

Reasons Contributing to Free-Roaming Dog Populations and their Effects on Society

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Dogs play different roles in societies, ranging from being pets, security, hunting, research, among others. Ideally, these dogs are supposed to be managed by owners to ensure their safety and welfare. There is raising concern on the menace arising from free-roaming dogs. In this review, we aimed to understand the available evidence on the reasons and effects of free-roaming dogs and the proposed solutions. By mentioning reasons for the growth of free-roaming dog populations, effects of these populations, and proposed solutions, the paper provides the reader with sufficient knowledge to be able to draw their own conclusions and discuss potential solutions. Most of the papers were done in the USA, with few studies conducted in Asia and Africa. The common reasons mentioned by authors were abandonment and unsterilized dogs. The reported effects were the spread of disease, negatively affecting wildlife, and negatively affecting dog welfare. This literature synthesis adds to the body of knowledge on dog management. This is specifically important because dogs are seen as pets and cherished by many people. There is a need for more research on the same but in Africa and Asia.

Keywords: Free roaming dogs, dog abandonment, Literature review

Introduction

The population of dogs globally, by various estimates in 2012, was around 500 million¹, but recent estimates state that the number is now up to 900 million²⁻⁴. Around the world, many households' own dogs, with ownership rates ranging from 37% in the US, 27% in Europe, 39% in Australia, and up to 86% in Chile (Wierzbowska et al., 2016). It is difficult to estimate the owned dog populations in Asia and Africa (Hite, 2019), because in many countries pet dogs are not registered. China is estimated to have a pet dog population of 110 million, India has around 32 million, and Japan has 9.5 million. The World Health Organization (WHO) estimated around 78 million owned dogs in Africa².

Traditionally, dogs were used for hunting, guarding, or herding sheep and cattle. Over the years, the roles of dogs in society have changed, and can comprise of what is mentioned previously⁵, but many other things as well, such as personal security, guarding property, and helping those with certain needs. However, dogs in modern society tend to be regarded as companions or part of the family. In most developing countries, dogs are used for guarding purposes. A study conducted in Zimbabwe⁶, found that 60% of owned dogs were kept as guards against human intruders and 37% were in charge of repelling wildlife that could get in the way of crops or livestock. In Soweto, South Africa, dogs were kept for personal security, as companions, for guarding property and to keep feral cats away. In Machakos

District, Kenya, 99% of households said that their dogs' main purpose is to guard property (Kitala et al., 2001). 50.4% of households in New Providence, Bahamas, 83% of households in the Thungsong District of Thailand, and 65% of houses in Miacatlan, Mexico, were keeping their dogs for security and guarding purposes⁷. In many cultures, the role of dogs is to act as guardians or part of the family, while other cultures have an aversion to dogs because of superstitious beliefs. Certain households that do not have access to as much money or resources are more likely to allow their dogs to be guardian dogs or have them roam freely, because it is easier for the household who would not have as much burden from taking care of a dog full-time. The roles of dogs vary depending on country, region, and cultural beliefs, but the presence of dogs in modern society is still very prevalent. However, many dogs globally are not owned by owners. Unowned dogs can be called free-roaming, but this title varies. There can be community dogs, who hang out in human populated areas and are dependent on them for food, strays, who have no ties to any specific neighborhood, and feral dogs, who rarely interact with people, and depend on slaughterhouses and landfills to feed⁸. According to the World Health Organization (WHO), there are approximately 200 million stray dogs worldwide, and 75–85% of all dogs are classified as free-roaming². There are many factors that contribute to this surge in free-roaming dog populations, and the truth that dogs are prolific can amplify these factors even more. From a single female dog and her offspring, around 67,000 puppies

can be born in six years^{9,10}. It is important to consider that this number is not entirely accurate, since the source used is from a blog/webpage, but the page provides an estimate that is backed by the Humane Society, an animal welfare charity. This abundance of free-roaming dogs can have many disadvantages for dogs, humans, and other animals. The objective of this paper is to provide the reader with a background knowledge of this problem, and allow them to be able to discuss it, draw their own conclusions on it, as well as create their own solutions.

Methodology

This paper used a variety of different resources to build a comprehensive literature review. The first set of sources was obtained through Google Scholar, and the second set of sources was obtained by citations from the first set. The keywords searched on Google Scholar included “free-roaming dogs”, “dog abandonment”, “dog predation”, “dog ownership”, and “dog behavior.” Articles that discussed the 3 core objectives of the study, which were the causes, effects and solutions towards the free-roaming dog population were selected to report on this paper. We also added papers that were relevant to dog ownership, such as demography and potential benefits. Only papers published in peer-reviewed scientific publications were selected with the final total number reaching 130 papers. We searched Google Scholar from June 2023 to August 2023 to gain sources. Data was not screened but was analyzed manually and extracted using a Microsoft Excel Document and Google Docs. Not all data from the papers was extracted, but only the most relevant data to the 3 core objectives. The papers were analyzed using a Microsoft Excel sheet to determine how many papers mentioned the 3 core objectives, as well as the most common reasons, effects, and solutions. The Excel sheet also contained a section on the countries the 3 core objectives focused on.

Results

Many articles were not accessible and only the abstracts were used so it led to less information being gained than could have been possible. Another weakness is that not many of the articles focused on reasons for abandonment, but more articles focused on effects and solutions. Some articles did not mention any of the three core objectives but instead mentioned dog demographics, behavior problems, and owner opinions.

The total number of papers used for this literature review was 93. 26/93 were from the USA, 6/93 were from India, 3/93 were from France. 2/93 were from the UK, Australia, South Africa, Mexico, Denmark, Taiwan, and 1/93 were from Qatar, Italy, Brazil, Thailand, Zimbabwe, South Korea, Azerbaijan, Nepal, Japan, Germany, Switzerland, Kenya, Spain, Czech Republic, Indonesia, The Netherlands, Canada, Ireland, Serbia,

and Poland. 27/93 are commentaries/opinion papers, 29/93 are research articles, 18/93 are blogs/webpages, 3/93 are observational studies, 4/93 are case-control and cohort studies, 3/93 are cross-sectional studies, 2/93 are case series, and 1/93 were an epidemiological study, a conceptual model, and a comparative overview.

59/93 did not report any reasons for free-roaming dogs. 33/93 reported various reasons. The most reported reasons were abandonment or relinquishment (18/33), unsterilized dogs (8/33), and feeding dogs (4/33). 41/93 did not report the effects of the rising population of free-roaming dogs and 51/93 studies reported reasons. The most reported reasons were the spread of disease to animals and humans (30/51), dogs attacking or having negative effects on wildlife (12/51), dog welfare (9/51), and Aggression, accidents, or attacks towards humans (18/51). Other studies found various effects, but most of them mentioned all the same common effects found in this paper. Many studies focused more on the spread of disease and negative effects on wildlife, rather than the negative effects towards dog welfare. 37/93 studies did not report solutions. 55/93 reported proposed solutions. The most common solutions were education (14/55), sterilization (12/55), and euthanasia (5/55). Euthanasia was also mentioned as a solution, though less common.

Reasons for the rising population of free-roaming dogs

Abandonment

Abandonment is the main cause of the increasing number of stray and feral dogs on the streets¹¹. The main causes of abandonment¹¹, can include a lack of space, inability to afford the costs of keeping pets, owners who grow weary of the disruptions pets cause, the possibility that pets will no longer be a “novelty,” and will be an outmoded animal, which is an animal that is no longer in “style”, or the purchase of another pet.

Another study that obtained reasons for relinquishment of dogs in Denmark¹², said that the most commonly reported of these reasons included owner health (29%), animal behavioral problems (23%), housing issues (21%) and lack of time (14%). Jensen et al., (2020)¹², also found that the majority of the issues related to relinquishment had to do with the owner (75%), rather than the dog. Abandonment of a dog can be a traumatic experience for the dog and contribute to many problems that the dog can face in the future.

Outside of abandonment, there are other things that can contribute to the population of free-roaming dogs. Dogs that are owned or free-roaming can easily reproduce with other dogs. If owners do not sterilize their dogs, and allow them to roam freely, they can easily contribute to the already existing population of free-roaming dogs. Male dogs can significantly contribute to the population, because they have the capabilities to mate multiple

times a week, and can have an infinite number of litters. Female dogs can have up to 3 litters a year, each consisting of around 6 to 8 puppies. Female dogs only have a pregnancy period of 2 months. With the average litter size being 7 puppies, a female dog and her babies can give birth to about 67,000 puppies in 6 years¹³. The current free-roaming dog population can also grow by depending on human sources to survive. Waste disposal is a major factor in free-roaming dog populations and bite incidences⁷. Researchers suggest that many free-ranging dogs get their food from households and individuals, both those that directly feed them and those that dump food waste. These dogs can also get sources of food from commercial areas with an abundance of organic material, such as food markets, temples, restaurants, and slaughterhouses¹⁴. There isn't a direct correlation between waste disposal practices and dog populations, but there is a correlation between high levels of waste and high levels of dog populations. One example of this is in Nepal, where stray dogs can feed at garbage dumps around the streets and slaughter facilities⁷. In areas where there is no loose garbage, such as Japan free-roaming dog populations lower⁷. It is important to analyze what food sources free-roaming and unowned dogs are the most dependent on in order to control their population growth.

- **Lack of Knowledge or Research:**

Besides leaving their dogs unsupervised, some owners do not fully prepare for their dog to be adopted, and end up abandoning them when things do not turn out as expected. According to animal rescuers¹⁵, dogs that are bought on impulse are more likely to be returned back to animal shelters. The process of dog ownership includes doing research on the most suitable breed for you, and the amount of care and money it will need. It requires you to have a commitment to a dog for the rest of its life¹⁶. When dogs are bought on impulse, the necessary procedure of research is not completed, and owners are not informed on the needs of their dog. This can lead to owners underestimating the costs of dog ownership over a long term. It is not always an owner's fault for not being informed, because in some developing countries, people do not have access to proper sources of information about their dogs. Different perceptions about dogs can also relate to problems like impulse buying. In a cultural context, dogs can be bought on impulse when they are considered to be sacred or as symbols of wealth. However, this is still a problem that can lead to abandonment. For example, if an owner fails to make sure a dog is neutered, it could display aggressive behavior when it is in mating season or get pregnant (if it is a female), which are both factors that are known to lead to abandonment. Vučinić et al., (2006)¹⁷ found that financial problems were the most common reason for dogs to be relinquished back to a municipal shelter. Financial problems can make an

owner unable to provide proper housing, care, sterilization, and veterinary visits to a dog. This may contribute to the abandonment of dogs because people in struggling financial situations will prioritize their care over their dogs. When people have financial problems with their dogs, it could be a case of irresponsible ownership, because the owner didn't fully research the costs of dogs. Dogs are expensive to own, because they need things like beds, bowls, collars, food, and visits to the veterinarian. However, a sudden change in financial situations may also render many people unable to own pets. This is not a case of irresponsible ownership but can still have dire consequences for the owner and the dog. Solving this problem should involve educating people on the costs of owning dogs, and financial assistance to pet owners who are struggling to enable them to afford veterinary care. Some owners may also fail to vaccinate their dogs and prevent the spread of disease. A study conducted in Soweto, South Africa, found that of dog owners, only 13.1% were up-to-date with vaccinations and only 6.2% knew which vaccines had been used¹⁸. If an animal is not vaccinated and subsequently becomes ill, it may not be able to receive proper care that it needs if the owner has a lack of money or lack of knowledge on the next necessary steps. In Zimbabwe⁶, a survey discovered that the most common action that was taken by dog owners when their dog fell ill was to do nothing. If owners ignore the suffering of sick dogs, it could cause the dogs to act out in certain ways that are undesirable. Some owners may not know behaviors that dogs display normally, behaviors they display when there is a problem, and what to do when dogs react in certain ways. (O'Haire, 2010)¹⁹ states that an owner's ability to correctly identify canine behavior is poor, despite most dog owners rating their understanding of dog behavior highly. The results of a study (Hsu et al., 2003)²⁰, on the most common reported justifications for giving up a dog—"too much trouble" and "behavioral problems"—suggested that many Taiwanese were unaware of the challenges of keeping dogs in spatially constrained urban housing and that they lacked a basic understanding of dog behavior²¹. All of this has the potential to damage the relationship of a dog and its owner, and can moreover cause abandonment and relinquishment.

- **Owner Expectations:**

Many owners, especially those who are not educated on dogs and their behavior, can have high expectations for how their dog will act. They also underestimate the amount of work and time it requires to take care of a dog. Mota-Rojas et al., (2021)¹¹ found that the most common type of abandonment was by owners who realized that dog ownership required more commitment than what they had expected. Two studies found that dog owners who realized dog owner-

ship required more effort were 9.9²² and 4.3⁹ times more likely to return their dogs. Besides not realizing the effort involved in taking care of a dog, many owners expect their dogs to behave in certain ways. The results of a study²³, revealed that owners expected their dogs to behave with children, not display destructive behavior, and not be fearful in new situations. Many dog owners also seem to think that owning a dog will have benefits for their overall lifestyle^{19,24} and there is evidence to prove that dog ownership does help decrease levels of stress, loneliness, and depression in children and adults^{19,25–28}. Owning a dog also contributes to physical activity, and dog owners are likely to be more physically active (O’Haire, 2010; Oka et al., 2009; Anderson et al., 1992; Dembicki and Anderson, 1996). This data is echoed in the expectations of dog owners in (Powell et al., 2018), who expected having a dog to promote walking (89%), improve physical fitness (52%), lower blood pressure (40%), and result in weight loss (30%). Other owners anticipated gains in happiness (89%), as well as decreased stress (74%), loneliness (61%), and sadness (57%). Perceptions of dog owners can be influenced by values and cultural expectations. The opinions of the community can affect perceptions on dog ownership and abandonment and the bonds made with dogs¹⁶. While dogs can have positive effects on an owner and their lifestyle, it is also important for owners to be open to the possibility that they will have to work harder to strengthen their relationship with their dog, rather than it being easy. It is important that owners’ expectations for both benefits and challenges in their relationship with their dog to be realistic²⁴. This way, the dog won’t end up getting relinquished to a shelter or abandoned when the relationship between the dog and the owner proves to be unsuccessful.

- **Behavioral Problems:**

Behavioral problems are also a common factor brought up when discussing the abandonment or relinquishment of dogs. Many studies have found that behavioral problems are a common problem in the population of domestic dogs. Dogs displaying behavioral problems can cause negative interactions and put a strain on the relationship between the dog and the owner²⁹, which can in turn lead to abandonment¹¹. On the other hand, it is believed that people generally prefer dogs who are calm, compliant, and not aggressive²⁹, and the dog’s personality can affect the dog-owner relationship. By combining the results of several studies, Martínez et al., (2011)³⁰ estimated that around 40% and 87% of dogs may display behavioral problems. Many studies also show that dogs can display more than one behavioral problem (Martínez et al., 2011; Hsu & Serpell, 2003). A study collecting the reports of behavioral problems from owners (Wells et al., 2000)³¹, found that out

of 269 dogs, 48.3% demonstrated one specific behavioral problem, 27.3% had displayed two undesirable behaviors, and 24.4% had shown three behavioral problems. There is no clear answer as to what the most common behavioral problems in dogs are, as studies vary, but many suggest it to be aggression^{22,23,32,33} with others noting separation anxiety^{33,34} and stimulus reactivity³³ as other common ones. There are different factors that are observed to influence the occurrence and type of certain behavior problems, such as the sex, breed, age, and reproductive status of the dog, although sources have some disagreements. Wells et al., (2000)³¹, found that the sex of a dog did not influence the occurrence of behavior problems, but male dogs were more likely to show aggression. Wells et al., (2000)³¹, did not find a relation between age and behavioral problems. Other studies found that there are generally more males represented in cases of behavior problems as compared to females. Martínez et al., (2011)³⁰, found that males were 1.63 times more likely than females to display aggressive behavior among dogs with this temperament. A study classifying behavior problems among dogs (Borchelt, 1983)³⁵, found that more aggression problems occurred in 67.4% of males compared to 32.6% of females. When it comes to reproductive status, many studies found that neutering a dog did not improve their behavior problems, and some found that it contributed to more or worsened the current ones. 58% of Dutch dog owners used neutering to correct unwanted behavior but didn’t see any changes in relation to aggressive behavior³⁶. Neutering can potentially create more behavioral problems and has been suspected to increase anxiety among dogs^{37,38}. A large-scale study implicated that neutered dogs were twice as likely than non-neutered dogs to display behavioral problems (Dinwoodie et al., 2019), and another noticed that neutered dogs displayed additional issues, such as excessive barking and aggression³⁹. However, the majority of studies did observe that many behavior problems reported among dogs come from intact males³³, and they are also more likely to exhibit roaming behaviors²⁰. Intact dogs are more likely to display aggressive behavior³². These inconsistencies can be because owners do not consider the effects other factors may have on behavior problems, rather than neutering. For example, dogs might display behavioral changes after being neutered for a short period and then behave normally or improve behavior. Dogs may also behave differently depending on age, breed, environment, and sex. A paper found that many studies did not consider the differences of male and female dogs when it comes to neutering⁴⁰. It is important to consider that the experience of abandonment can also contribute to the surfacing of behavior problems, such as separation anxiety³¹. Abandonment is a stressful and traumatic factor for dogs and can

affect the success of dogs being sent to new homes. Even animal shelters are stressful places for dogs to be in, due to excessive noise, being locked up, and changes in light and dark cycles, which can result in behavioral problems, such as separation anxiety for the animals. While it is possible for dogs to form bonds again with different humans, the experience of abandonment is capable of disrupting relationships with a new owner, which can in turn lead again to abandonment¹¹. This is why behavioral problems are a relevant issue to consider when discussing the problems of dog abandonment.

Irresponsible ownership

Abandonment contributes to the population of stray dogs, which are part of the free-roaming dog population. Other times, owned dogs can be allowed to roam freely by their owners, which allows them to contribute to many problems that arise from stray and feral dogs¹¹. A household questionnaire survey gathering data on the demography of dog populations in communal lands in Zimbabwe (Butler and Bingham, 2000)⁶, found that only 10% to 5% of people tied up their dogs on rare occasions, otherwise they were allowed to roam freely. This sample is representative, but it must be considered that dog patterns differed depending on the communal land. Besides domestic dogs, other dogs owned, such as shepherd or park ranger dogs, can roam freely, without much supervision, allowing them to partake in damaging activities. This is a form of irresponsible ownership, because it is an owner's responsibility to ensure the dog doesn't destroy or defecate on public property, create unsanitary conditions, or disturb areas by barking, chasing vehicles, molesting, attacking, or interfering with other dogs or people⁵. However, this may not be seen as irresponsible ownership. Some owners may allow their dogs to roam freely as a component of their welfare, seeing as dogs are living beings who should not be restricted to a certain area. However, this can still allow for harm to be caused without owners realizing. Irresponsible ownership, which can be tied to a lack of education and knowledge, can produce an unsuccessful relationship between the dog and the owner, further leading to abandonment or relinquishment.

Effects of free-roaming dogs on society

The effects of free-roaming and stray dogs on society can be harmful to both humans and dogs and can also cause conflict and strained relationships between both parties.

Societal Welfare

While free-roaming dogs face an abundance of problems regarding their health and welfare, the presence of free-roaming dogs in society can also be a disturbance to people. Dogs can

contribute to public health issues⁴¹, pollution and the spread of disease in cities by defecating and urinating¹¹.

The average output of fecal matter for a large dog is estimated to be about 0.75 pounds per day¹¹, which means that the pollution of feces can become a significant health issue. In Quito, where there are about 150,000 stray dogs, the sewerage system receives around 51 tons of droppings per day¹¹. However, there are no studies on direct correlations between considerable amounts of feces and the spread of disease to humans. Dogs may also directly or indirectly cause accidents while interacting with humans. Firstly, dogs can cause traffic accidents. A study conducted in a major city in Eastern India⁴², found that 69% of impacts on the roads were caused by stray and free-roaming dogs. Because road accidents caused by wandering animals are increasing, free-roaming dogs can cause problems regarding road safety, which can result in the injuries of both dogs and humans. When assessing the injuries of victims in dog road accidents⁴², 49% of all victims had polytrauma, which means they had multiple traumatic injuries. This means their injuries were greater than 15 on the ISS scale. A score greater than 15 on the ISS scale is defined as a major trauma, which has the potential to cause disability or death. A study in Naples found that among 423 dogs involved in road accidents, the majority had bone lesions (81%) while 94 dogs (19%) had soft-tissue lesions. A report from Mysore, India estimates about 40,000 dogs on the road⁴³. This risk of collisions can be deadly to both parties involved.

Welfare of the free-roaming dog population

As mentioned before, abandonment can be a source of trauma for a dog, as it involves a drastic change in environment and social conditions. This can negatively affect the mental state of a dog. Free-roaming dogs can also be affected by a myriad of different health conditions. Dogs that are stray and free-roaming have little access to proper care and resources. Free-roaming pets, particularly dogs and cats, are forced to survive without human care, which poses serious risks to the animals' health and welfare as well as public safety and environmental issues⁴⁴. Free-roaming dogs face malnutrition, starvation, and dehydration, and can also be poisoned, harassed by people, or hit by vehicles¹⁶. Dogs can also be infected with disease and develop other clinical conditions. Echinococcus, toxocara, parvovirus, heartworm, leptospirosis, and venereal tumors are among the diseases that plague free-roaming dogs^{45,46}. Many dogs have infectious skin diseases, such as mange, along with secondary bacterial infections. A study in Mexico found that 34 percent of stray dogs had mites, the most common being *D. canis*⁴⁷. A cross-sectional study done in a rural community in southern Africa found a high prevalence of serious diseases among dogs, stating that 51% of the population had one or more serious clinical conditions⁴⁸. The same study also concluded that a

significant portion of the population was in a chronic state of malnutrition and starvation. The high rate of disease, illness, and death can be linked to the low amounts of sterilization. Besides many other diseases, dogs can also contract rabies, which kills them within two to three days of experiencing symptoms. Other dogs can be suspected to be carrying rabies and be killed in fear of it spreading to people.

Attacks on Humans

Dogs may directly contribute to accidents by biting or attacking humans that they interact with. Stray dogs may be facing many problems, and they may be scared, rabid, sick, or hurt, which can lead to them displaying signs of aggression towards humans. This aggression sees an increase if they feel their territory is being invaded, they are provoked, or during mating seasons⁴⁹. In Asansol, Paschim Bardhaman District, West Bengal, India, the behavior of stray dogs was observed, and the observations included that humans who intruded a stray dog's territory were generally chased, attacked, or forced out of its territory⁵⁰. Dog bites and attacks happen more frequently in children than adults^{44,51}. In fact, the Centers for Disease Control and Prevention (CDC) estimated in 1995 that dogs bite about 4.7 million Americans every year, with half of them being children between the ages of 5 and 9 years old⁵². In Bangkok, 55% of the victims of dog attacks and bites are children and teenagers⁵³. A study conducted in a suburban Denver pediatric group revealed that 53.6% of children were less than 5 years old when they were bitten⁵⁴. Besides a survey in Multnomah County, Oregon⁵⁵, that stated that the largest proportion - 36% - of reported bite victims didn't know the dog that bit them, the majority of the recorded bites were by dogs that were part of a household. However, even though there are less bites from free-roaming dogs, they can also pose greater threats to children and adults through biting. Since free-roaming dogs are less likely to be treated and vaccinated, they have a higher chance of causing infection and spreading disease. The main reason why children are more likely to be bitten by dogs compared to adults is because many children may be too young to realize when certain behaviors might provoke an aggressive or defensive reaction from a dog⁵⁴. Some behaviors that a dog might react to in defensive ways include bending over or leaning on a dog, reaching for, or taking away an object, and petting, hugging, or pushing a dog⁴⁴, or just getting too close to a dog. It is important for both children and adults to be educated about how to act around dogs and the body language of a dog, so that they can know the proper steps and prevent attacks from occurring.

Attacks on Wildlife

Surprisingly, not much is known about the impacts of dogs ecologically on animals, despite it being a significant issue⁵⁶. Dogs

threatening wildlife can affect conservation efforts, as well as strain the relationships between dogs and humans, dogs and wildlife, and humans and wildlife. The predation of dogs depends on many factors, especially the presence of other apex predators, such as wolves, bears, tigers, lions, etc. However, dogs can become a significant threat to wildlife in areas where other predators are absent, or have been restricted because of repopulation efforts⁵⁶. Also, in areas that are becoming increasingly urban, predators can become exterminated, which causes dogs to become the main predators⁵⁷. Dogs have very flexible diets and can change their needs depending on the environment around them, which makes many wildlife suitable prey. Smaller and more isolated populations of animals are also less able to cope with predation from dogs because there is insufficient reproduction⁵⁶. Dogs are known to be the main contributors of declining populations among many different species.

Multiple previous studies found that dogs preyed on species such as the mountain gazelle, the tibetan antelope, rock hyraxes, rat sized rodents, mole rats, and Starck's hare, and were responsible for the near extinction of rock iguanas in the Caicos Islands, North Island brown kiwi in New Zealand, the marine iguana in the Galapagos, and the Cuban hutia in Cuba^{56,58}. A study in Poland (Wierzbowska et al., 2016)⁵⁹, found that free-ranging dogs killed around 332,779 wild animals and 2,835 livestock in hunting reports from 2002 to 2011 within all 49 Hunting Districts of the Polish Hunting Association. In some cases, the impacts of dog predation on wildlife can be even more severe than the predation of other predators. One study conducted in the French Pyrenees⁶⁰, recorded that among 733 kills of domestic sheep, 91% of them were by free roaming and feral dogs with brown bears being responsible for the remaining 9%. Another instance of conflict was observed between dogs and wolves in Poland⁵⁹, with dogs being responsible for an average of 205.7 livestock annually on hunting grounds, and wolves killing around 362.7. This competition between dogs and wildlife can lead to strained relationships, as well as violent reactions to one another. Vanak et al., (2013)⁵⁷ observed over various articles that threatened species of carnivores such as the Andean cat, Kodkod, Darwin's fox, smooth coated otter, and southern river otter have been killed by dogs. Competition can also lead to strain on the relationship between humans and wildlife. If predators are the ones responsible for the deaths of dogs, it can lead to strained relationships between humans and predators. For example, wolves will usually perceive dogs as both competition and prey and will kill them. In Poland, wolves killed an average of 61 domestic dogs annually on hunting grounds from 2006 to 2011⁵⁹. The killing of domestic dogs can cause many people to blame predators, which may lead to the killing of many.

Other than disease and predation, dogs can also have indirect effects on animals. Dogs have certain behaviors that can cause other animals to be alert, and tend to evoke the most dramatic

responses among wildlife⁶¹. Dogs can contribute to behavior changes and increased stress in the lives of wildlife⁶⁰. These behavior changes include ceasing normal activities, such as resting, foraging, parental care, and dogs can also cause increased heart rates, and hormone release. Some studies demonstrate that these disturbances can have an effect on the population of a species, because of reduced rates of reproduction and growth, as well as a weakened immune system and higher chances of acquiring diseases and parasites⁶², due to disturbances causing a lower quality of habitat and lower carrying capacity. This can result in problems for conservation efforts for certain species, as well as disturb the welfare of the animals⁶¹. A paper found that among other studies, dogs increased the sensitivity, heart rates, and flushing distances of various mammals⁶³. One literature review⁶⁴, found that among a large variety of wildlife species, including amphibians, reptiles, birds, and mammals, predator odors caused escape, avoidance, freezing, and changes in behavior. It has also been observed that dogs can displace certain wildlife from their territories by chasing them, and a dogs scent can prevent wildlife from returning to their territories⁶². Dog interference with wildlife that is indirect can affect smaller wildlife populations and can affect conservation efforts.

Feral, stray, and free-ranging dogs can have greater impacts on wildlife and livestock compared to owned dogs, because they can range further into wildlife areas, and are also dependent on catching wildlife as food. Free-roaming dogs tend to be more nocturnal than owned dogs, which can cause them to have more encounters with other wildlife during the night^{56,61,65}. Vanak and Gompper (2009)⁶⁶, found that 63% of free-roaming dogs were almost entirely dependent on wildlife as prey. When discussing stray dogs, who receive very little veterinary treatment and can therefore be exposed to more diseases, it is important to note they are also more likely to spread diseases to different wildlife. It is also important to know that information about dog effects on wildlife may not be as relevant since the studies are not recent. There should be additional studies conducted on dog effects on wildlife to gain a more recent understanding of the issue. All of the mentioned factors show that dogs have very significant effects on wildlife, and can negatively affect the welfare and populations of them.

Effects on Livestock

Free-roaming dogs can also have drawbacks for livestock. Livestock do not tend to be killed outright by dogs, instead they die from their injuries or acquire infections. Jennens (1992)¹² reported that in Perth, Australia between 1989 to 1991, local authorities found that over 1,900 dogs were involved in the attacks of 5,400 goats, sheep, and cattle. These attacks on wildlife affect the productivity and wellbeing of livestock and farms. This also damages the relationship between dogs and farmers, which could lead to the killing of free-roaming and wild dogs.

Dog attacks on livestock affect its well-being and productivity, but it can also lead back to wildlife welfare. Carnivores can often be blamed for the attacks of dogs on livestock or domesticated animals, which can also lead to persecution of carnivores. In northern Spain, sheep were 36% of prey items found in dog feces, while in wolf feces, sheep were only 3% of prey items, showing that more dogs were responsible for the predation of sheep than wolves, and the actual impact of wolves was overestimated⁵⁷. These issues can affect the conservation efforts of carnivores and strain relationships between humans and predators.

Disease Transmission

Overlap between dogs and other animals can cause risk of the spread of disease in environments⁶⁵. Dogs can transmit diseases such as rabies, parvovirus, and canine distemper virus, which can cause population declines in native wildlife. They also act as carriers for parasites, with at least 60 parasite species shared between dogs, cats, and humans⁶⁰. Some of the diseases that dogs transmit to wildlife include rabies, giardia, distemper, and parvovirus⁶². A study conducted in Mexico City observed that feral dogs frequently spread rabies, toxoplasma and parvovirus to opossums, ringtails, skunks, weasels, and squirrels⁴⁶. WHO (1996), estimates that 25,000–27,000 domestic production animals contract rabies as a result of exposure to dogs or other rabies vectors⁷. A commonly mentioned example of the transmission of disease from dogs to wildlife is canine distemper virus (CDV), which is mainly transmitted by dogs⁶⁷. Costanzi et al., (2021)⁶⁵ found that among different literature, it has been widely described that CDV has led to consequences on wildlife conservation. Dogs could be victims of disease, but could also be responsible for the transmission of it, which means their presence could be a threat to many species. Ng et al., (2019)⁶⁷ stated that several studies have associated CDV with high mortalities of ferrets, lions, and wolves. CDV is easier to observe among dogs that are free-roaming and unowned. In a study that consisted of unowned dogs⁶⁷, 94.1% of dogs between 5–12 months were seropositive for CDV, and 47.1% of those above 12 months were seropositive for CDV. A study conducted in the Alps detected CDV, as well as other diseases, such as CPV(2a, 2b, 2c), salmonella, leishmania, neospora caninum, and toxoplasma gondii in Shepherd and Park ranger dogs⁶⁵.

As well as wildlife and livestock, stray animals can spread disease to humans and domestic animals from bites, but also, as mentioned before, from direct contact with feces, urine, and other bodily excretions. Stray animals scavenging for food in slaughterhouses and markets can also have direct contact with the food, unknowingly spreading disease⁶⁸. The urine and feces of dogs does not only pollute areas, but it also allows for the transmission of diseases from dogs to humans. The Oregon Department of Environmental Quality identifies one of

the most significant contributors to the region's most common and dangerous pollutant, *Escherichia coli* (E. Coli), is pet waste. Contact with E. Coli. infected water can give people nausea, vomiting, and diarrhea. Adults usually recover from E.Coli, but children and older adults have a greater risk of developing kidney failure⁶⁹. The spread of disease from dogs and other animals to humans can be fatal and have dire consequences. One of the most commonly mentioned diseases when talking about zoonosis, infectious diseases that spread from humans to animals, is rabies. Rabies is a viral disease which occurs in more than 150 countries and territories. It causes tens of thousands of deaths every year, with 40% of the deaths being children under 15 years old. Dogs contribute up to around 99% of all rabies transmissions to humans, making them the main source of human deaths from rabies¹³. Rabies spreads through saliva of infected animals, generally through bites and scratches⁷⁰. Patients may display symptoms of fever, pain, tingling and burning at the wound site¹³, as well as agitation, anxiety, confusion, hallucination, and hydrophobia, an abnormal fear of water⁷¹. As the virus moves to the central nervous system, a patient develops a deadly inflammation of the brain and spinal cord¹³. If a person bitten by a rabid dog is left untreated by post-exposure prophylaxis (PEP) and bitten on the face, they have a 70% chance of developing clinical rabies, which can very rarely be cured without severe neurological disadvantages^{13,72}. Rabies can be controlled by the vaccination of dogs^{13,72}. However, in some countries, it may be harder for people to get access to centers of rabies vaccinations and treatments, and many people are not educated on the dangers of dog bites and rabies. This explains why the majority of rabies deaths take place in developing countries, which do not have the proper resources necessary to take care of rabies^{5,7}.

While rabies is the most well known among diseases spread by dogs, dogs can also be responsible for the spread of a whole array of different zoonotic diseases. There are over 100 diseases that can be passed between dogs and humans. The most common ones include ringworm, salmonellosis, leptospirosis, Lyme Disease, campylobacter infection, giardiasis, roundworms, hookworms, echinococcus, toxoplasmosis, toxocara, canine influenza, ancylostoma, and ehrlichiosis^{62,68,73}. These infections can be spread in many different ways. Some diseases spread through contact with urine or feces (Leptospirosis, salmonellosis, roundworms, hookworms), viral zoonotic diseases are transmitted through bites (rabies, canine influenza), tick-borne diseases (Lyme disease, ehrlichiosis) are transmitted through tick bites, parasitic infections (e.g., toxoplasmosis, giardiasis) can be acquired from contact with infected feces, fungal zoonotic diseases, and other diseases can be contracted through direct contact with infected hair or skin (ringworm)⁷¹. Dogs are also capable of being carriers of disease from wildlife and spreading it to humans. Dogs were also recognized as sources of zoonotic parasites such as *Echinococcus* spp. and as a possible

bridge for rabies between wildlife and humans⁷⁴. People who are immunocompromised, such as children under 5, pregnant women, adults over the age of 65, and people with AIDS/HIV, can be more susceptible to these diseases (Zoonotic diseases in dogs). Infection from these diseases is not very common among domestic dogs as long as people follow the proper hygiene procedures (Zoonotic diseases in dogs). But among dogs that are stray and do not have owners, it is very rare that they will be bathed and groomed, treated, or looked after, which gives them a higher chance of spreading disease to others. Zoonotic diseases are also more common in developing countries, as they might not have effective hygiene methods, and may have to deal with larger populations of free-roaming and stray dogs. The spread of zoonotic disease from dogs to humans is a very serious issue that is largely due to the numbers of free-roaming and stray dogs that humans can come into close contact with.

Proposed Solutions

The most fundamental approach to effectively address the myriad issues stemming from free-roaming dogs is to tackle the root cause—their unchecked population growth. As previously highlighted, a significant contributor to the vast population of free-roaming dogs is the widespread act of abandonment. By curbing this practice, we can significantly curtail the population's expansion. Simultaneously, it is imperative to manage the existing free-roaming dog population. This can be achieved by either implementing measures to actively decrease their numbers or by implementing strategies that prevent them from reproducing further. By focusing on these two essential avenues—reducing abandonment rates and implementing population control measures—we can lay the groundwork for a sustainable solution to the challenges posed by free-roaming dogs.

Population Control

- **Sterilization:**

Sterilization, which is called spaying in females and neutering in males, is the most common type of birth control used in dogs. Other options for birth control in dogs are shots and pills. These would be administered by veterinarians, are low cost, and easy to implement. But they would need to be repeated many times, which would be difficult to do with free-roaming dogs. This is why sterilization is a more effective method in controlling dog populations. Sterilization is a more effective strategy than adopting or bringing dogs into animal shelters, because it saves hundreds of future dogs from being born without homes and proper resources. Both spaying and neutering are surgical procedures that are performed by vets. Male dogs will get an orchiectomy, where a vet will castrate

the dog. Female dogs will usually get an ovariohysterectomy, in which the ovaries and a portion of the fallopian tubes are removed, leaving the majority of the uterus left intact⁷¹. Owners can also opt for a hysterectomy and an ovariectomy for female dogs, or a vasectomy for male dogs (Spaying and Neutering). Castration is preferred over vasectomy in male dogs because vasectomies do not remove a male dog's testicles, which means they will still be producing hormones, and won't reduce specific behaviors like roaming, territory marking, and fighting⁷⁵. In male dogs, castration has been shown to decrease urine marking, roaming, and aggressive behavior⁷⁶. Animals that are sterilized have also been shown to live longer and healthier lives⁷⁷. Dogs that are spayed and neutered have less of a risk for developing ovarian, mammary, prostate, and testicular diseases, disorders, infections, and tumors^{11,78}. After sterilization, dogs have less of a chance of developing cancer⁶⁴. Non-governmental organizations (NGOs) can implement mass sterilization programs while collaborating with local authorities. These organizations can work by setting up camps in various areas where free-roaming populations of dogs are large. Sterilization does have some downsides when conducting it on free-roaming dogs on a large scale. Firstly, surgical sterilization must be carried out by trained veterinarians who can handle animals well, have good surgical technique, and have access to proper equipment, and anesthesia for the animal. The process also requires monitoring during the surgery and recovery period⁷⁷. Because of these reasons, implementing neutering will require large amounts of money, which will be difficult to provide⁷⁹. Expenses also make it difficult to ensure the long-term sustainability of sterilization programs. Secondly, while non-governmental organizations and programs like the SPCA play important roles, sterilization programs cannot be solely dependent on them⁷⁹. This is because they can often face challenges like limited funds and resources and might not be able to fully help the problem. Sterilization programs may also be difficult to enforce with the government policies in a specific area. Cultural resistance is also important to consider. In countries where dogs are considered more important, prohibiting their reproduction could cause opposition⁷⁹. To navigate these challenges, local authorities should play bigger roles in this method of population management for dogs, creating and enforcing policies that relate to the cultural beliefs of a community and providing funding. Sterilization is the best solution to control dog populations, as it doesn't directly hurt or kill dogs, or have negative effects on their welfare.

- **Euthanasia/Culling:**

There are some methods of population control that involve the killing of free-roaming dogs. Some of these meth-

ods are painful, while others are painless. Euthanasia is a way to kill dogs painlessly through medical procedures. It is generally accepted worldwide, due to it being a humane method. Euthanasia can potentially be used to deal with populations of free-roaming dogs. Euthanasia works by administering large volumes of anesthetic agents, for example, barbiturates⁸⁰ and ketamine⁴⁵. It then causes unconsciousness, which is followed by respiratory and cardiac arrest, leading to death⁶⁸. Euthanasia has advantages because it induces a painless death, is accepted, chemical agents are not costly, and a small number of materials is required. However, euthanasia does have some downsides. It must be performed by an expert, requires some chemical agents that might be unavailable at times, and needs a large volume of chemical agents, which may make it expensive⁸¹. Euthanasia is also not very suitable in controlling the free-roaming dog population, and shouldn't be considered an active effort in controlling free-roaming dogs⁶⁸, because it is inhumane to kill so many innocent dogs, despite it being in a painless method. The fairness of euthanasia is something to be considered when discussing it as a solution, because many people could argue that it is not fair and ethical to the dogs, and is bad for animal welfare. Others can argue that euthanasia will benefit dog and human populations. Free-roaming dogs can live in terrible conditions, so euthanasia might seem like a better solution for them. It can also be more humane than allowing the spread of diseases to negatively affect dogs and human populations. It is important for veterinarians and law enforcement to discuss euthanasia and ensure that it is in the best interest for dog and human populations. Besides euthanasia, there are even less ethical solutions to rapid population growth among free-roaming dogs. These solutions are the poisoning and shooting of dogs. When dogs are poisoned, they absorb or are exposed to chemical substances that cause damage to the organs. They experience symptoms of vomiting, diarrhea, vocalization, excessive salivation, biting, and eventually die after cardiac and respiratory arrest⁸². Besides this method being unethical and severely stressful for a dog to go through, it presents many other risks to other species that may or may not be targets to the poison. There could be a risk of poison exposure to other species, especially to children who are in close proximity to free-roaming dogs⁷⁹. Shooting dogs is a solution that has many potential risks. Firstly, it requires a skilled and trained person to shoot a gun, with government permission. If the person shooting the gun is not skilled or trained, there could be a possibility of mistakenly hitting a person or non-target animal⁸³. As well as having risks, shooting itself can inflict severe injuries upon a dog, and would be an exceptionally painful experience if the dog doesn't die instantly from the shot. These two methods are

not effective solutions, and are considered inhumane and brutal acts against dogs. Many countries ban poisoning or shooting animals, as it goes against animal welfare. In contrast, euthanasia does not promote painful deaths and directly harm the dogs involved, but it still may be seen as unethical in the eyes of many. Sterilization programs are a better solution than mass euthanasia, and they are also more humane⁸⁴.

- **Control of Food Waste:**

Those who share close spaces with dogs should be aware that their households can play major roles in the growth of populations¹⁴. Controlling these food sources can decrease the rates of rapid population growth. This can be noted in Japan, where there is almost no loose garbage, and populations of stray dogs are lower than other countries⁷. There are several steps to controlling food waste. Firstly, there should be precautions made to ensure that dogs should not have accessibility to sources of food like food markets, slaughterhouses, and landfill sites. Second, there should be policies for not properly disposing of waste. There should also be policies against feeding free-roaming dogs. However, keeping food away from dogs is not the most ethical option. Free-roaming dog welfare is already awfully poor, as mentioned above, and not having reliable food sources is one of the main factors contributing to this. It would be unethical to force dogs to die of starvation to control their population.

Policies and legislations against dog abandonment

In order to ensure people do not abandon their dogs, it is important for countries to have laws that prevent abandonment. Many countries already have established laws and codes that promote responsible dog ownership and satisfying pet needs. For example in Spain, there are codes and regulations which establish that people must do all they can to promote animal welfare, including satisfying animals needs for food, space, hygiene, vaccinations, sterilization, and sometimes registering the animal in a database³⁰. In Europe, an international treaty called the Convention for the Protection of Pets, was introduced. The Convention promotes responsible pet ownership and understanding, and prohibits breeding and boarding. This Convention also seeks to lower the numbers of stray animals⁸⁴. When people abandon their dogs, it is seen as an act of cruelty that goes against the welfare of the animal. According to Czech law, abandoning an animal with the intention of getting rid of it is categorized as cruelty against an animal, which is prohibited⁸⁴. The same is also stated by Belgian law. The Universal Declaration of the Rights of Animals, published in January 1978, states that the abandonment of an animal is a cruel and degrading act⁴. Laws like these can ensure that people participate in more responsible ownership behaviors, and are aware of the punishments for not

properly providing for an animal or abandoning them in any way.

Public education

In developing countries, the best way to mitigate a problem such as free-roaming dogs and their effects on society, is to start at the root of it. This can be done by educating the public. Public education on dog health, disease, welfare, and behavior is an important aspect that should be emphasized and taught by professionals. Public education can promote responsible ownership of dogs, disease control, a clean environment, and the welfare of dogs and humans. Owners of dogs are important targets when discussing the topic of public education. Owners should be educated on the responsibilities of keeping and caring for a dog, certain behaviors that they display, and necessary steps that must be taken to insure the dogs' wellbeing and health^{1,11}. This prevents the owner from misinterpreting a dog's behavior, having high expectations, or neglecting the needs of the dog. This improves the relationship between the dog and the owner, and ensures that the dog will be secure and unharmed in its new home. Everyone in a community should also have sufficient knowledge on these topics, regardless of whether they are dog owners or not, because it is important for people to understand dog behavior and needs. For example, if communities are more informed on dog behavior and the danger signals that dogs project when they are feeling threatened, they can be more prepared in situations that may lead to bad interactions or attacks from free-roaming dogs¹⁹. Communities understanding dog behavior may also improve the public perceptions of free-roaming and stray dogs⁸⁵, and decrease instances of confrontation.

Besides educating people on how to treat dogs and read their behaviors, it is also important to educate people on disease and specific precautions that they should take to make sure they don't acquire disease. Communities should also be educated on diseases, and specific precautions that they can take to be safe from them. Public education is significant in aiding the control of rabies and other zoonotic diseases. It can reduce disease by encouraging people to get vaccinations, and ensuring that people seek out services if they are potentially exposed to a disease⁸⁶. Public education of disease has proven to be successful in the past with campaigns. In a study that conducted awareness campaigns in Azerbaijan, participants were 1 to 3 times more likely to give correct answers about rabies. Also, the awareness campaign group was around 1-4 times more likely to have their dog vaccinated⁸⁶. As well as preventing dangerous circumstances, education can also increase the success of future solutions that are implemented to solve the issues that stem from free-roaming dogs. Community involvement in certain solutions, as well as a community's understanding of dogs and their behavior, is a factor that the success of solutions is dependent on¹.

Discussion

In this study, we aimed to understand the available literature on three critical issues: reasons and effects for free-roaming dog populations, and the proposed solutions. Most of the papers were done in the USA, with few studies conducted in Asia and Africa. The common reasons mentioned by authors were abandonment and unsterilized dogs. The reported effects were the spread of disease, negatively affecting wildlife, and negatively affecting dog welfare. This literature synthesis adds to the body of knowledge on dog management. This is specifically important because dogs are seen as pets and cherished by many people. There is a need for more research on the same but in Africa and Asia.

From our results, most of the studies were done in the US. This might be because the US is more likely to focus on the issues relating to free-roaming dogs, or because the issue of free-roaming dogs in the US is more prevalent. But there were other sources from a variety of different countries, except they only had one paper. India was more common than other countries, which shows how the issue of free-roaming dogs is more prevalent. However, because this paper focuses on a lot of studies from the US, it shows that there needs to be more studies conducted in countries in Africa and Asia to gain more information about the issue of free-roaming dogs in the world.

The available evidence is from research articles, although commentaries/opinion papers and webpages/blogs were also identified. The many research articles identified could be explained by our inclusion criteria where we focused on original studies during selection of studies. The increasing number of webpages and blog posts could be explained by the rigorous peer review process as some researchers are now opting for blog posts. We included such papers in our study because of the scant information available on this subject. We feared that if we could eliminate them, we would have few studies in our literature synthesis. This, however, shows the need for well-designed original studies on this subject matter. This could prioritize the gaps we have identified in this review, but also review some of the studies conducted in the US in different geographical settings. We recommend this as there was a gap in generalizing most of the studies.

The most common reasons reported were abandonment and relinquishment, and unsterilized dogs. Problems like abandonment are more likely in developing countries because these countries are less likely to have actual animal shelters that owners can adopt and return their dogs from. This can also exemplify free-roaming dog populations when abandoned dogs reproduce. This paper agrees with Mota-Rojas et. al, 2021¹¹ who found that abandonment was one of the main causes for the rising population of free-roaming dogs. However, more exploration needs to be done in Africa specifically, to understand the conditions they are in. We argue this because two studies were from South

Africa and one from Kenya and Zimbabwe, yet Africa has 55 different countries. The evidence from those countries coupled with Asia and South America, will be very vital in informing ministries of animals, pet owners, and policy enforcers. The lack of data from these countries made it difficult to be informed on the problems of free-roaming dogs, which may have decreased the credibility of our solutions. Filling in these gaps will be beneficial for creating the most relevant and feasible solutions for a variety of countries with different socio-cultural contexts.

The most common effects of dog populations were the spread of disease, having negative effects towards wildlife, and negative effects towards dog welfare. Regarding the spread of diseases, many free-roaming dogs do not have access to proper health care and vaccination against diseases like rabies and therefore they can easily be carriers of diseases. This should concern us because these free-roaming dogs if played with, could bite people or children who may want to play with them [roaming dogs] and in the process, they can be bitten. This leads to the transmission of diseases. Some diseases like rabies have a high case fatality rate and we may lose people in the due course. This shows the importance of controlling the rising population of free-roaming dogs since it can pose serious downsides for a variety of different populations. There should be more information spread about the negative effects free-roaming dogs can have on their own welfare, which will increase empathy and make it less likely for solutions to be enacted to be unethical towards the dog populations.

The most common solutions for the rising populations of dogs were education and sterilization. This is because many countries that have high populations of free-roaming dogs do not have access to sterilization for their dogs, and many owners do not have proper education of dog actions and dog care, which can contribute to abandonment or uncontrolled reproduction. These solutions might be possible in developing countries, but it is important to consider that developing countries might not have the resources or law enforcement to create sufficient sterilization programs or education programs. Law enforcement may also face specific obstacles including people not being aware of the laws. Some countries may not have resources to keep track of and enforce laws, and some may not have strong penalties for dog abandonment. In other cases, what constitutes “abandonment” may not be clearly defined. Additionally, investigating cases of abandonment may be difficult and complex for law enforcement. In countries such as India, laws for the free-roaming dog population are poorly enforced and do not tend to be noticed¹. To mitigate these challenges, countries should allow sufficient funds to go towards animal shelters and control agencies. They should also review their laws to prevent loopholes and create strong penalties for dog abandonment.

There may also be some cultural differences when it comes to implementing solutions that can hinder them. Solutions usually rely on attitudes towards dogs, which can depend on the

area. In some areas, dogs are seen as animals that should be protected and not interfered with. In these cases, solutions like sterilization can interfere with the natural reproduction of dogs. Some cultures may have also created traditional practices to manage dogs, and introducing new methods might cause resistance. Solutions like euthanasia are more difficult to implement because people worry about their ethical concerns, especially when the role of dogs in society is more important⁸⁷. Due to this, solutions should be considered differently depending on the country and there should be open collaboration with local leaders and communities to understand their relationship with dogs, and correct any misconceptions, while working to develop new methods that fit the community best. More research should be done on the economic and legislative state of a variety of communities, their relationship with dogs, and the prevalence of free-roaming dog populations to create the best solutions. This paper agrees with other studies that found that education and sterilization would be the best solutions^{20,83}.

This literature review has several strengths. First, it focused on different countries across the globe, and it was able to show the evidence gap in Africa, South America, and Asia. The search was done in PubMed and Google Scholar. A longer duration was considered during the search for articles. The review was done by more than one person, and this could have minimized paper selection bias. This paper used rigorous synthesis of information in Microsoft Excel spreadsheet, which is attached in the submission. We think this is very important as it can inform future researchers of the available gaps as we have highlighted in the Excel document. However, we have several limitations, and these are largely because this study was led by a high school student (Tanisha Pingle, Dougherty Valley High School). This was part of her research program at Lumiere. In this program, Tanisha was learning how to conduct research, which shows that literature synthesis was a great starting point for her. The first limitation is that the methodology/approach in the search for studies was not systematically conducted and this could have led to potential miss of some studies. This paper did not use any statistical analysis, which removes the generalizability from the study and may have led to the risk of bias. Only two databases were searched (PubMed and Google Scholar) raising a possibility of us missing studies from other databases like Web of Sciences, Scopus. Only English papers were considered as the review team could not interpret international languages. It is possible some studies could have been missed because of this. Furthermore, some studies were inaccessible (required paying), and yet this was not a funded study making it hard for these papers to be inputted in this review. There was no focused search guided by epidemiological knowledge on dog roaming before the search started. This could have guided which countries could be targeted in the search for articles. Lastly, we found most studies from the US and therefore our review may not be generalizable to other regions in the world. Conclusion We aimed

to understand the reasons and effects for free-roaming dogs and proposed solutions. Few studies exist on this subject with the biggest evidence gap from Africa, Asia, and South America. The common reasons are abandonment and unsterilized dogs. The reported effects are the spread of disease, negatively affecting wildlife, and negatively affecting dog welfare. The proposed solutions are education and sterilization. There should be more studies conducted in Asian and African countries, but location specific interventions.

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References

- 1 J. Reese, *The state of the animals III: 2005*, Humane Society Press, Washington, DC, p. 55–64.
- 2 S. Atitwa, *How Many Dogs Are There In The World? WorldAtlas*, <https://www.worldatlas.com/articles/how-many-dogs-are-there-in-the-world.html>.
- 3 B. Bundy, *How many dogs are there in the US*, [https://www.hepper.com/how-many-dogs-are-there-statistics/, worldwide? 2023 Updated statistics](https://www.hepper.com/how-many-dogs-are-there-statistics/,worldwide?2023). Hepper.
- 4 N. Cosgrove, *US Worldwide Statistics 2023*, Pet Keen.
- 5 A. Wandeler, A. Budde, S. Capt, A. Kappeler and H. Matter, *Clinical Infectious Diseases*, **10**, 684–688.
- 6 J. Butler and J. Bingham, *Veterinary Record*, **147**, 442–446.
- 7 J. Jackman and A. Rowan, *The state of the animals 2007*, Humane Society Press, Washington, DC, p. 55–78.
- 8 J. Falconer, *Slumdogs by the millions*, Humane Society International.
- 9 G. Patronek, L. Glickman, A. Beck, G. McCabe and C. Ecker, *PubMed*, **209**, 572–581.
- 10 T. Stancheva, *Stray Animal Statistics What Are The Actual Numbers In 2022*, Awesome Advice.
- 11 D. Mota-Rojas, N. Calderón-Maldonado, K. Lezama-García, L. Sepiurka and R. Cassia Maria Garcia, *Abandonment of dogs in Latin America: Strategies and ideas*, *Veterinary World*, p. 2371–2379.
- 12 J. Jensen, P. Sandøe and S. Nielsen, *Animals*, **10**, 1064.
- 13 *World Health Organization: WHO*, <https://www.who.int/news-room/fact-sheets/detail/rabies>.
- 14 S. Bhalla, R. Kemmers, A. Vasques and A. Vanak, *Urban Ecosystems*, **24**, 1245–1258.
- 15 J. Greenebaum, *Journal of Social and Ecological Boundaries*, **2**, 34–55.
- 16 O. Baquero, E. Chiozzotto, R. Cassia Maria Garcia, M. Amaku and J. Ferreira, *Journal of Applied Animal Welfare Science*, **20**, 289–295.

- 17 M. Vučinić, M. Djordjevic, T. Radislava, J. Ljiljana, R. Brana and K. Radislavljević, *Acta Veterinaria-beograd*, **59**, 309–317.
- 18 C. McCrindle, J. Gallant, S. Cornelius and H. Schoeman, *Anthrozoos*, **12**, 157–161.
- 19 M. O’Haire, *Journal of Veterinary Behavior*, **5**, 226–234.
- 20 Y. Hsu and J. Serpell, *Javma-journal of the American Veterinary Medical Association*, **223**, 1293–1300.
- 21 H. Weng, P. Kass, L. Hart and B. Chomel, *Preventive Veterinary Medicine*, **77**, 82–95.
- 22 G. Diesel, D. Pfeiffer and D. Brodbelt, *Preventive Veterinary Medicine*, **84**, 228–241.
- 23 L. Powell, B. Lee, C. Reinhard, M. Morris, D. Satriale, J. Serpell and B. Watson, *Animals*, **12**, 1053.
- 24 L. Powell, D. Chia, P. McGreevy, A. Podberscek, K. Edwards, B. Neilly, A. Guastella, V. Lee and E. Stamatakis, *PLOS ONE*, **13**, 0200276.
- 25 F. E., K. A.H., T. S.A., L. J.J. and M. P.R., *The Journal of Nervous and Mental Disease*, **171**, 461–465.
- 26 K. Allen, J. Blascovich, J. Tomaka and R. Kelsey, *Journal of Personality and Social Psychology*, **61**, 582–589.
- 27 F. E., Z. L. B. and L. R., *Anthrozoos*, **6**, 115–134.
- 28 F. E., T. S.A., C. L.K., T. C.-C. and P. S.J., *Anthrozoos*, **20**, 51–63.
- 29 I. Meyer and B. Forkman, *Journal of Veterinary Behavior*, **9**, 143–150.
- 30 Martínez, G. Pernas, F. Casalta, M. Rey and L. Cruz Palomino, *Journal of Veterinary Behavior*, **6**, 225–231.
- 31 D. Wells and P. Hepper, *Applied Animal Behaviour Science*, **69**, 55–65.
- 32 Y. Takeuchi, N. Ogata, K. Houpt and J. Scarlett, *Applied Animal Behaviour Science*, **70**, 297–308.
- 33 J. Wright and M. Nesselrote, *Applied Animal Behaviour Science*, **19**, 169–178.
- 34 Y. Hsu, L. Severinghaus and J. Serpell, *Journal of Applied Animal Welfare Science*, **6**, 1–23.
- 35 P. Borchelt, *Applied Animal Ethology*, **10**, 45–61.
- 36 P. Roulaux, I. Herwijnen and B. Beerda, *PLOS ONE*, **15**, 0234917.
- 37 C. Marcus, *Effects of neutering on undesirable behaviours in dogs*, Veterinary Practice.
- 38 C. Kaufmann, S. Forndran, C. Stauber, K. Woerner and U. Gansloßer, *Veterinary Medicine*, **2**, 22–37.
- 39 T. Chung, C. Park, Y. Kwon and S. Yeon, *Journal of Veterinary Behavior*, **11**, 26–30.
- 40 S. R. Urfer and M. Kaeberlein, *Animals*, **9**, 1086.
- 41 A. Beck, *American Journal of Public Health*, **65**, 1315–1318.
- 42 C. Mohanty, R. Radhakrishnan, M. Jain, P. Sasmal, H. U., S. Vupalla and S. Doki, *Journal of Emergencies, Trauma, and Shock*, **14**, 23–27.
- 43 S. Shishir, *Animal Homelessness: Stray animals rule the roads, ‘dog’ MCC*, Star of Mysore.
- 44 A. Fournier, E. Geller and E. Fortney, *Behavior and Social Issues*, **16**, 89–105.
- 45 N. Harris, *Journal of the Royal Army Medical Corps*, **147**, 367–370.
- 46 G. Suzán and G. Ceballos, *Journal of Zoo and Wildlife Medicine*, **36**, 479–484.
- 47 R. Rodriguez-Vivas, A. Ortega-Pacheco, R.-A. J.A. and G. Bolio, *Veterinary Parasitology*, **115**, 61–65.
- 48 G. Rautenbach, J. Boomker and I. Villiers, *Journal of the South African Veterinary Association*, **62**, 158–162.
- 49 F. Explainers and F. Explainers, *Noida baby dies after street dog attack: Why do strays become feral and how can they be tamed? Firstpost*, <https://www.firstpost.com/explainers/stray-dog-kills-baby-noida-street-dog-attacks-rise-india-11471771.html>.
- 50 T. Banerjee, *UGC Care Journal*, **68**, 239–242.
- 51 M. Kato, H. Yamamoto, Y. Inukai and S. Kira, *PubMed*, **57**, 261–266.
- 52 S. Watson, *Dog bites*, WebMD.
- 53 K. Bhangnada, H. Wilde, P. Sakolsataydorn and P. Oonsombat, *Acta Tropica*, **55**, 249–255.
- 54 E. Lauer, W. White and B. Lauer, *PubMed*, **136**, 202–204.
- 55 C. Shuler, E. DeBess, J. Lapidus and K. Hedberg, *Javma-journal of the American Veterinary Medical Association*, **232**, 542–546.
- 56 E. Ritchie, C. Dickman, M. Letnic and A. Vanak, *Oxford University Press eBooks*, p. 55–68.
- 57 A. Vanak, C. Dickman, E. Silva-Rodríguez, J. Butler and E. Ritchie, *Oxford University Press eBooks*, p. 69–93.
- 58 J. Hughes and D. Macdonald, *Biological Conservation*, **157**, 341–351.
- 59 I. Wierzbowska, M. Hedrzak, B. Popczyk, H. Okarma and K. Crooks, *Biological Conservation*, **201**, 1–9.
- 60 J. Young, K. Olson, R. Reading, S. Amgalanbaatar and J. Berger, *BioScience*, **61**, 125–132.
- 61 M. Weston and T. Stankowich, *Oxford University Press eBooks*, p. 94–116.
- 62 L. Hennings, *The impacts of dogs on wildlife and water quality: A literature review*, Metro Parks and Nature.
- 63 B. Lenth, R. Knight and M. Brennan, *Natural Areas Journal*, **28**, 218–227.
- 64 L. Kats and L. Dill, *Ecoscience*, **5**, 361–394.
- 65 L. Costanzi, A. Brambilla, A. Blasio, A. Dondo, M. Gorla, L. Masoero, M. Gennero and B. Bassano, *European Journal of Wildlife Research*, **67**, year.
- 66 A. Vanak and M. Gompper, *Mammal Review*, **39**, 265–283.
- 67 T. Hite, *Which country has the most dogs? My Animals*, <https://myanimals.com/breeds/dogs-breeds/which-country-has-the-most-dogs/>.

-
- 68 A. Abdulkarim, M. Khan and E. Aklilu, *World's Veterinary Journal*, **11**, 319–326.
- 69 E., *coli - Symptoms and causes - Mayo Clinic*, <https://www.mayoclinic.org/diseases-conditions/e-coli/symptoms-causes/syc-20372058>, Mayo Clinic.
- 70 *Rabies - Symptoms causes - Mayo Clinic*, <https://www.mayoclinic.org/diseases-conditions/rabies/symptoms-causes/syc-20351821>, Mayo Clinic.
- 71 B. Team, *Birth Control For Dogs: Dog Contraceptive Injection, Pills, More! K9 Of Mine*, <https://www.k9ofmine.com/birth-control-for-dogs/>.
- 72 O.I.E., *Stray dogs population control. OIE*, https://www.woah.org/fileadmin/Home/eng/Health_standards/tahc/current/chapitre.aw.stray-dog.pdf.
- 73 B. Team, *Zoonotic Diseases in Dogs: A complete guide — BetterVet*, Better-Vet.
- 74 A. Salb, H. Barkema, B. Elkin, R. Thompson, D. Whiteside, S. Black, J. Dubey and S. Kutz, *Emerging Infectious Diseases*, **14**, 60–63.
- 75 H. Bacon, H. Walters, V. Vancia, L. Connelly and N. Waran, *Animals*, **9**, 564.
- 76 J. Neilson, R. Eckstein and B. Chi, *PubMed*, **211**, 180–182.
- 77 K. Frucht, G. Drysdale and J. Remfry, *Guidelines for dog population management*, World Health Organization.
- 78 M. Kustritz, *Clinical Techniques in Small Animal Practice*, **17**, 124–128.
- 79 P. Lyu, *Proposal on solutions to stray dog problem in American cities*, Journal of Political Sciences Public Affairs.
- 80 L. Materstvedt, D. Clark, J. Ellershaw, R. Førde, B. G. A. M., H. Müller-Busch and C. Rapin, *Palliative Medicine*, **17**, 97–101.
- 81 B. Purswell and K. Kolster, *Theriogenology*, **66**, 510–513.
- 82 M. Sherley, *Toxicology Letters*, **151**, 399–406.
- 83 A. Alho, C. Lima, V. Colella, L. Carvalho, D. Otranto and L. Cardoso, *Parasites Vectors*, **11**, year.
- 84 A. Passantino, *DOAJ (DOAJ: Directory of Open Access Journals)*, **48**, 97–104.
- 85 L. Gamble, A. Gibson, K. Shervell, F. Lohr, I. Otter and R. Mellanby, *Revue Scientifique Et Technique De L Office International Des Epizooties*, **37**, 543–550.
- 86 E. Hasanov, S. Zeynalova, M. Geleishvili, E. Maes, E. Tongren, E. Marshall, A. Banyard, L. McElhinney, A. Whatmore, A. Fooks and D. Horton, *Epidemiology and Infection*, **146**, 227–235.
- 87 D. Peacock, Unpublished.