free-roaming dogs and dog ownership practices, but few repeated surveys to assess the effectiveness of dog population control on human attitudes and behaviour (29,65). The results from this present study can be used to target interventions to those who are less likely to practice responsible ownership and the results can also be used as a baseline for monitoring the effect of dog population management interventions on dog ownership behaviours and public attitudes in Bulgaria, Italy, and Ukraine.

Limitations of questionnaire research methods

There are limitations in using questionnaires to determine public attitudes and behaviours. The self-selection process involved in the recruitment for questionnaires can result in a biased sample of the target population, as certain members of the public may be more motivated to complete the survey, for example dog owners, or those with strong views about the subject. In this survey, as with other similarly themed surveys (59), a high percentage of the respondents were female. As responses from male members of the public were lacking, the survey results may not necessarily reflect the views of the wider population. A similarly high percentage of respondents reported to have or be in tertiary education, which is not representative of the wider populations. The questionnaire was also primarily advertised through social media; therefore, members of the public who do not have access to social

569 media are likely to have been missed. Although this is a limitation, social media provides
570 opportunities to recruit a large and diverse range of participants (see (66,67) for review).
571 Despite the clear biases in questionnaire surveys, given the range of participants in this study
572 (for example, in terms of ages and regions), the results provide an indication of ownership
573 practices and public attitudes, and the statistical models still give us information about the risk
574 factors for behaviours and attitudes.

575

576 Conclusions

577 When planning dog population management interventions, it is important to understand how
578 human behaviour may impact the success of an intervention. This involves understanding how
579 public behaviour, such as dog ownership practices, may influence intervention success, and
580 gauging the level of public support for management interventions. This study found evidence
581 for significant effects of demographic factors on ownership practices and public attitudes.
582 These results can be used to inform future dog population management interventions in these
583 countries. Interventions should consider also carrying out periodic questionnaire surveys to
584 evaluate changes in public attitudes towards responsible ownership and the free-roaming dog
585 population.

586

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Supporting information

S1 File. Facebook adverts.

S2 File. English copy of questionnaire.

S3 File. Answer option to question "*Are your dog(s) registered and identified*" in Bulgarian questionnaire

S1 Table. Number of "No responses" to outcome and predictor variables in statistical analysis.

S2 Table. Demographic information about respondents in Bulgaria, Italy and Ukraine.

S3 Table. Number of respondents in Bulgaria, split by oblasts in Bulgaria.

S4 Table. Number of respondents in Italy, split by regions in Italy.

S5 Table. Number of respondents in Ukraine, split by oblasts in Ukraine.

S6 Table. Respondents answers to questions about ownership practices in Bulgaria, Italy and Ukraine.

S7 Table. Respondents answers to questions about attitudes to free-roaming dogs in Bulgaria, Italy and Ukraine.

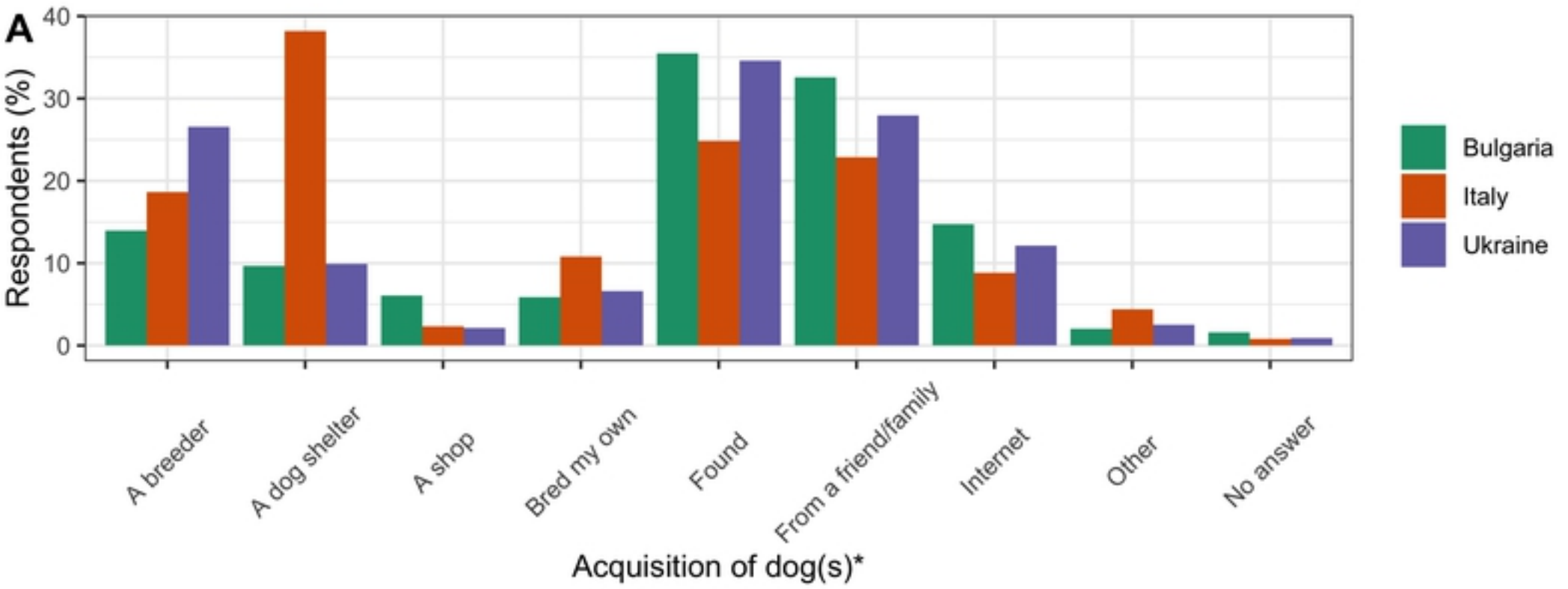
S8 Table. The posterior mean values, error estimates, the 2.5 and 97.5 percentiles of the posterior distribution (CI), Rhat values and bulk and tail effective sample sizes (ESS) for Model 1.

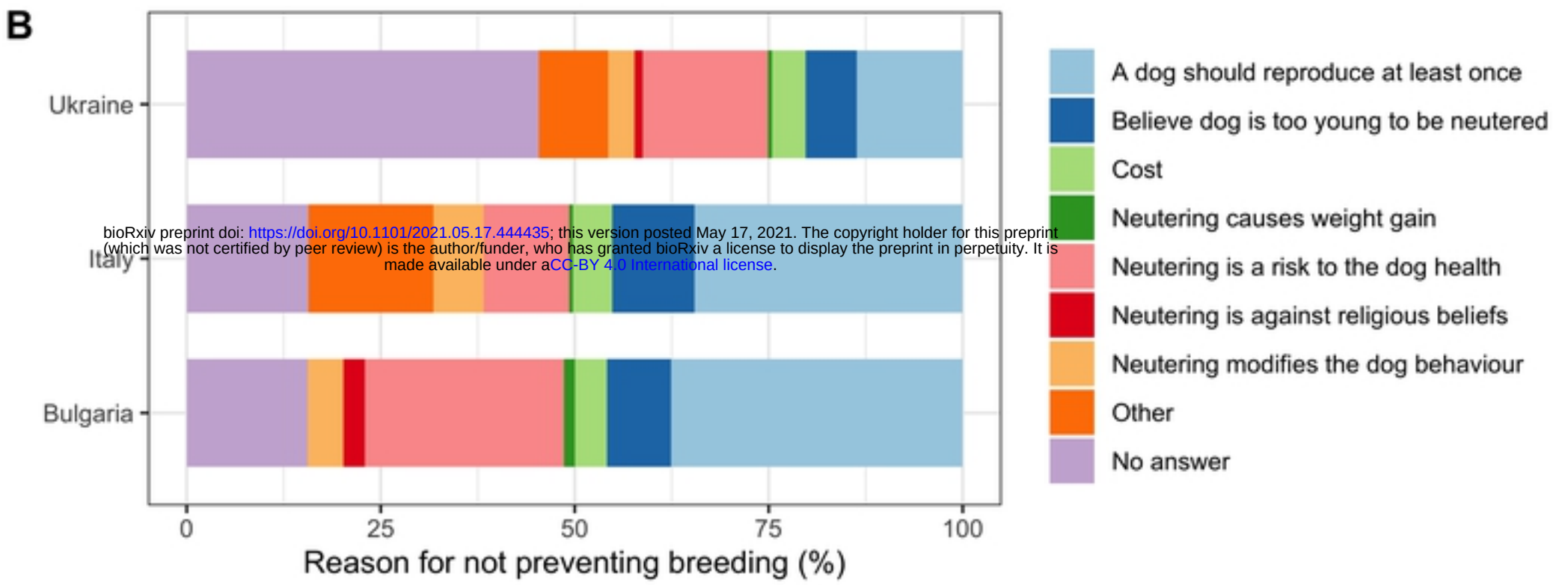
S9 Table. The posterior mean values, error estimates, the 2.5 and 97.5 percentiles of the posterior distribution (CI), Rhat values and bulk and tail effective sample sizes (ESS) for Model 2.

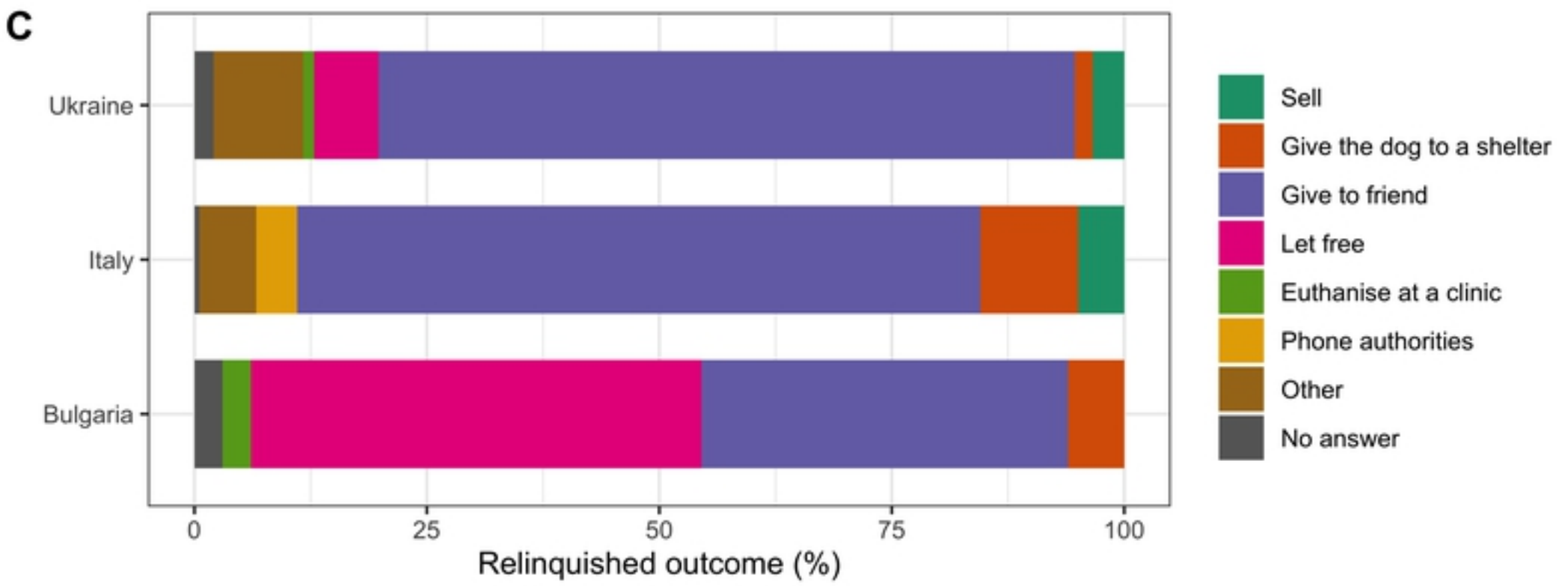
S10 Table. The posterior mean values, error estimates, the 2.5 and 97.5 percentiles of the posterior distribution (CI), Rhat values and bulk and tail effective sample sizes (ESS) for Model 3.

S11 Table. The posterior mean values, error estimates, the 2.5 and 97.5 percentiles of the posterior distribution (CI), Rhat values and bulk and tail effective sample sizes (ESS) for Model 4.

S12 Table. The posterior mean values, error estimates, the 2.5 and 97.5 percentiles of the posterior distribution (CI), Rhat values and bulk and tail effective sample sizes (ESS) for Model 5.







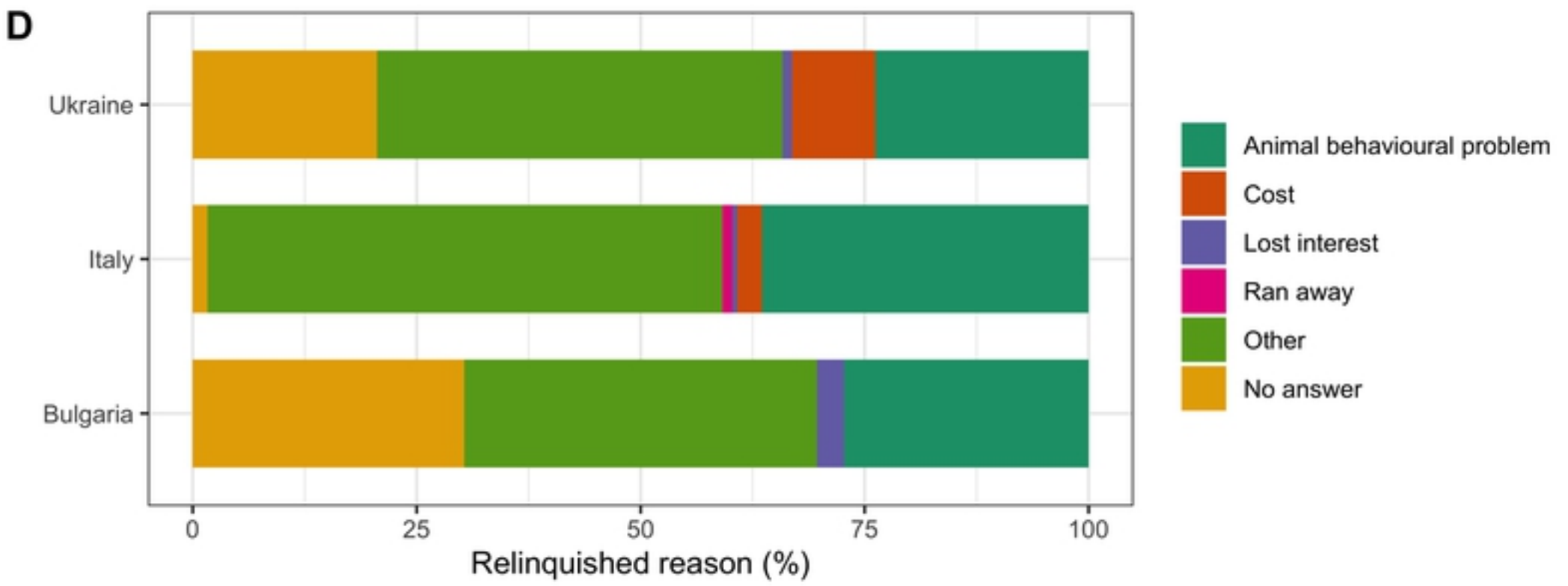


Figure 1

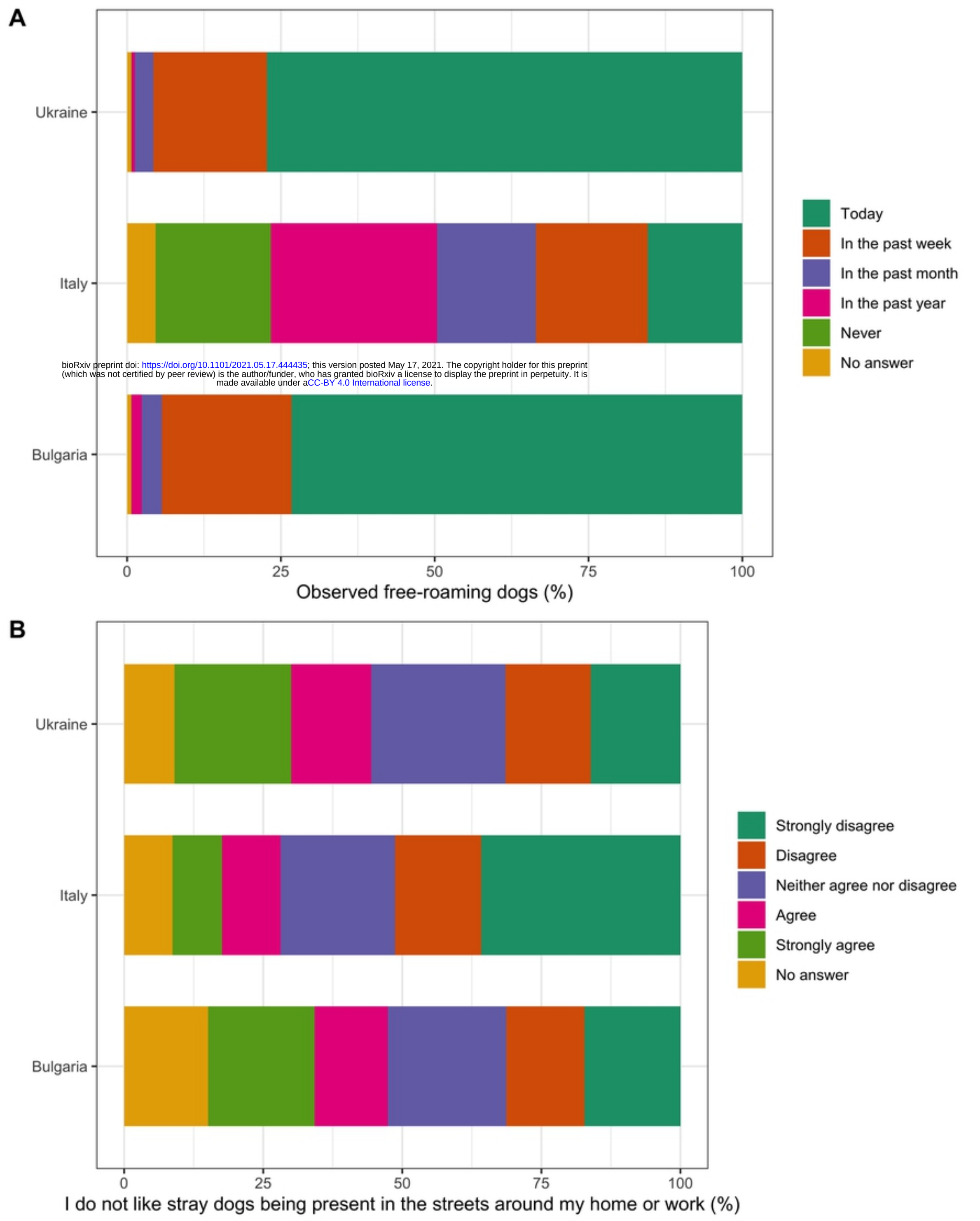


Figure 2

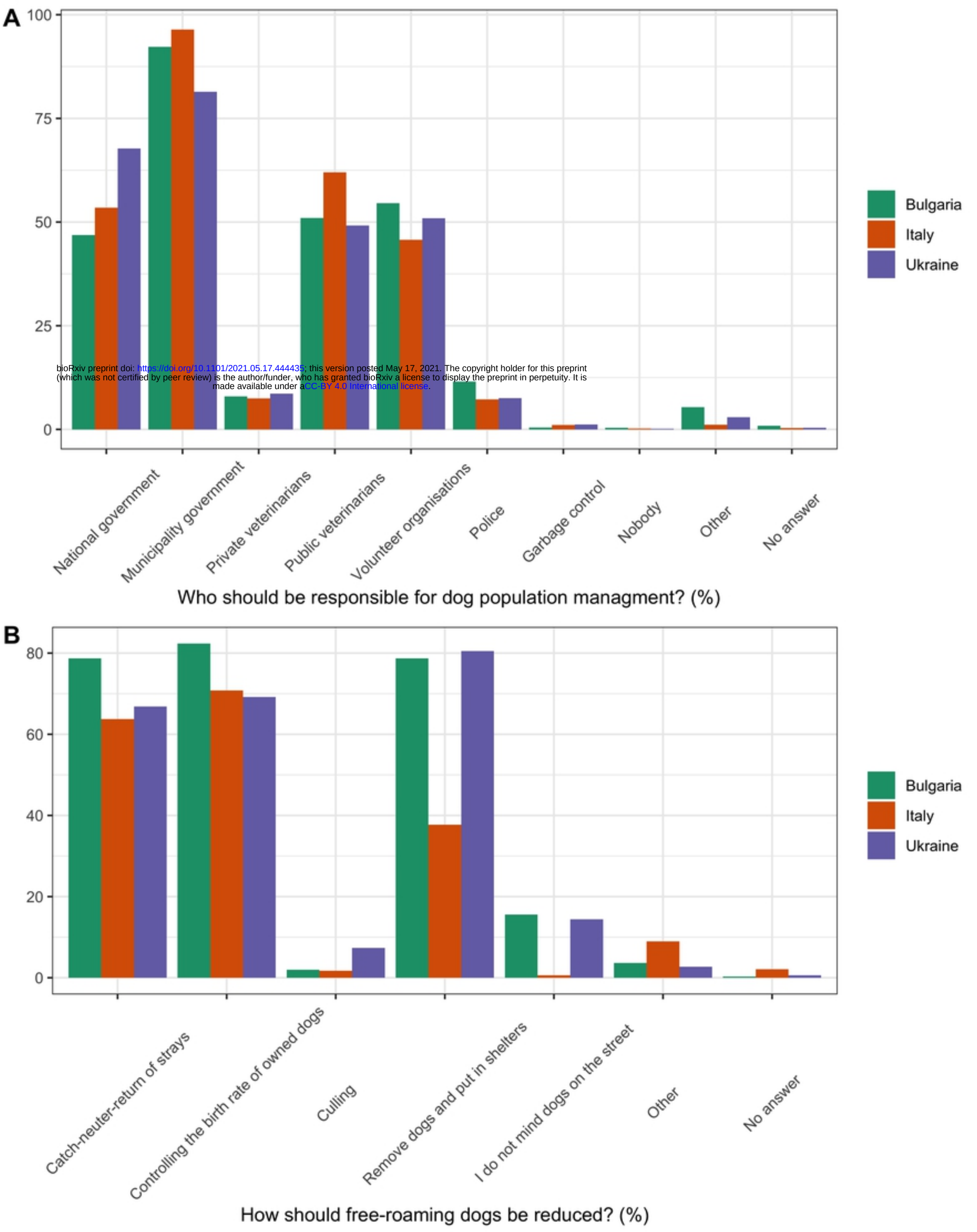


Figure 3