University of Kent

Kent Academic Repository

Cook, David C., Siettou, Christina and Fraser, Rob W. (2026) *Social welfare implications of policy reform for dog shelters in the United Kingdom*. Discover Animals, 3 (99). ISSN 3004-894X.

Downloaded from
https://kar.kent.ac.uk/116900/ The University of Kent's Academic Repository KAR

The version of record is available from
https://doi.org/10.1007/s44338-026-00258-z

This document version
Publisher pdf

DOI for this version

Licence for this version
CC BY-NC-ND (Attribution-NonCommercial-NoDerivatives)

Additional information

Versions of research works

Versions of Record
If this version is the version of record, it is the same as the published version available on the publisher's web site. Cite as the published version.

Author Accepted Manuscripts
If this document is identified as the Author Accepted Manuscript it is the version after peer review but before type setting, copy editing or publisher branding. Cite as Surname, Initial. (Year) 'Title of article'. To be published in ***Title of Journal*** , Volume and issue numbers [peer-reviewed accepted version]. Available at: DOI or URL (Accessed: date).

Enquiries
If you have questions about this document contact ResearchSupport@kent.ac.uk. Please include the URL of the record in KAR. If you believe that your, or a third party's rights have been compromised through this document please see our Take Down policy (available from https://www.kent.ac.uk/guides/kar-the-kent-academic-repository#policies).

Discover Animals

RESEARCH Open Access

Social welfare implications of policy reform for dog shelters in the United Kingdom

David C. Cook[1,2*], Christina Siettou[3] and Rob W. Fraser[1,4]

*Correspondence:
David C. Cook
david.c.cook@uwa.edu.au
[1]School of Agriculture and Environment, The University of Western Australia, 35 Stirling Highway, Crawley, WA 6009, Australia
[2]Harry Butler Institute, Murdoch University, Murdoch, WA 6150, Australia
[3]UCL Arena Centre, Higher Education Development & Support Institute, University College London, London WC1N 1LE, UK
[4]Department of Economics, The University of Kent, Canterbury CT2 7NZ, UK

Abstract
Statistics suggest that the policies currently in place to manage free-roaming dog numbers in the United Kingdom have met with limited success, and more innovative alternatives should be considered. This paper explores potential policy reform options that could reduce welfare losses associated with free-roaming dog management with the aid of a dynamic systems model that describes subpopulations of owned dogs, shelter dogs, and dogs held by breeders. Using this model, we simulate the population effects over time of a range of hypothetical governmental policies, including taxes, subsidies and a representation of a new Greek policy which features a national dog DNA database. We then evaluate the impact of policy alternatives on social welfare by comparing each to a base case reflecting the current situation. Our results suggest that implementation of the new Greek policy delivers a clear social welfare benefit compared with the other policies, but our results were sensitive to the social welfare implications of euthanising shelter animals and the stress animals undergo while in shelter facilities.

Keywords Adoption and rehoming, euthanasia, Dog shelter intake, DNA database, Dynamic systems model

1 Introduction

Free-roaming dog population management is a global challenge with each country developing its own unique policy framework to address this complex animal welfare issue, where sub-optimal management can result in increased animal euthanasia and subsequent social welfare losses [1]. Social welfare refers to the combined aggregate utility or well-being of all individuals in society, and it can be negatively affected when free-roaming dog populations are mismanaged resulting in wild dog attacks on humans and their pets (causing medical and veterinary costs), dog shelter overcrowding (causing mental health costs for shelter staff), and increased dog euthanasia (causing opportunity costs and moral distress for veterinarians and nursing staff). European countries are now home to over 87.5 million pet dogs, while the number of free-roaming dogs, including wild or free-ranging dogs and dogs in shelter and rescue facilities, is estimated to be at least as high [2]. In the United Kingdom (UK), where approximately one third of all households own at least one dog [3, 4], free-roaming dog overpopulation manifests as

© The Author(s) 2026. **Open Access** This article is licensed under a Creative Commons Attribution-NonCommercial-NoDerivatives 4.0 International License, which permits any non-commercial use, sharing, distribution and reproduction in any medium or format, as long as you give appropriate credit to the original author(s) and the source, provide a link to the Creative Commons licence, and indicate if you modified the licensed material. You do not have permission under this licence to share adapted material derived from this article or parts of it. The images or other third party material in this article are included in the article's Creative Commons licence, unless indicated otherwise in a credit line to the material. If material is not included in the article's Creative Commons licence and your intended use is not permitted by statutory regulation or exceeds the permitted use, you will need to obtain permission directly from the copyright holder. To view a copy of this licence, visit http://creativecommons.org/licenses/by-nc-nd/4.0/.

overcrowding in animal shelters. The reasons influencing pet rejection are complex, and can include human factors (e.g., socioeconomic status, health, education, housing insecurity, cost-of-living pressures) and animal factors (e.g., behavioural issues, aggression, disease) [5–9]. The most recent data in the UK indicate the number of dogs entering shelter facilities increased by almost 32% between 2022 and 2024 [10]. Only 39% of these animals were reclaimed (compared to 54% in 2022), and 8% were euthanised (compared to 2% in 2022) [10]. These statistics suggest that the policies currently in place to manage free-roaming dogs in the UK need to be improved, and more innovative alternatives should be considered.

Over the past three decades, the UK has adopted a "light-touch" approach to free-roaming dog policy. Under the *Environmental Protection Act 1990*, animal wardens employed by local government authorities are responsible for collecting and caring for free-roaming dogs for a statutory seven-day period. If within this time dogs are not reclaimed by their owners, they are either transferred to shelter facilities run by animal welfare organisations or, as a last resort, euthanised [11]. Complementary regulations to promote responsible dog ownership are in place, including the *Control Dogs Order 1992*, which requires dogs to be fitted with a collar and tag with their owner's address and phone number displayed when in public spaces. By 2016, compulsory dog microchipping was also enforced under separate legislation for Scotland, Wales, and Northern Ireland, but this has been problematic due to owners supplying incorrect contact details for their pets' microchips or failing to update details when they move or transfer animals to new owners [10, 12, 13].

Other European nations have adopted more comprehensive free-roaming dog management policies. Germany, for example, has in place an intricate set of laws developed to promote and sustain responsible dog ownership, including municipal and state laws requiring compulsory dog registration and microchipping, a payable annual dog licensing fee known as the 'pet tax' (waived for one year for dogs adopted from shelters), and liability insurance [14–16]. As in the UK, local authorities are responsible for collecting and, together with animal welfare organisations, caring for free-roaming dogs [17]. Although there is no nationally prescribed statutory holding period, standard administrative practices across local authorities allow for a maximum holding period of four weeks before dogs are considered ownerless [18], whilst under the German Civil Code, to protect owner's property rights, dogs are declared legally ownerless after a six-month period [19]. This means that if an animal's original owner presents within six months, they can legally reclaim the dog even if it has been adopted. Under Germany's Animal Welfare Act, dog abandonment is illegal, punishable with financial penalties and potential imprisonment, dog breeding is heavily regulated, and dog euthanasia is prohibited except in instances of medical necessity [17].

Greece has developed a comprehensive set of laws to manage one of the highest per capita free-roaming dog populations in the world [11]. In addition to compulsory dog microchipping, compulsory registration, prohibition of euthanasia, and strict dog breeding laws, Greece has recently legislated compulsory dog sterilisation with an opt-out route for those owners who do not wish to sterilise their dogs. This involves submitting DNA samples from unaltered dogs to a national DNA database, meaning that any animal that is not sterilised will be recorded, and their offspring will be traceable, holding owners accountable for contributing to the future free-roaming dog population [11].

Fines and penalties linked to non-compliance are varied, ranging from administrative fines targeted at owners and veterinary practitioners to more severe criminal penalties including imprisonment. Authorities responsible for the enforcement of these laws vary according to the nature of violations and jurisdiction, including but not limited to municipal and national police forces, customs authorities, coast guard, forestry service and hunting organisations [11].

The objective of the current paper is to explore potential UK policy reform options that could reduce social welfare losses associated with shelter dog management with the aid of a dynamic population model. We assume the traditional view of social welfare depending solely on human well-being is extended to include both intrinsic (or non-use) and instrumental (or use) values of animals (despite it being difficult to evaluate the welfare of animals since behavioural responses and needs are species-dependent) [20, 21]. In this sense, social welfare is affected directly in terms of the well-being or utility of individual animals (e.g., reducing shelter dog euthanasia rates may lower mental health related costs for shelter staff and decrease staff turnover costs), as well as indirectly through human utility affected by the perceived well-being of animals (e.g., emotional satisfaction of communities affected by reduced dog euthanasia). Assuming policymakers and social welfare institutions share a similar view of social welfare, we explore what sort of interventions should be applied to the problem of free-roaming dogs in UK society – that is, dogs that exceed the number of available human carers able to house and nurture them.

Dog population dynamic models are important tools for planning, implementing, and evaluating dog population management strategies, allowing interactive systems to be explained and the impact of policies on model behaviour to be evaluated [22]. They have been extensively used to simulate how different approaches to population management are likely to affect the number of dogs in a country or region over time [22–31]. However, few studies have included interactions between different dog subpopulations (e.g., owned dogs, shelter dogs, free-roaming dogs, dogs held by breeders), and the impacts of management policies on social welfare have not been considered. While some studies have included management cost information [22, 23, 28, 29], this has not extended to the societal costs associated with animal stress in shelter facilities or euthanasia.

In the following section of the paper, we develop a dynamic systems model which describes the UK dog population with subpopulations of owned dogs, shelter dogs and dogs held by breeders. This model enables us to simulate the population effects over time of a range of hypothetical UK governmental policies, and to evaluate their impacts on animal welfare and associated social outcomes. In Section 3 we present the results from using our model to simulate the effects of five hypothetical government policies that could potentially influence subpopulations and therefore the extent of the free-roaming dog population problem. These include increasing shelter capacity, increasing the euthanasia rate, imposing a breeder tax, offering a shelter adoption subsidy, and introducing a DNA-based policy akin to the new Greek policy. Policy impacts are compared to a base case, or status quo policy, reflecting the current situation. Section 4 of the paper provides a discussion of the key results of the simulations and a sensitivity analysis, and considers the robustness of our overall conclusion to the potential problem of non-compliance in the context of the representation of the new Greek policy, and Section 5 draws a brief conclusion and suggests avenues for future research.

2 Methods

2.1 Dynamic systems model

A dynamic systems model based on Smith et al. [22] was constructed to describe the UK dog population, however the subpopulations were modified to include only owned dogs, shelter dogs, and dogs held by breeders to fit the situation in the UK where free-roaming dogs are not widespread. Owned dogs were deemed to be those with a specific person with custody or responsibility for them identifiable through microchipping and registration on a database recognised by the UK government. Shelter dogs were defined as animals temporarily residing in a shelter or rescue facility, arriving as free-roaming, relinquished or abandoned animals. Dogs held by breeders were defined as animals in the custody of registered commercial dog breeders. Dogs could move between each of the subpopulations, with the total number of dogs in each varying accordingly over time. The subpopulations were simulated over a period of ten years using ordinary differential equations solved numerically in R [32] with the deSolve package [33].

The change in each subpopulation was described as follows:

$$\frac{dB}{dt} = r_b B\left(1 - \frac{B}{K_b}\right) - a_b - \sigma B \tag{1}$$

$$\frac{dS}{dt} = (\gamma O + \sigma B)\left(1 - \frac{S}{K_s}\right) - a_s - \mu S - \alpha S \tag{2}$$

$$\frac{dO}{dt} = r_o O\left(1 - \frac{S}{K_o}\right) + a_b + a_s - \gamma O \tag{3}$$

where:

B is the initial number of dogs held by breeders.

r_b is the natural change in the number of dogs held by breeders including births and deaths.

K_b is the maximum number of dogs held by breeders.

a_b is the number of dogs purchased from breeders, moving to the owned dog population (see Eq. 4, below).

σ is the relinquishment rate of dogs held by breeders to the shelter population.

S is the initial population of dogs in shelters and adoption centres.

γ is the owned dog relinquishment rate.

K_s is the carrying capacity of UK dog shelters.

a_s is the number of shelter dogs adopted, moving to the owned dog population (see Eq. 5, below).

μ is the natural fatality rate of the shelter population.

α is the euthanasia rate of the shelter population.

O is the initial owned dog population.

r_o is the natural change in the owned dog population including births and deaths.

K_o is the carrying capacity or maximum number of owned dogs.

Equation 1 states that the number of dogs held by breeders increases due to natural population growth ($r_b B$) and decreases through purchases (a_b) and relinquishment to shelters (σB). Equation 2 states that the shelter dog population increases due to owned dog relinquishments to shelters and relinquishments of dogs held by breeders to shelters ($\gamma O + \sigma B$), and decreases because of adoption from shelters (a_s), natural fatalities

while dogs are housed within shelter facilities (μS) and euthanasia (αS). Equation 3 states that the owned dog population increases through natural population growth ($r_o O$), purchases from breeders (a_b) and shelter dog adoptions (a_s), and decreases through relinquishments to shelters (γO).

The number of dogs purchased from breeders (a_b) and adopted from shelters (a_s) are influenced by price, which in turn could be influenced in our model by government taxes and subsidy payments. The demand for adoption was described as follows:

$$a_b = \delta B \left[1 + \left(\epsilon \frac{(p_b + T) - p_b}{p_b}\right)\right] \tag{4}$$

$$a_s = \beta S \left[1 + \left(\epsilon \frac{(p_s - G) - p_s}{p_s}\right)\right] \tag{5}$$

where:

δ is the purchase rate of dogs held by breeders.

p_b is the initial purchase price of dogs held by breeders.

T is a government tax on dogs purchased from a breeder.

ϵ is the elasticity of purchase/adoption demand with respect to price (assumed constant over dogs held by breeders and shelter dogs).

β is the adoption rate of shelter dogs.

p_s is the initial shelter dog price (i.e., adoption fees).

G is a government subsidy paid to shelter dog adopters.

The price elasticity of demand, ϵ, is the ratio of the percentage change in quantity of pet dogs demanded by consumers to the percentage change in their price, where $\epsilon < 0$ indicates an inverse relationship between price and quantity demanded. Equation 4 states that the after-tax demand for dogs held by breeders is equal to the pre-tax demand for dogs held by breeders (B) plus the change in demand induced by a government tax ($\epsilon \frac{(p_b + T) - p_b}{p_b}$) multiplied by the adoption rate of dogs held by breeders (δ). Equation 5 states that the post-subsidy demand for shelter dogs is equal to the pre-subsidy demand (S) plus the change in demand induced by a government subsidy ($\epsilon \frac{(p_b - S) - p_b}{p_b}$) multiplied by the shelter dog adoption rate (δ).

Social welfare is captured in the model in two ways. Firstly, direct social welfare losses are approximated using a constant marginal social welfare cost per shelter dog euthanised (ω^d). Secondly, indirect social welfare losses capture losses associated with the stresses animals endure when placed in a crowded shelter environment. This is specified as a fixed proportion (ω^i) of the maximum carrying capacity of shelters. Hence, the change in social welfare is:

$$e^{-\eta t} \frac{dW}{dt} = e^{-\eta t} \left[\omega^d \alpha S + \omega^i \frac{S^2}{K_s}\right] \tag{6}$$

where:

W is the initial social welfare loss associated with surplus dogs.

η is the discount rate.

t is the year.

ω^d is the marginal social welfare loss per shelter dog euthanised.

ω^i is the marginal social welfare loss per shelter dog associated with overcrowding.

Equation 6 states that the social welfare loss associated with surplus dogs in the UK increases at a constant rate with the number of shelter animals euthanised ($\omega^d \alpha S$) and at an increasing rate as the shelter population approaches carrying capacity ($\omega^i \frac{S^2}{K_s}$). As social welfare accrues over time, it is subject to discounting, which has an erosive effect on monetary values that increases with time via a continuous discounting factor ($e^{-\eta t}$).

2.2 Policy simulations

The model was used to simulate the effects of five hypothetical government policies that could potentially influence the dog subpopulations. These were compared to a base case, or status quo policy reflecting the current situation. The policies examined were:

2.2.1 Increased shelter capacity

The effects of this policy were simulated by increasing the parameter K_s. We did not account for time lags that might be involved as new facilities are purchased or constructed, nor did we factor in logistical issues. These could be considerable given that most shelters in the UK are privately owned and operated by charities and non-for-profit organisations with their own decision-making and administrative processes, but for the purposes of the analysis we simply assumed a one-off increase in shelter capacity was possible. We included this policy to illustrate the perverse social welfare outcomes such a strategy might produce.

2.2.2 Increase euthanasia

This policy simulation involved increasing the α parameter by approximately 50% (to 15%). We did not consider logistical, ethical or moral issues concerning this policy, but included it as a useful comparison to the other policies. While this strategy would have indirect social welfare benefits by reducing shelter congestion, direct social welfare losses will increase.

2.2.3 Breeder tax

This policy simulation involved setting a hypothetical value for the parameter T, which is a fixed rate tax added to the price of dogs held by breeders, p_b. Assuming the price elasticity of demand (ϵ) is negative, indicating a negative relationship between price and demand, the tax causes consumer demand for dogs held by breeders to fall.

2.2.4 Shelter adoption subsidy

This policy simulation involved setting a hypothetical value for the parameter G, which is a fixed rate subsidy deducted from the price of shelter dogs, p_s. The effect of the subsidy in lowering the price of shelter dogs will increase demand for these animals, thus lowering the number of animals in shelters. This policy is similar to the German pet tax waiver for dogs adopted from shelters.

2.2.5 DNA database

This policy is based on the Greek model whereby dog DNA is stored on a central database and registered owners are liable for severe penalties for shelter animals with shared

DNA [11]. The policy's effects were represented by increasing the price of dogs held by breeders (p_b), lowering the natural change in the owned dog population (r_o) and lowering the owned dog relinquishment rate (γ). The price of dogs held by breeders increases as breeders seek to minimise future liabilities by sterilising dogs they sell, passing costs on to consumers. The shelter dog adoption price remains constant as these dogs are routinely sterilised before being offered for adoption [34]. The natural change in the owned dog population falls as owners also seek to minimise the risk of future penalties by sterilising their pets, reducing the number of owned dog litters. The owned dog relinquishment rate also falls due to sterilisation [35].

2.3 Parameters

Model parameters and their assumed values are shown in Table 1. The study area included England, Scotland, Wales and Northern Ireland, and model simulations were carried out over ten yearly timesteps. Where possible, relevant parameter estimates from the literature were used, but in several instances a lack of information necessitated the use of international data or plausible estimates. We use hypothetical values for direct and indirect social welfare loss associated with shelter dogs (£50 and £5, respectively), the breeder tax (£200) and shelter adoption subsidy (£100). The sensitivity of results to changes in all parameter values was tested to gauge the implications of misspecifications (Fig. 2).

For the status quo scenario, the initial number of dogs held by breeders was assumed to be 230,000, which includes approximately 25,000 stud and brood dogs, 150,000 puppies and 55,000 imported dogs [36]. Assuming each breeding bitch produces an average of 6 puppies per year that breeders can sell [36], this implies a natural increase in the population of dogs held by breeders of 600% per year. We assumed the maximum number of dogs held by breeders was around 250,000, but this is highly uncertain. We assumed 80% of dogs held by breeders were sold for an average price of £930 [44]. In the DNA database scenario, the cost of collecting a DNA sample (£130 [11]) was assumed to be passed on to consumers, raising the average price of dogs purchased from breeders to £1,060. The elasticity of demand for dogs held by breeders was assumed to be -0.5, which is the mid-point of the range suggested in Lord, Olynk Widmar [45]. The relinquishment rate of dogs held by breeders to shelters was assumed to be 1.6% [37].

The initial owned dog population was assumed to be 11.6 million, corresponding to the midpoint and maximum of the range reported in Murray, Gruffydd-Jones [42]. The maximum population was arbitrarily assumed to be 13.0 million. In the absence of data showing the natural change in the owned dog population in the UK, we assumed an equivalent natural change to the Brazilian owned dog population (4 per cent per year) [43], and a relinquishment rate the same as observed in the U.S.A. (0.8%) [39].

The initial shelter dog population was assumed to be 250,000, which was extrapolated from Clark, Gruffydd-Jones [38] assuming an average annual increase in the number of dogs presenting to shelters of 5% per year. This is uncertain, however, as the change from year to year has varied considerably (2–15%) in the period following the covid-19 response [47]. We arbitrarily assumed the maximum shelter capacity was 260,000. The shelter dog adoption rate we assumed was 2.5%, which was the mid-point of the range reported in Smith, Quinnell [22], and the average adoption fee paid to shelters was assumed to be £350 per dog. Due to a lack of specific information, we assumed that

Table 1 Parameter values used to simulate the effect of each policy on subpopulations

Parameter	Description	Value						Source (status quo)
		Status quo	Increase shelter capacity	Increase euthanasia	Breeder tax	Shelter subsidy	DNA database	
B	Initial number of dogs held by breeders (#)	230,000	230,000	230,000	230,000	230,000	230,000	Naturewatch Foundation [36]
r_b	Natural change in the number of dogs held by breeders (%)	600	600	600	600	600	300	Naturewatch Foundation [36]
K_b	Max number of dogs held by breeders (#)	250,000	250,000	250,000	250,000	250,000	250,000	Plausible estimate
σ	Relinquishment rate of dogs held by breeders (%)	1.6	1.6	1.6	1.6	1.6	1.6	Powell, Duffy [37]
S	Initial shelter dog population (#)	250,000	250,000	250,000	250,000	250,000	250,000	Clark, Gruffydd-Jones [38]
γ	Owned dog relinquishment rate (%)	0.8	0.8	0.8	0.8	0.8	0.4	New, Kelch [39]
K_s	Shelter carrying capacity (#)	260,000	300,000	260,000	260,000	260,000	260,000	Plausible estimate
μ	Natural fatality rate of shelter dogs (%)	2.9	2.9	2.9	2.9	2.9	2.9	Vecerek, Vitulova [40]
α	Euthanasia rate for shelter dogs (%)	10.4	10.4	15	10.4	10.4	10.4	Stavisky, Brennan [41]
O	Initial owned dog population (#)	11,600,000	11,600,000	11,600,000	11,600,000	11,600,000	11,600,000	Murray, Gruffydd-Jones [42]
r_o	Natural change in the owned dog population (%)	4	4	4	4	4	2	Baquero, Marconcin [43]
K_o	Max population of owned dogs (#)	13,000,000	12,500,000	12,500,000	12,500,000	12,500,000	12,500,000	Plausible estimate
δ	Purchase rate of dogs held by breeders (%)	80	80	80	80	80	80	Plausible estimate
p_b	Initial price of a dog purchased from a breeder (£)	930	930	930	930	930	1,260	Ross, Langford [44], Siettou, Theodoropoulou [11]
T	Government tax on dog purchases from breeders (£)	0	0	0	200	0	0	Hypothetical
ϵ	Price elasticity of dog adoption demand (unitless)	-0.5	-0.5	-0.5	-0.5	-0.5	-0.5	Lord, Olynk Widmar [45]
β	Shelter dog adoption rate (%)	30	30	30	30	30	30	Smith, Quinnell [22]
p_s	Initial shelter dog price (£)	350	350	350	350	350	350	Plausible estimate
G	Government shelter dog adoption subsidy (£)	0	0	0	0	100	0	Hypothetical
η	Discount rate (%)	7	7	7	7	7	7	Commonwealth of Australia [46]
ω^d	Direct welfare loss per dog euthanised (£)	50	50	50	50	50	50	Plausible estimate
ω^i	Indirect welfare loss per shelter dog (£)	5	5	5	5	5	5	Plausible estimate

the price elasticity of demand for shelter dogs was the same as for dogs held by breeders (-0.5) [45]. We used a euthanasia rate of 10.4%, taken from Stavisky, Brennan [41].

3 Results

At the beginning of the simulation, the number of owned dogs was 230,000, the number of shelter dogs was 250,000 and the number of owned dogs was 11,600,000. After 10 years, the status quo scenario resulted in 14,000 less dogs held by breeders, 123,680 less shelter dogs and 1,394,900 more owned dogs (Table 2). In comparison, the increased shelter capacity scenario led to 8,810 more shelter dogs and 20,190 more owned dogs after 10 years than in the status quo scenario. The increased euthanasia scenario produced 6,580 less shelter dogs and 15,990 less owned dogs than the status quo. The breeder tax scenario led to there being 3,580 more dogs held by breeders and 129,940 less owned dogs than in the status quo scenario whilst the number of shelter dogs was largely unaffected. The shelter adoption subsidy led to 11,360 less shelter dogs and 58,010 more owned dogs than in the status quo scenario. Finally, the DNA database scenario resulted in 34,000 less dogs held by breeders, 41,500 less shelter dogs and 26,210 more owned dogs compared to the status quo scenario after 10 years.

All the policies represented in the analysis produced a social welfare loss as all involved excess dogs, euthanasia and exposure to crowded shelters. In the status quo scenario, cumulative social welfare losses over the 10 years simulated in the model were £40.4 million. Two scenarios had worse social welfare consequences after 10 years compared to the status quo scenario. The poorest result was achieved under the increase euthanasia scenario, which produced a social welfare loss £8.6 million more than the status quo scenario. The second poorest result occurred in the increase shelter capacity scenario, which produced a social welfare loss £0.6 million more than in the status quo scenario. Two policies produced a substantial positive effect on social welfare. The best result was produced in the DNA database scenario, which improved social welfare by £7.3 million when compared to the status quo. The next best result was achieved in the shelter adoption subsidy scenario in which social welfare loss was £3.9 million lower than in the status quo scenario. The breeder tax had a small positive effect on social welfare, but the overall difference compared to the status quo was negligible.

Annualised social welfare losses recorded in each of the scenarios are shown in Fig. 1, where panel A shows the present value of social welfare loss per year for the status quo case and each of the policy scenarios and panel B plots the change in social welfare achieved by each policy with respect to the status quo scenario. Social welfare losses in panel A increase at a decreasing rate over time due to the effects of discounting. Annual social welfare loss was around £5.3 million by year 10 of the simulation in the status quo scenario (panel A). The best performing policy in comparison to this was the DNA database. By year 10 of the simulation, annual social welfare loss using this policy amounted to £3.9 million (panel A), which was £1.4 million per year lower than in the status quo scenario (panel B). The second-best performing policy was the shelter subsidy with an annual social welfare loss of £4.7 million in year 10 (panel A), which was £0.6 million per year less than the status quo (panel B). The worst performing policy was increased euthanasia. By year 10, the social welfare loss resulting from this policy was £6.4 million per year (panel A), approximately £1.1 million more than in the status quo scenario (panel B). The next worst performing policy was increased shelter capacity

Table 2 Subpopulations and social welfare under each policy scenario

Policy	Year	No. dogs held by breeders	No. shelter dogs	No. owned dogs	Cumulative social welfare loss (£)	Δ social welfare (£)
Status quo	0	230,000	250,000	11,600,000	0	-
	1	216,070	178,290	11,790,940	1,694,200	-
	2	216,000	146,640	11,957,910	4,362,740	-
	3	216,000	133,000	12,111,780	7,690,650	-
	4	216,000	127,380	12,256,590	11,512,830	-
	5	216,000	125,300	12,394,180	15,725,990	-
	6	216,000	124,770	12,525,470	20,255,130	-
	7	216,000	124,900	12,650,930	25,039,980	-
	8	216,000	125,300	12,770,850	30,029,250	-
	9	216,000	125,800	12,885,450	35,178,060	-
	10	216,000	126,320	12,994,900	40,446,660	-
Increase shelter capacity	0	230,000	250,000	11,600,000	0	0
	1	216,070	185,450	11,792,210	1,639,990	54,210
	2	216,000	155,600	11,961,570	4,276,070	86,670
	3	216,000	142,110	12,117,960	7,605,130	85,520
	4	216,000	136,290	12,265,160	11,459,830	53,000
	5	216,000	134,040	12,404,980	15,732,350	-6,360
	6	216,000	133,420	12,538,340	20,343,500	-88,370
	7	216,000	133,540	12,665,760	25,229,550	-189,570
	8	216,000	133,970	12,787,550	30,336,360	-307,110
	9	216,000	134,530	12,903,930	35,616,640	-438,580
	10	216,000	135,130	13,015,090	41,028,530	-581,870
Increase euthanasia	0	230,000	250,000	11,600,000	0	0
	1	216,070	171,960	11,789,790	2,063,700	-369,500
	2	216,000	139,070	11,954,700	5,299,640	-936,900
	3	216,000	125,540	12,106,490	9,328,280	-1,637,630
	4	216,000	120,250	12,249,380	13,953,920	-2,441,090
	5	216,000	118,430	12,385,230	19,054,390	-3,328,400
	6	216,000	118,050	12,514,920	24,540,300	-4,285,170
	7	216,000	118,260	12,638,890	30,339,100	-5,299,120
	8	216,000	118,700	12,757,420	36,388,620	-6,359,370
	9	216,000	119,210	12,870,700	42,634,210	-7,456,150
	10	216,000	119,740	12,978,910	49,027,320	-8,580,660
Breeder tax	0	230,000	250,000	11,600,000	0	0
	1	219,640	178,280	11,774,550	1,694,190	10
	2	219,580	146,600	11,926,470	4,362,530	210
	3	219,580	132,900	12,065,920	7,689,700	950
	4	219,580	127,200	12,196,930	11,510,180	2,650
	5	219,580	125,050	12,321,340	15,720,360	5,630
	6	219,580	124,450	12,440,040	20,244,980	10,150
	7	219,580	124,520	12,553,510	25,023,590	16,390
	8	219,580	124,860	12,662,020	30,004,820	24,430
	9	219,580	125,310	12,765,784	35,143,760	34,300
	10	219,580	125,780	12,864,960	40,400,660	46,000

Table 2 (continued)

Policy	Year	No. dogs held by breeders	No. shelter dogs	No. owned dogs	Cumulative social welfare loss (£)	Δ social welfare (£)
Shelter adoption subsidy	0	230,000	250,000	11,600,000	0	0
	1	216,070	166,730	11,805,800	1,614,980	79,220
	2	216,000	133,040	11,980,720	4,092,060	270,680
	3	216,000	119,770	12,140,210	7,135,220	555,430
	4	216,000	114,840	12,289,840	10,599,990	912,840
	5	216,000	113,780	12,431,960	14,398,930	1,327,060
	6	216,000	113,060	12,567,600	18,468,810	1,786,320
	7	216,000	113,370	12,697,260	22,758,400	2,281,580
	8	216,000	113,860	12,821,230	27,223,690	2,805,560
	9	216,000	114,410	12,939,720	31,825,900	3,352,160
	10	216,000	114,960	13,052,910	36,530,530	3,916,130
DNA database	0	230,000	250,000	11,600,000	0	0
	1	186,380	170,950	11,798,050	1,661,470	32,730
	2	182,480	128,820	11,962,270	4,185,770	176,970
	3	182,050	106,560	12,112,640	7,206,840	483,810
	4	182,010	94,970	12,254,840	10,539,130	973,700
	5	182,000	89,070	12,391,480	14,078,830	1,647,160
	6	182,000	86,200	12,523,870	17,761,770	2,493,360
	7	182,000	84,940	12,652,720	21,544,250	3,495,730
	8	182,000	84,530	12,778,430	25,393,850	4,635,400
	9	182,000	84,560	12,901,180	29,284,870	5,893,190
	10	182,000	84,820	13,021,110	33,196,050	7,250,610

which resulted in a social welfare loss of £5.4 million (panel A), approximately £0.1 million more than in the status quo scenario (panel B). The breeder tax resulted in a similar social welfare loss to the status quo.

Given the uncertainty in many model parameters, a sensitivity analysis was conducted to determine which assumptions had the greatest influence on the results. A simple approach was used in which the model was recalculated using parameter values ± 50% while all other parameters were held constant. This assumes each parameter is independent from the others. The effect the minimum and maximum values for each parameter had on the present value of combined costs is reported in Fig. 2. Here, the influence of each parameter is indicated by the length of corresponding bars, and parameters are ranked from top to bottom in order of the change they produced in the present value of cumulative social welfare loss after 10 years.

The model parameters that had the biggest influence on our results were the direct welfare loss associated with euthanasia and the indirect welfare loss associated with overcrowding and animal stress in shelters. Both were positively related to social welfare loss, and increasing their assumed values by ± 50% produced a change in social welfare loss of approximately ± 25%. Results were also sensitive to the assumed shelter capacity at the beginning of the simulation. This was also positively related to social welfare loss, but decreasing shelter capacity from our assumed value of 260,000 to 130,000 produced a larger change in social welfare loss (-33%) than when its value was increased to 390,000 (+ 19%). The initial shelter population was also a sensitive parameter with social welfare loss varying ± 19% when the parameter values were changed ± 50%. The euthanasia rate also had a strong influence on social welfare loss. Lowering this parameter from its assumed value of 10.4% to 5.2% (-50%) lowered resultant social welfare loss by 20%,

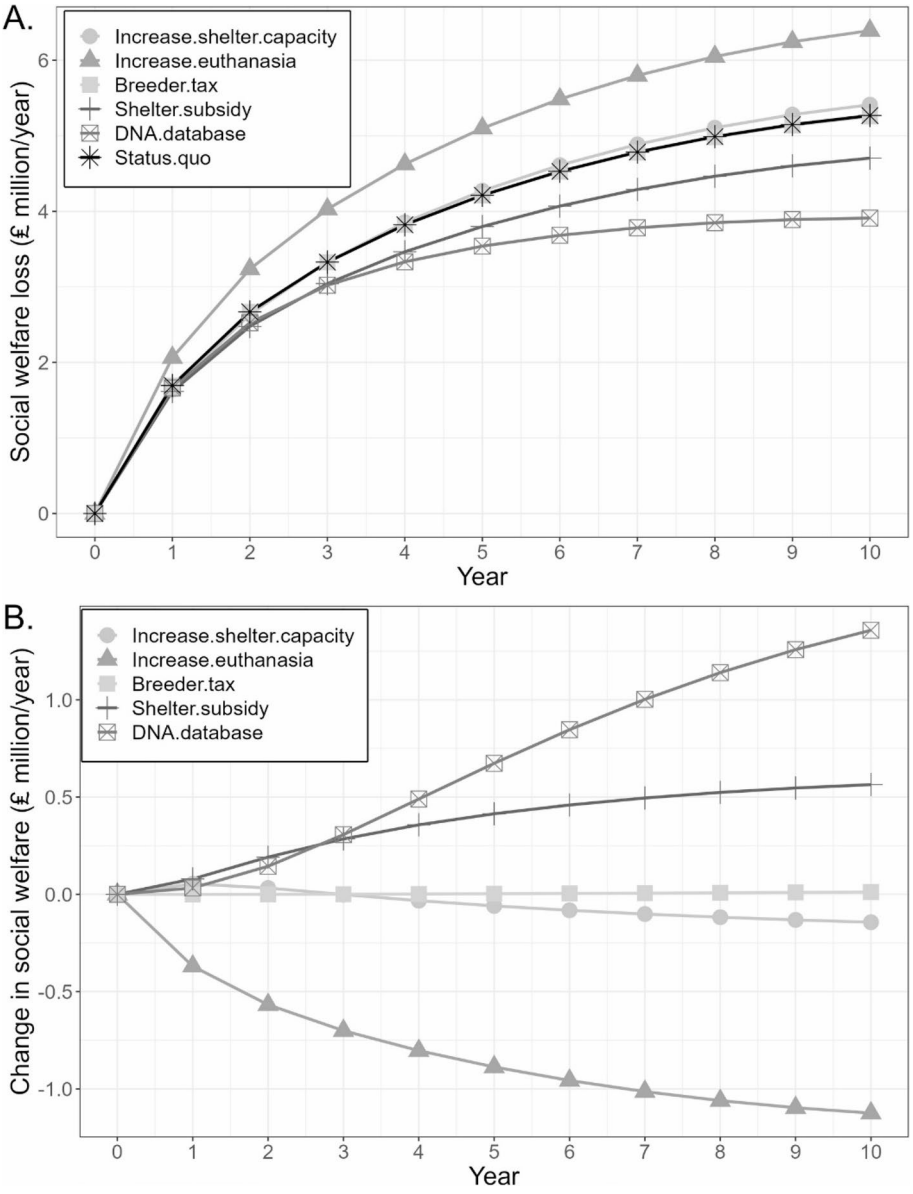


Fig. 1 Social welfare loss over time in each policy scenario. Panel (**A**) shows the present value of social welfare loss per year for the status quo case and each of the policy scenarios. Panel (**B**) plots the vertical distance between each scenario and the status quo in panel (**A**), which represents the annual benefit or loss associated with each policy. The best performing policy was the DNA database which produced a social welfare loss of £3.9 million per year by year 10 of the simulation (panel **A**), which was £1.4 million per year lower than in the status quo scenario (panel **B**). The worst performing policy was increased euthanasia which resulted in a social welfare loss of £6.4 million per year by year 10 (panel **A**), which was £1.1 million per year more than in the status quo scenario (panel **B**)

while increasing its value to 15.6% (+ 50%) increased social welfare loss by 18%. Other parameters that exerted minor influences on the results of the model were the owned dog relinquishment rate and the initial owned dog population.

4 Discussion

Since we have focused on the social welfare implications of free-roaming dog management policies in the UK, we have not accounted for compliance in our model. This would largely depend on government investment in monitoring and enforcement of the

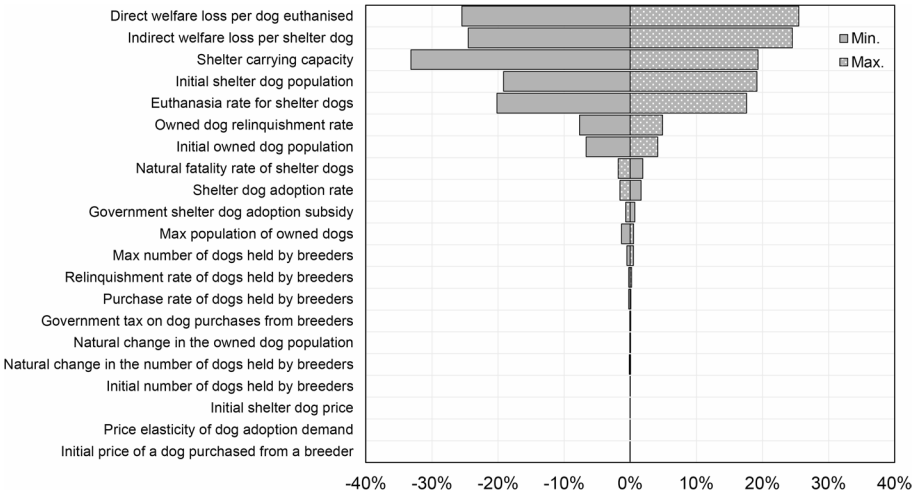


Fig. 2 Sensitivity of social welfare loss to changes in model parameters. Parameters are ranked from top to bottom according to the sensitivity of the present value of cumulative social welfare loss over 10 years to changes in each, with the length of the bars corresponding to each parameter reflecting the change in results produced. The value of each parameter was changed by ± 50% while all other parameters remained unchanged, and the resultant social welfare loss estimate recorded. Results were most sensitive to changes in the direct welfare loss associated with euthanasia, indirect welfare loss associated with shelter stress, shelter carrying capacity, the initial shelter population and the euthanasia rate

policy chosen, the fees and charges imposed on compliant owners and breeders, and the severity of penalties applied to those found to be in breach of regulations. In the case of a policy based around a DNA database and increased sterilisation, dog owners would make a comparison between the potential gains from not complying (i.e., avoided fees and charges) and the expected penalty for non-compliance when choosing whether to comply with the policy. In the Greek policy, for instance, failure of owners to neuter/spay a dog or submit genetic samples to the National Laboratory for Storing and Analysing Companion Animal DNA can result in a €1,000 fine, and failure of dog breeders to report, microchip, or register breeding animals can result in a €3,000 fine [11]. However, these penalties must be weighted by the probability of being caught and prosecuted for being in violation of animal breeding or companion animal ownership laws.

Further research is needed to explore the likely levels of compliance amongst dog owners and breeders in response to different amounts of government oversight, particularly as this has proved a significant problem for existing policies. For example, while compulsory dog microchipping has contributed to a decrease in the overall number of shelter dogs handled in the UK [10, 48], the success of this policy has been severely undermined by inaccurate contact details stored on pet microchips [10, 12]. There are likely to be other significant challenges, including securing sufficient funding to ensure a strong DNA database and enforcement resources to avoid selective compliance and pushback from breeders and other social groups. Nonetheless, even if non-compliance reduces the effectiveness of our hypothetical DNA database policy by 50% (i.e., the natural change in the number of dogs held by breeders falls to 450% rather than 300%, the owned dog relinquishment rate falls to 0.6% rather than 0.4%, and the natural change in the owned dog population falls to 3% rather than 2%), this policy will still be the best performing policy. However, the change in social welfare compared to the status quo scenario will be £3.4 million rather than £3.9 million (Table 2).

Future research eliciting the value of our direct and indirect welfare loss parameters would also be beneficial. The sensitivity analysis showed these to be the two most influential parameters on our results, but the values we have used are plausible estimates rather than values taken from quantitative research. We currently have no way of verifying the values we have used, so the magnitude of social welfare changes from each of the policies we examined are merely indicative. However, provided that the direct welfare loss per dog euthanised is greater than the indirect welfare loss per shelter dog, which seems reasonable, the rank order of policies will not change, and a policy based on a DNA database and increased dog sterilisation will remain the social welfare maximising option. The extent of the welfare advantages this policy may or may not have over the other alternatives will vary according to what parameter values are used, although as we have shown, changing the direct and indirect welfare loss parameter values produces a less than proportional change in social welfare (Fig. 2). Future studies that investigate the magnitude of social welfare impacts would be of great importance as they would enable a benefit cost analysis of a policy proposal to be performed.

The stress on shelter, clinic or laboratory settings staff induced by animal euthanasia in is well documented [49–54]. It follows that any policy advocating an increase in shelter dog euthanasia should consider the resultant social welfare effects. We felt it was important to include one such option given recent history. In 2024, the government of Türkiye adopted amendments to legislation concerning the treatment of free-roaming animals that will likely lead to the large scale euthanasia of shelter dogs due to overpopulation [55]. This has led to public consternation [56]. Our scenario involved a minor increase in the euthanasia rate, but hypothetically, if a policy were to involve the euthanasia of all excess dogs, our model suggests the social welfare implications would be severe. Raising the euthanasia rate, α, from its base rate of 10.4% [41] to 100% lowered social welfare to -£135.6 million. This societal loss (-£95.1 million) was more than double the social welfare loss estimated in the status quo scenario.

Perhaps a counterintuitive finding from the current study is that raising the shelter capacity in the UK could have a negative effect on social welfare, rather than a positive one, because of the stress placed on animals in care. By including the indirect welfare loss per shelter dog parameter to capture the adverse health effects on dogs placed into the shelter system, our model links greater numbers of dogs in shelters with increased levels of stress, and therefore, more social welfare loss. Events that are novel, unpredictable, or out of a dog's control, such as entering a shelter facility, can trigger its "fight or flight" response [57–59]. This involves the release of the hormone cortisol, which in the short-term boosts energy levels to respond to the perceived threat, but prolonged cortisol elevation often impairs the immune system and causes anxiety and abnormal behaviours [60]. Current best practices to reduce stress in shelter dogs involve environmental enrichment, enhanced human interaction, increased exercise, novel feeding strategies, music, and group housing [61]. However, as the number of dogs increases, it becomes more difficult for individual animals to benefit from these activities.

5 Conclusion

In this paper, we have explored potential policy reform options that could reduce welfare losses associated with free-roaming dog management in the UK. With the aid of a dynamic population model, we described the UK dog population with subpopulations

of owned dogs, shelter dogs, and dogs held by breeders, and simulated the population effects over time of a range of hypothetical UK governmental policies, including taxes, subsidies and a representation of a new Greek policy which features a national dog DNA database and increased dog sterilisation, and evaluated their impact on social welfare. All the policies we examined involved excess dogs, euthanasia and exposure to crowded shelters. In the base scenario, representing policies currently in place, we estimated cumulative social welfare losses over the 10 years simulated in the model of £40.5 million. Only two of the policies we considered produced a positive effect on social welfare, with the best result produced by the scenario based on the Greek policy, which improved social welfare by £7.3 million when compared to the status quo. Sensitivity testing showed that the model parameters with the biggest influence on our results were the direct welfare loss associated with euthanasia and the indirect welfare loss associated with overcrowding and animal stress in shelters. However, further analysis showed that provided that the direct welfare loss per dog euthanised is greater than the indirect welfare loss per shelter dog, the rank order of policies will not change, and implementing a policy based on the new Greek policy remains the social welfare maximising option. While there is a need for further research to explore the likely levels of compliance amongst dog owners and breeders in response to different amounts of government oversight, we showed that even if the simulated effectiveness of this policy was reduced by 50% compared with the initial policy specification, the DNA datanase policy remains the clear social welfare maximising option. Consequently, the main conclusion of our research is that the UK government should consider implementing a new dog-overpopulation policy based on that already adopted in Greece given our simulation results show its relative policy superiority is robust with respect to both alternative modelling parameter values and to the degree of compliance of dog owners and breeders.

Authors' contributions
D.C.: conceptualization, methodology, data curation, formal analysis, investigation, writing - original draft, writing - review and editing, visualization.C.S.: conceptualization, validation, writing - review and editing.R.F.: conceptualization, methodology, writing - original draft, writing - review and editing.

Funding
The authors declare that the study was not funded.

Data availability
Data is available from the corresponding author upon reasonable request.

Declarations

Ethics approval and consent to participate
Not applicable.

Consent for publication
Not applicable.

Competing interests
David C. Cook has declared an affiliation with a Western Australian Government department (Department of Primary Industries and Regional Development). Rob W. Fraser and Christina Siettou have declared no competing interests.

Received: 9 April 2026 / Accepted: 21 September 2026
Published online: 29 September 2026

References

1. Kang JH, Han J. Optimizing the operation of animal shelters to minimize unnecessary euthanasia: A case study in the seoul capital area. Sustainability. 2019;11:6702.
2. Papavasili TH, Kontogeorgos A, Mavrommati A, Sossidou EN, Chatzitheodoridis F. Review of stray dog management: Dog days in the european countries. Bulgarian J Veterinary Med. 2024;27:322–42.

3. Anderson KL, Casey RA, Cooper B, Upjohn MM, Christley RM. National dog survey: Describing UK dog and ownership demographics. Animals. 2023;13:1072.
4. McMillan KM, Harrison XA, Wong DC, Upjohn MM, Christley RM, Casey RA. Estimation of the size, density, and demographic distribution of the UK pet dog population in 2019. Sci Rep. 2024;14:31746.
5. Miller DD, Staats SR, Partlo C, Rada K. Factors associated with the decision to surrender a pet to an animal shelter. J Am Vet Med Assoc. 1996;209:738–42.
6. Lezama-García K, Domínguez-Oliva A, Buenhombre J, Mora-Medina P, Daza-Cardona EA, Olmos-Hernández A, et al. Exploring the stray dog crisis: When the human-canine relationships breakdown. J Anim Behav Biometeorol. 2025;13:10–31893.
7. Lambert K, Coe J, Niel L, Dewey C, Sargeant JM. A systematic review and meta-analysis of the proportion of dogs surrendered for dog-related and owner-related reasons. Prev Vet Med. 2015;118:148–60.
8. Fatjó J, Bowen J, García E, Calvo P, Rueda S, Amblás S et al. Epidemiology of dog and cat abandonment in Spain (2008–2013). Animals, 2015: 426 – 41.
9. Sharkin BS, Ruff LA. Broken bonds: Understanding the experience of pet relinquishment. In: Blazina C, Boyraz G, Shen-Miller D, editors. The Psychology of the Human-Animal Bond: A Resource for Clinicians and Researchers. New York, NY: Springer New York; 2011: 275–87.
10. Dogs Trust. Stray dog survey report 2023-24. London: Dogs Trust Legacy; 2025.
11. Siettou C, Theodoropoulou E, Siettou AS. An overview of Greece's newly established progressive stray dog management laws. Pets. 2024;2:1.
12. Battersea Dogs and Cats Home. Compulsory microchipping – how effective has it been? London: Battersea Dogs and Cats Home; 2024.
13. Lancaster E, Rand J, Collecott S, Paterson M. Problems associated with the microchip data of stray dogs and cats entering RSPCA Queensland shelters. Animals, 2015: 332 – 48.
14. Animal Lawyer. Hundesteuer – German Tax on Dogs. Hannover: horak Attorneys at Law; 2021.
15. El-Saghir J. Dog Insurance in Germany. How-to-Germany.com; 2025.
16. Berlin Senate Department for Consumer Protection. Berlin Dog Law – Law on Keeping and Handling Dogs in Berlin (HundeG). Berlin: Senate Department for Consumer Protection; 2025.
17. Federal Ministry of Food and Agriculture. German Animal Welfare Act. Berlin: Federal Ministry of Food and Agriculture; 2010.
18. Ministry of Rural Affairs and Consumer Protection Baden-Württemberg. Statement on the handling of found animals, stray animals, animals in accommodation and surrendered animals. Stuttgart: Ministry of Rural Affairs and Consumer Protection Baden-Württemberg; 2017.
19. German Federal Ministry of Justice and Consumer Protection. Bürgerliches Gesetzbuch (BGB) – German Civil Code. Berlin: German Federal Ministry of Justice and Consumer Protection; 2024.
20. Budolfson M, Spears D. Quantifying animal well-being and overcoming the challenge of interspecies comparisons. The Routledge Handbook of Animal Ethics. London: Routledge; 2019: 92–101.
21. Espinosa R. Animals and social welfare. Soc Choice Welf. 2024;62:465–504.
22. Smith LM, Quinnell RJ, Goold C, Munteanu AM, Hartmann S, Collins LM. Assessing the impact of free-roaming dog population management through systems modelling. Sci Rep. 2022;12:11452–14.
23. Frank J. An interactive model of human and companion animal dynamics: the ecology and economics of dog overpopulation and the human costs of addressing the problem. Hum Ecol. 2004;32:107–30.
24. Di Nardo A, Candeloro L, Budke CM, Slater MR. Modeling the effect of sterilization rate on owned dog population size in central Italy. Prev Vet Med. 2007;82:308–13.
25. Amaku M, Dias RA, Ferreira F. Dynamics and control of stray dog populations. Math Popul Stud. 2010;17:69–78.
26. Carroll MJ, Singer A, Smith GC, Cowan DP, Massei G. The use of immunocontraception to improve rabies eradication in urban dog populations. Wildl Res. 2010;37:676–87.
27. 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;97:51–7.
28. Høgåsen HR, Er C, Di Nardo A, Dalla Villa P. Free-roaming dog populations: A cost-benefit model for different management options, applied to Abruzzo, Italy. Prev Vet Med. 2013;112:401–13.
29. Dias RA, Baquero OS, Guilloux AGA, Moretti CF, de Lucca T, Rodrigues RCA, et al. Dog and cat management through sterilization: Implications for population dynamics and veterinary public policies. Prev Vet Med. 2015;122:154–63.
30. Fitzpatrick MC, Shah HA, Pandey A, Bilinski AM, Kakkar M, Clark AD, et al. One Health approach to cost-effective rabies control in India. Proc Natl Acad Sci. 2016;113:14574–81.
31. Santos Baquero O, Akamine LA, Amaku M, Ferreira F. Defining priorities for dog population management through mathematical modeling. Prev Vet Med. 2016;123:121–7.
32. R Core Team. R: A language and environment for statistical computing. Vienna, Austria: R Foundation for Statistical Computing; 2023.
33. Karline S, Thomas P, Setzer RW. Solving differential equations in R: Package deSolve. J Stat Softw. 2010;33.
34. Siettou C. An economic analysis of the UK pet dog market and animal welfare: The case of the UK pet dog overpopulation problem. Canterbury: University of Kent; 2015.
35. Patronek GJ, Glickman LT, Beck AM, McCabe GP, Ecker C. Risk factors for relinquishment of dogs to an animal shelter. J Am Vet Med Assoc. 1996;209:572–81.
36. Naturewatch Foundation. Licensed dog breeding in the UK and Ireland 2025. Gloucestershire, U.K.: Naturewatch Foundation;: Cheltenham; 2025.
37. Powell L, Duffy DL, Kruger KA, Watson B, Serpell JA. Relinquishing owners underestimate their dog's behavioral problems: Deception or lack of knowledge? Front Veterinary Sci. 2021;8:734973.
38. Clark CC, Gruffydd-Jones T, Murray JK. Number of cats and dogs in UK welfare organisations. Vet Rec. 2012;170:493.
39. New JC Jr., Kelch WJ, Hutchison JM, Salman MD, King M, Scarlett JM, et al. Birth and death rate estimates of cats and dogs in U.S. households and related factors. J Appl Anim Welfare Sci. 2004;7:229–41.
40. Vecerek V, Vitulova S, Voslarova E, Volfova M. Mortality and euthanasia rates of dogs at a no-kill shelter. 43rd World Small Animal Veterinary Association Congress. Singapore: World Small Animal Veterinary Association; 2018. p. 659.

41. Stavisky J, Brennan ML, Downes M, Dean R. Demographics and economic burden of un-owned cats and dogs in the UK: Results of a 2010 census. BMC Vet Res. 2012;8:163–474.
42. Murray JK, Gruffydd-Jones TJ, Roberts MA, Browne WJ. Assessing changes in the UK pet cat and dog populations: Numbers and household ownership. Vet Rec. 2015;177:259.
43. Baquero OS, Marconcin S, Rocha A, Garcia RCM. Companion animal demography and population management in Pinhais, Brazil. Prev Vet Med. 2018;158:169–77.
44. Ross KE, Langford F, Pearce D, McMillan KM. What patterns in online classified puppy advertisements can tell us about the current UK puppy trade. Animals, 2023.
45. Lord E, Olynk Widmar N, Litster A. Economic impacts of adoption and fundraising strategies in animal shelters. Prev Vet Med. 2014;113:423–9.
46. Commonwealth of Australia. Handbook of Cost-Benefit Analysis. Canberra: Department of Finance and Administration; 2006. p. 180.
47. Loeb J, Gray A. At crisis point: The challenges facing the UK's rescue and rehoming sector. Vet Rec. 2024;194:334–8.
48. Siettou C. Evaluating the recently imposed English compulsory dog microchipping policy. Evidence from an English Local Authority. Prev Vet Med. 2019;163:31–6.
49. White DJ, Shawhan R. Emotional responses of animal shelter workers to euthanasia. J Am Vet Med Assoc. 1996;208:846–9.
50. Frommer SS, Arluke A. Loving them to death: blame-displacing strategies of animal shelter workers and surrenderers. Soc Anim. 1999;7:1–16.
51. Rohlf V, Bennett P. Perpetration-induced traumatic stress in persons who euthanize nonhuman animals in surgeries, animal shelters, and laboratories. Soc Anim. 2005;13:201–19.
52. Reeve CL, Rogelberg SG, Spitzmüller C, DiGiacomo N. The caring-killing paradox: Euthanasia-related strain among animal-shelter workers. J Appl Soc Psychol. 2005;35:119–43.
53. Newsome JT, Clemmons EA, Fitzhugh DC, Gluckman TL, Creamer-Hente MA, Tambrallo LJ, et al. Compassion fatigue, euthanasia stress, and their management in laboratory animal research. J Am Assoc Lab Anim Sci. 2019;58:289–92.
54. Andrukonis A, Hall NJ, Protopopova A. The impact of caring and killing on physiological and psychometric measures of stress in animal shelter employees: A pilot study. Int J Environ Res Public Health. 2020;17:9196.
55. Çınar B, Polat E, İspir ÇB. Affective polarization in online reactions to Turkey's 2024 stray animal law. OPUS J Soc Res. 2025;22:832–46.
56. Günay K, Üçler N. The multi-dimensional controversy: mapping instagram's response to Turkey's stray animals policy. Momentdergi. 2025;12:126–57.
57. Hennessy MB. Using hypothalamic–pituitary–adrenal measures for assessing and reducing the stress of dogs in shelters: A review. Appl Anim Behav Sci. 2013;149:1–12.
58. Protopopova A. Effects of sheltering on physiology, immune function, behavior, and the welfare of dogs. Physiol Behav. 2016;159:95–103.
59. Hennessy MB, Willen RM, Schiml PA. Psychological stress, its reduction, and long-term consequences: What studies with laboratory animals might teach us about life in the dog shelter. Animals, 2020.
60. Kaszycka K, Goleman M, Krupa W. Testing the level of cortisol in dogs. Animals, 2025.
61. Epstein J, Dowling-Guyer S, McCobb E, Glotzer C, Dodman NH. Addressing stress in dogs in shelters through a novel visual and auditory enrichment device. Appl Anim Behav Sci. 2021;236:105215.

Publisher's Note

Springer Nature remains neutral with regard to jurisdictional claims in published maps and institutional affiliations.