

# 14 The Humane Management of Dog Populations and the Contribution to Rabies Elimination

Elly Hiby<sup>1\*</sup>, Pankaj KC<sup>1</sup>, Eric Brum<sup>2</sup> and Katie Hampson<sup>3</sup>

<sup>1</sup>The International Companion Animal Management coalition (ICAM), Cambridge, UK; <sup>2</sup>Emergency Centre for Transboundary Animal Diseases (ECTAD), Food and Agriculture Organization of the United Nations (FAO), Dhaka, Bangladesh; <sup>3</sup>Institute of Biodiversity, Animal Health & Comparative Medicine, University of Glasgow, Glasgow, UK

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## Abstract

Effective rabies elimination requires direct interaction with dogs, principally mass vaccination of dog populations and surveillance for suspected dog rabies cases. The most important dogs to reach are free-roaming dogs who, through their behaviour, are most epidemiologically relevant to rabies. Dog population management (DPM) uses a system of services designed to suit local dog population dynamics to improve responsible dog ownership and humanely minimize the population of unwanted and unmanaged dogs. DPM contributes to rabies control by increasing access to epidemiologically relevant dogs to reach and maintain herd immunity and ensure all dogs are monitored for effective surveillance; this has the potential to reduce the costs of rabies elimination actions. The impacts of effective humane DPM are multiple, hence the political will and funding for DPM should be accessed in addition to funding earmarked for mass vaccination. DPM should not divert resources away from vaccination.

## 14.1 Introduction

The prompt and effective use of post-exposure prophylaxis (PEP) in the treatment of people exposed to the rabies virus through a dog bite is a highly valued lifesaving action in rabies control. But to achieve zero human deaths demands more by ridding the world of this dog-mediated virus completely. This would eliminate the fear and anxiety of people bitten by suspect dogs, the suffering and inevitable death of people and animals from this nearly 100% fatal virus once symptoms appear, and the enormous cost to our health services around the world. It is

this aim that underpins the global call to action 'Zero by 30' which sets the goal of zero human dog-mediated rabies deaths by 2030 worldwide (Minghui *et al.*, 2018).

Elimination of the rabies virus can only be achieved if we interrupt transmission within its reservoir host. For the Zero by 30 goal, this host is domestic dog (*Canis familiaris*). To achieve elimination, we need to recruit the dogs themselves and their immune systems, to kill the virus circulating within their populations by using mass dog vaccination. Thankfully in this war on rabies, we have in our arsenal a highly efficacious, long-lasting and affordable vaccine

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\*Corresponding author: [ellyhiby@icam-coalition.org](mailto:ellyhiby@icam-coalition.org)

against rabies in dogs. And as dogs are a domesticated species, rather than wildlife, we benefit from the dogs being an accessible population to be our soldiers.

Elimination also requires good surveillance of rabies in dogs so that any suspect cases can be promptly and appropriately managed to prevent the virus from spreading further. As a domesticated species, dogs depend on the care provided by people for their survival and hence dogs and people have a close relationship. Even in the absence of formally recognized ownership, we see free-roaming dogs congregating in and mostly reliant on human settlements. This can be a great benefit to surveillance as suspect cases are likely to be noticed by a well-informed public that knows the signs of rabies in dogs.

There are clear gains made from the rabies control journey towards elimination, with proven reductions in dog-bite prevalence (e.g. Tanzania (Cleaveland *et al.*, 2003)), costs to the health service, in terms of PEP (e.g. India (Larkins *et al.*, 2020)) and prevention of human rabies deaths (e.g. Latin America (Vigilato *et al.*, 2013)). The examples of successful rabies control projects, and the political will channelled by Zero by 30, provide the foundation for the elimination of dog-mediated rabies. But it is only by harnessing the immune power of dogs, and in particular, those that are the most epidemiologically relevant to rabies, that virus elimination can be achieved.

Any intervention involving dogs, and in particular these epidemiologically relevant dogs (see [Box 14.1](#)), will need to consider dog

population management (DPM). DPM involves a cohesive set of measures to influence dog population dynamics to achieve a number of goals. These goals include a reduction in public health risks but are not limited to rabies control. In this chapter, we provide an overview of DPM, key factors for effective rabies vaccination campaigns, and then focus on the overlap between DPM and rabies control, specifically on the contribution of DPM to rabies elimination through achieving and sustaining sufficient vaccination coverage and effective surveillance.

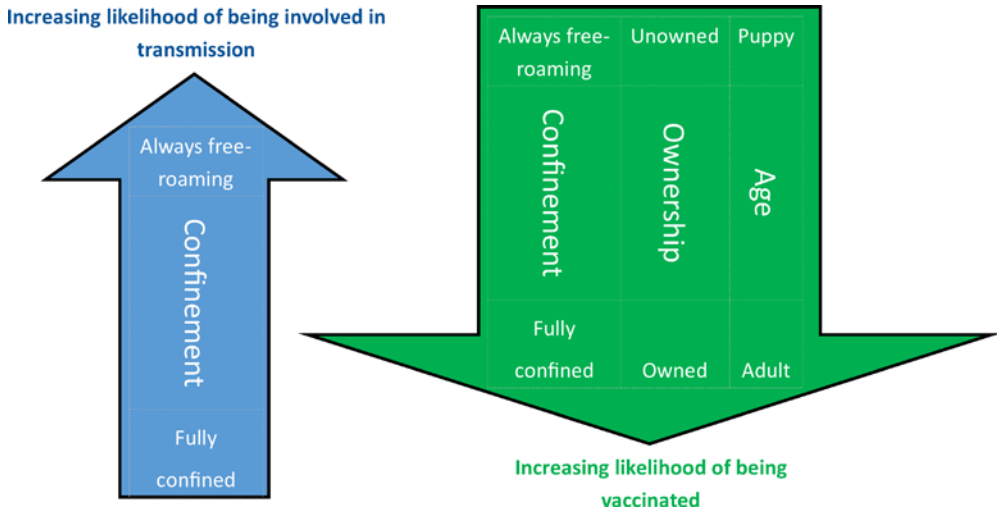
## 14.2 What Is Dog Population Management (DPM)?

DPM starts with an understanding of dog population *dynamics* ([Fig. 14.2](#)). Rabies elimination may require a focus on epidemiologically relevant free-roaming dogs, but population management does not only look at the current unwanted and unowned free-roaming dogs. It also seeks to understand the sources of these dogs and aims to sustainably influence the processes that bring dogs on to the street and make them less accessible to management actions like vaccination. Interventions that work only with the current unwanted and unowned free-roaming dogs may be more accurately termed 'stray control'.

Dog population dynamics differ across communities in Asia, driven by variations in human behaviours. It may seem surprising to emphasize

### Box 14.1. Epidemiologically relevant dogs.

From the perspective of rabies, not all dogs pose equal risk. Dogs that roam freely are likely to have the greatest contact with other dogs and therefore opportunity for viral transmission. Hence if vaccinated, these free-roaming dogs then have the greatest ability to act as a barrier to prevent further spread. Dogs are also not equal in their likelihood of being vaccinated. Owned adult dogs that are confined are more likely to be vaccinated through traditional vaccination delivery strategies such as central-point campaigns or through reliance on owners/carers proactively arranging vaccination with vets or animal health workers. This illustrates how the likelihood of vaccination tends to run in the opposing direction to epidemiological relevance – the most valuable dogs epidemiologically are paradoxically the least likely to be vaccinated ([Fig. 14.1](#)). Vaccination campaign approaches that target free-roaming dogs of all ages and levels of ownership bring vaccination coverage in line with epidemiological relevance. These approaches include door-to-door campaigns, engaging the support of dog feeders and carers to identify and handle community dogs or using expert dog catchers to catch unmarked and therefore unvaccinated dogs in the street.



**Fig. 14.1.** Epidemiological relevance and opposing likelihood of vaccination against rabies for the characteristics of confinement, ownership and age of dogs. Diagram created by International Companion Animal Management coalition (ICAM).

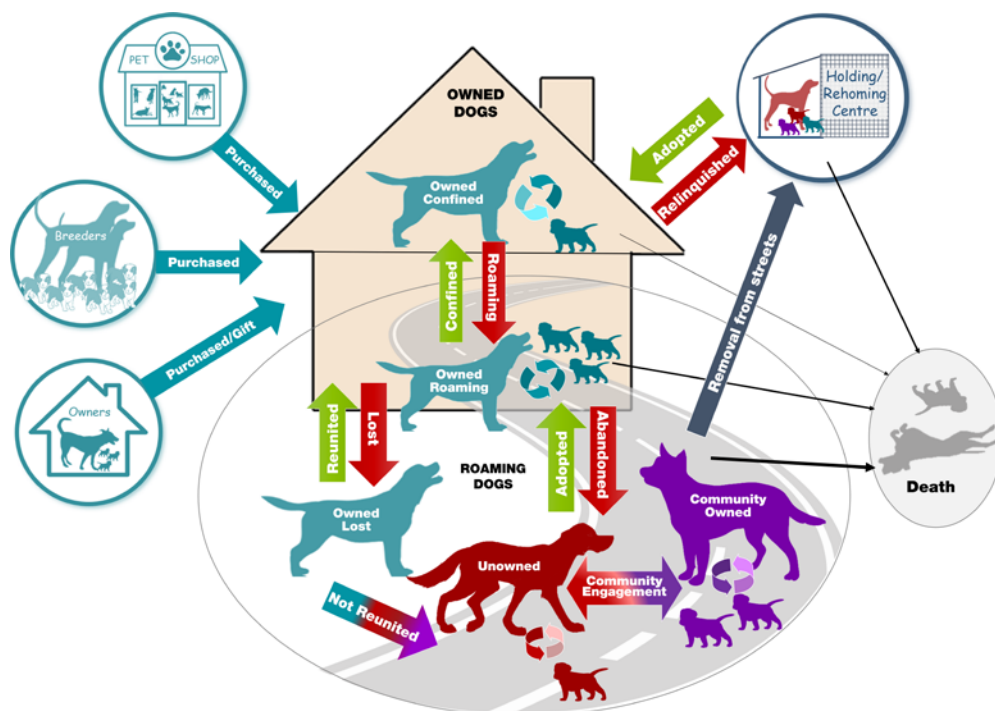
the importance of *human* behaviour in the context of DPM, but all dog population dynamic processes are under the influence of what people *do* with dogs. The process of domestication has resulted in dogs being reliant on care provided by people for their survival and reproduction and they are unable to maintain their populations independently of the resources provided by people (Boitani *et al.*, 2017).

Some communities will be tolerant towards free-roaming dogs, offering them food and shelter and hence community dogs will make up a large proportion of their free-roaming dog population. Other communities, particularly in rural areas, will allow their owned dogs to roam freely to fulfil homestead, crop and livestock protection roles or because the physical structures of their home do not offer humane methods of confinement, resulting in most free-roaming dogs being owned roaming dogs. Some communities keep owned dogs confined within private property and are intolerant of free-roaming dogs. In other communities in Asia, there is an active trade in dog meat with consequences for animal welfare and rabies transmission. These differences in human behaviour will alter what types of dogs make up the free-roaming and epidemiologically

relevant population and the processes that act as sources of these dogs. By identifying these sources, authorities can then select which DPM services will be most effective.

A DPM system is a cohesive programme of services, supported by a foundation of legislation, political will and social motivation (ICAM, 2019a, pp. 31–78) (Fig. 14.3). This system works to establish a positive relationship between dogs and their owners or carers ('carers' in the case of community animals without a single referral household). This positive relationship is characterized by responsible human behaviour to maintain good welfare and mitigate risks that dogs may present to other animals, the environment and people.

The services which make up the DPM system include four fundamental services which are critical to all DPM systems; and five context-dependent services (ICAM, 2019a, pp. 48–76) (Fig. 14.3). Context-dependent services are not always required but there will be some communities in which they become important to implement and also possible to enforce. For example, introducing identification and registration into a community where animal health services have neither the resources nor capacity for inserting and reading microchips would be a



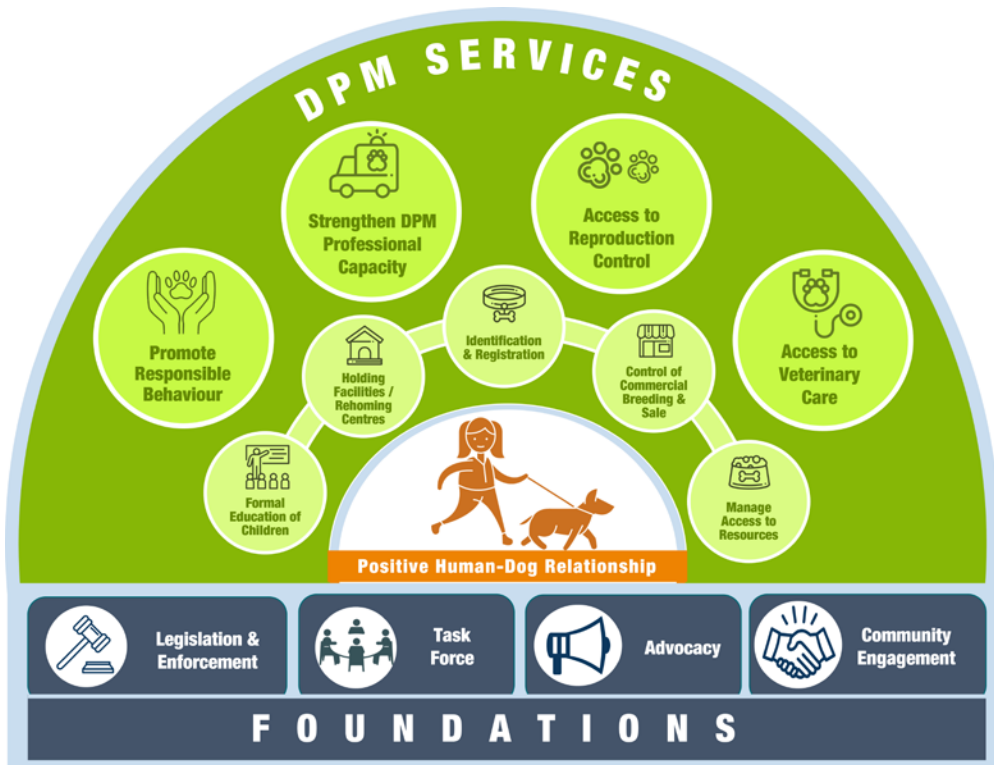
**Fig. 14.2.** Simplified representation of dog population dynamics. Dog states are represented by labelled dog icons and dynamic processes by labelled arrows. From ICAM, 2019a.

waste of resources that could be better spent on greater vaccination efforts.

Fundamental services:

1. Promoting responsible behaviour – This involves a combination of legislation, behaviour change communication and social pressure to increase responsible, safe and compassionate behaviour towards dogs.
2. Strengthening DPM professional capacity – Recognizing and investing in relevant professions, including veterinarians, animal handling/care and enforcement agencies is vital so that the services required for responsible ownership are accessible and of good quality.
3. Reproduction control – Access to reproduction control services is fundamental to all population management as the humane way to limit population size (rather than increased mortality) and limit the production of puppies to those that are wanted. Ensuring access requires overcoming
4. Veterinary care – Access to veterinary care ensures owners and carers can keep their animals in a good state of welfare and limit the risk of zoonotic diseases. It brings them into contact with animal health workers and veterinarians who can encourage responsible ownership behaviours and provide an opportunity for disease surveillance. Ensuring access may require subsidies for owners with limited resources and outreach services for those owners unable to reach static facilities. Veterinary care includes timely rabies vaccination to protect animals

barriers to reproduction control, which may include cost, veterinary capacity and skills, and transporting animals to clinics. Catch, neuter, vaccinate and return (CNVR) is an approach to control the reproduction of unowned animals that are to be managed *in situ* on the streets. (See discussion at the end of this section for how this can be used as an alternative/in combination with rehoming services.)



**Fig. 14.3.** Diagrammatic representation of a dog population management (DPM) system. From the 'Humane dog population management guidance' in ICAM (2019a)

and people from this virus and to mitigate inappropriate reactions to rabies outbreaks.

Context-dependent services:

1. Formal education of children – This includes education about safe and compassionate interaction with dogs and preventative measures for both children and animals to protect health, including prompt dog-bite treatment.
2. Holding facilities and rehoming – These can be provided through shelters or foster networks, achieving efficient and reliable reuniting of lost dogs and a humane and responsible option of relinquishment (rather than abandonment) followed by efficient rehoming to new suitable homes. (See discussion at the end of this section for how this can be used as an alternative/in combination with CNVR services.)
3. Identification and registration – Central or interoperable regional/local databases support efficient reuniting of identified and registered lost owned animals. This also provides proof of ownership for enforcement, traceability and tracking/reminders relating to health measures (where health records are linked to registration). Widespread adoption may be achieved through voluntary systems but mandatory legislation may be required.
4. Control of commercial breeding and sale – Puppies should be healthy, well socialized and habituated, leading to increased retention by new owners. Breeders, sellers and consumers are aware of expected standards and those below standard are identified and improved/penalized.
5. Managing access to resources – This is important to reduce conflict with free-roaming dogs. Improved waste management has been touted as a solution to stray control.

However, if free-roaming dogs are reliant on this food source, a sudden reduction would lead to starvation and is hence not humane and can lead to increased conflict as free-roaming dogs search for alternative sources. Rather than *reducing* food sources, these can be *manipulated* by moving food sources away from high-conflict areas to more appropriate locations, for example, using feeding stations. Poor waste management causes other more significant problems, including water contamination and air pollution, so an improvement in waste management over time is to be expected regardless of population management motivations. It is the role of population management to prepare the dog population for the inevitable improvement in waste management driven by other motivations, ensuring free-roaming dogs are appropriately resourced by owners and carers and not reliant on waste for their nutrition.

Core to the population management system is addressing the source of future unwanted and unowned free-roaming animals. Owners that have the knowledge, motivation, and ability to access services to practise responsible ownership behaviours can prevent their dogs from contributing to population management problems. This includes the services of affordable reproduction control and veterinary care for owners to invest in managing their dog's reproduction and health. The animal health services may also have the capacity to support owners by implementing an identification and registration system to reunite lost owned dogs and to enforce regulations on dog breeding and sale to ensure owners can acquire dogs knowing they are safe and healthy.

But this DPM system must also address the current unwanted and unowned free-roaming dogs. This requires careful consideration of how to use two relevant services. These are not mutually exclusive and can be used in combination:

- Holding facilities/rehoming centres or 'shelters' for relinquished pets and unowned dogs removed from the streets for reuniting or rehoming. Factors to consider include:
  - Rehoming 'centres' do not need to be physical structures. This service can be delivered through foster networks with potential economic and animal welfare benefits.
  - For rehoming centres to be a functional service, there must be a culture of adoption, providing a reasonable chance that an animal will be rehomed, otherwise centres fill to capacity or become places where most dogs will be euthanized. CNVR may provide a management option while building adoption capacity.
- Reproduction control and veterinary care provided to unowned animals using CNVR leading to the management of unowned animals *in situ* on the streets. Factors to consider include:
  - Tolerance and acceptance of free-roaming dogs by the majority of the public is necessary for dogs to maintain good welfare following CNVR.
  - For an individual animal to be considered a suitable candidate for CNVR, there should be evidence that the animal can maintain an acceptable level of welfare living on the streets. Very young animals or those with health issues may be best suited to rehoming. Where CNVR is used, ideally, rehoming is also available as an option for individual animals that are not suitable for release.
  - Community dogs that enjoy some care from local people may be able to breed successfully on the street. CNVR will also limit their breeding as a source of future unowned dogs.
  - There is a risk that when legislation prohibits the abandonment of owned animals, authorities may interpret the release of sterilized dogs as a form of abandonment. In such situations, agreement with the authorities on the difference between 'abandonment' and 'release' will need to be sought before starting CNVR.

The assessment of which of these two options is most appropriate for managing

unwanted and unowned dogs will differ between communities and over time. Both shelters and CNVR have been misunderstood as equating to population management when used in isolation. A service focused only on the current free-roaming population is not comprehensive population management as it does not address the sources of unwanted and unowned dogs; conceptually akin to continuously refilling a leaking bucket without first fixing the leak. Although it should be noted that CNVR does have the benefit of addressing one important source: the birth of unowned puppies on the street by currently unowned or community dogs. Rehoming and CNVR function as part of a DPM system and must be used in combination

with other services that also address other sources of future unwanted and unowned dogs.

### 14.3 Culling

Culling of dogs as a method of stray control, and as part of rabies control, has been used many times throughout history but has been repeatedly found to be ineffective and unpopular. Reasons for its lack of effect and unpopularity are listed in [Table 14.1](#).

From a rabies perspective, one may argue that when faced with a free-roaming unowned or community-owned dog, killing it removes the dog as a potential transmission vector. However,

**Table 14.1.** Reasons for not culling dogs.

Reason	Explanation <sup>a</sup>
Population dynamics	<ul style="list-style-type: none"> <li>Minimal impact on the source of future unwanted and unowned free-roaming dogs and culling reduces competition over resources for the remaining dogs, hence populations quickly recover.</li> </ul>
Disease (rabies) transmission	<ul style="list-style-type: none"> <li>Mistaken assumption that fewer dogs will mean less rabies, but rabies transmission is largely density independent, so there is only a minimal reduction in transmission with reduced density (Hampson <i>et al.</i>, 2009).</li> <li>Where vaccinated dogs are either not marked, or these markers fail over time, culling may disproportionately remove vaccinated dogs as they tend to be more accessible. Culled dogs quickly replaced by owners (through purchase or birth) are also likely to be unvaccinated. Together this reduces herd immunity.</li> <li>Culling can inadvertently increase contact between dogs and lead to rabies spread to other populations due to social perturbation or people moving their dogs to avoid culling teams.</li> </ul>
Social acceptability	<ul style="list-style-type: none"> <li>Support for culling is limited and may be actively protested against in some communities, in particular when alternatives such as vaccination or CNVR are possible. Reports of owned and vaccinated dogs being culled are frequent and lead to further mistrust between government services and local communities.</li> <li>Acceptability will be particularly low where inhumane methods of culling are used (WOAH lists recommended and unacceptable methods of killing dogs in Chapter 7.7 of the <i>Terrestrial Animal Health Code</i>; (WOAH, 2022b)).</li> </ul>
Cost	<ul style="list-style-type: none"> <li>Culling appears straightforward and cheap, but costs per dog can be higher than rabies vaccination, not least because vaccination campaigns can recruit widespread public action in support of campaigns, which is not the case for culling.</li> </ul>
Ethics	<ul style="list-style-type: none"> <li>Non-lethal and effective alternatives to culling for DPM and rabies control exist, and dogs are sentient beings with the capacity to suffer, hence ethical arguments do not support culling.</li> </ul>

<sup>a</sup>CNVR, catch, neuter, vaccinate and return; DPM, dog population management; WOA, World Organization for Animal Health.

this dog will be quickly replaced through birth and immigration by a new dog, almost certainly unvaccinated, resulting in no benefit to rabies control. Instead, there is the option to vaccinate and release such dogs, maintaining population stability and creating a biological barrier to virus spread with an immunity 'trap' of rabies antibodies in these vaccinated and released dogs. To be an effective biological barrier, 70% of the population needs to be vaccinated to achieve herd immunity, as described in Section 14.6.1 'Sustaining herd immunity', later in this chapter.

In recent history, the attempt to control a rabies outbreak in Bali was wholly unsuccessful when mass culling was used, but showed immediate and significant improvements in reducing dog bites, dog rabies cases and human rabies cases once mass dog vaccination was used instead (Putra *et al.*, 2013; Suseno *et al.*, 2019). The expert consultation by WHO reports:

Mass dog vaccination has repeatedly been shown to be effective for controlling dog-mediated rabies, whereas removal of dogs does not decrease dog density or control rabies in the long run. Mass culling of dogs should therefore not be a part of a rabies control strategy: it is ineffective and may be counterproductive to vaccination programmes, particularly when they target free-roaming dogs.

(WHO, 2018a, pp. 79–80)

Culling is the killing of an animal for purposes other than its own welfare, while euthanasia is killing an animal to prevent its further suffering. Although culling has no place in DPM or rabies control, all organizations that have direct interaction and responsibility over dogs must have a euthanasia policy in place and the capacity for humane methods of euthanasia (the World Organization for Animal Health (WOAH) lists recommended and unacceptable methods of killing dogs in Chapter 7.7 of the *Terrestrial Animal Health Code*; WOAH, 2022b). This includes organizations responsible for implementing mass rabies vaccination campaigns, holding and rehoming centres and CNVR services. This policy should be founded on animal welfare principles, appropriate to national legislation and local regulations, and realistic to implement within their veterinary, physical

and staff capacity. The goal is that euthanasia is only used for those dogs that are suffering from an incurable illness, an injury, or have an unmanageable behaviour problem that prevents them from being rehomed or released, or are not coping well enough with rehoming facilities to maintain reasonable welfare. For some countries with limited rehoming potential and limited resources, this threshold for euthanasia may not be achieved immediately, but is the goal to work towards. The use of euthanasia for dogs showing signs of rabies is encouraged to prevent their suffering and protect human health and should be followed by prompt testing for laboratory confirmation of a rabies diagnosis. Where feasible, quarantine may be used to observe the dog for the progression of signs of rabies. If signs of rabies become evident, dogs should be euthanized, while any dog that remains healthy can be confirmed as not rabid. Further details about quarantining in the event of an animal bite are discussed in Section 14.6.2 'DPM contribution to rabies surveillance' and in other chapters on Integrated Bite Case Management (e.g. see Chapter 6, this volume).

In addition to culling, another common practice in parts of Asia that is both relevant to animal welfare and rabies control is the dog meat trade (Asia Canine Protection Alliance, 2013). We purposely do not cover the dog meat trade in any detail here, since it is beyond the scope of this chapter. However, we note that the dog meat trade is renowned for inhumane practices and has no place in humane DPM (FOUR PAWS, 2020). Hence our discussion is only to highlight potential rabies risks inherent in the trade. In countries where the dog meat trade is large and purposeful breeding of dogs for meat is limited, the removal of dogs for meat may impact owned and free-roaming populations. The turnover of dog populations in settings with an active dog meat trade is expected to be particularly high, creating large susceptible populations in which rabies can easily spread. The movement of dogs for the meat trade is frequent, often over large distances, and even across national borders, making rabies incursions into new areas a risk. These factors, together with the complete lack of regulations to reduce transmission through quarantine or vaccination means that the trade presents an obstacle to rabies elimination. Moreover, in communities with dog meat



consumption, the risk of transmission between dogs and people, at all points of handling, killing and during the slaughter process is high (Wertheim *et al.*, 2009). For these reasons, there is a need for engagement with the dog meat trade for the joint aims of improved animal welfare and for eliminating dog-mediated rabies.

#### **14.4 Key Factors for Successful Vaccination**

Successful dog vaccination campaigns for progressive control and elimination of rabies share the key factors outlined in [Table 14.2](#).

#### **14.5 Intersection Between DPM and Rabies Control**

Rabies control and DPM share a focus and a need to access epidemiologically relevant dogs. Although they have aims specific to their particular scope, they also share the overlapping aims of protecting animal and human health. Hence there is an opportunity for synergy and mutual benefit between these interventions. In this section, we return to the concept of rabies elimination as a war against the rabies virus and dogs as our soldiers to hunt down and kill the virus with their immune systems. We look specifically at how DPM helps us to leverage the capacity of these dog soldiers towards rabies elimination through achieving and sustaining vaccination coverage and effective surveillance ([Fig. 14.4](#)). The question we aim to answer here is: 'If I am responsible for vaccinating the greatest possible proportion of the dog population, or I am responsible for spotting and quickly responding to suspect rabies cases, how can DPM help me do that?'

#### **14.6 Vaccination Coverage Where It Matters Most**

We started this chapter with the concept of epidemiologically relevant dogs and their value in the war on rabies. But we know that many rabies vaccination campaigns achieve their

greatest coverage in populations of dogs that are confined and are at limited risk of rabies transmission as well as in populations already covered by previous campaigns. This is not to say that vaccination of these dogs should not be done, but coverage in only this subpopulation will not achieve rabies elimination. It is the epidemiologically relevant dogs that need to be recruited, and yet they are often missed by vaccination campaigns year after year, providing an ongoing reservoir of susceptible hosts. DPM can increase the accessibility of these dogs through improved responsible dog ownership, community engagement, CNVR and improved staff capacity and skill. Finally, accessing these dogs for vaccination breaks the cycle of transmission within their populations and supports virus elimination.

The promotion of responsible dog ownership is a fundamental service of DPM and is achieved through legislation, behaviour change communication, social pressure and legislation working together to change human behaviour. A feedback loop of owner behaviour improvement can be supported through DPM services by increasing the value of their dog; the more management investment made in the dog, including sterilization and parasite control, the more it may be valued by an owner and the more effort they may expend in maintaining their dog in good health and welfare through future management investment, including regular vaccination. In practical vaccination campaign terms, an owner that values their dog is more likely to make an effort to catch and physically transport, or at least handle, their dog for vaccination teams, reducing campaign effort and therefore resources. They may even take the step of proactively having their dog vaccinated through animal health services outside of vaccination campaigns, eliminating the cost of vaccinating this dog entirely from campaign budgets. Conversely, an owner that has amassed a perceived excess of dogs through unwanted breeding, may not value his/her dogs sufficiently to spend their time and resources on vaccination, or may only expend effort on a preferred few.

Accessing more than 70% of the dog population during an annual mass vaccination campaign is not feasible without community engagement and support. Some

**Table 14.2.** Factors for successful vaccination campaigns.

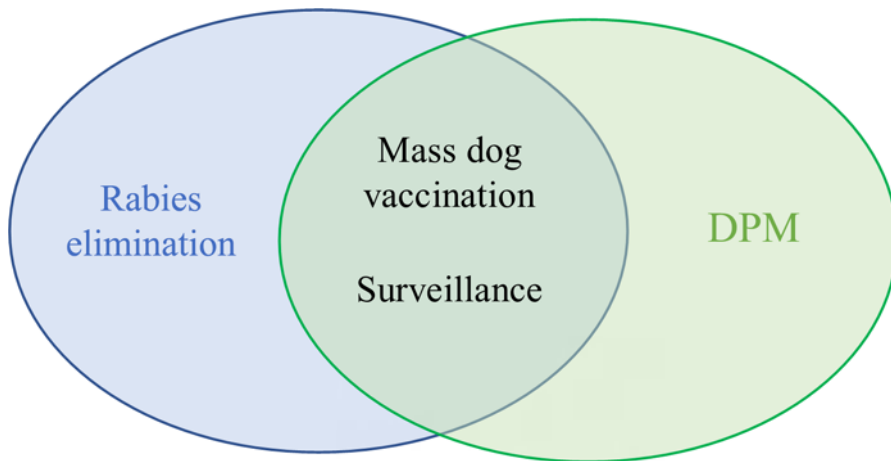
Factor	Description <sup>a</sup>
Preparation for vaccination	<ol style="list-style-type: none"> <li>1. Prepare and document vaccination plan in consultation with stakeholders, including required financial, human and material resources.</li> <li>2. Provide pre-exposure prophylaxis and training in humane dog capture and handling, appropriate vaccine storage and handling, vaccine administration, and managing exposure to suspect rabid animals.</li> <li>3. Procure and prepare all required materials and equipment.</li> <li>4. Inform communities ahead of planned vaccination activities to increase community participation and reduce the time required to complete vaccination.</li> <li>5. See further guidance in the WOAAH <i>Terrestrial Animal Health Code</i> Chapter 4.18 (WOAH, 2022a).</li> </ol>
Vaccination	<ol style="list-style-type: none"> <li>1. A 3 year vaccine should be used for mass dog vaccination and stray dog vaccination, including during CNVR activities. The cold chain should be maintained at all levels of vaccine storage until administration, but importantly, efforts to maintain the cold chain should also ensure no vaccine is frozen, which is more likely to reduce vaccine efficacy.</li> <li>2. A minimum coverage level of at least 70% of the dog population should be achieved in all administrative units of the area targeted for control. For accelerating time to elimination, higher coverage levels may be targeted.</li> <li>3. For maximal impact on rabies virus transmission, epidemiologically relevant dogs should be prioritized. Methods for safe capture and handling (e.g. dog nets) should be used when dogs cannot be readily caught or safely restrained by hand.</li> <li>4. Long-term markers (e.g. permanent collars) should be applied to all vaccinated adult dogs for monitoring vaccination coverage and enabling communities to differentiate vaccinated from unvaccinated dogs. Short-term markers (e.g. non-toxic paint marks) should be used for vaccinated puppies and applied to adult dogs only when there are insufficient resources for the purchase of long-lasting collars.</li> <li>5. Vaccination should be applied on at least an annual basis. For accelerating viral elimination, 6-monthly vaccination campaigns may be considered and/or strategies to target new puppies in the interval between campaigns.</li> <li>6. To slow the decline in vaccination coverage levels over time, population turnover should be minimized by utilizing the DPM tools described in this chapter.</li> </ol>
Monitoring vaccination coverage	<ol style="list-style-type: none"> <li>1. Vaccination data should be recorded following the vaccination of each individual animal and stored within an electronic database (resolved to the smallest available administrative unit).</li> <li>2. Vaccination coverage should be monitored at the smallest administrative level possible (e.g. sub-village) by either post-vaccination surveys or by comparing to vaccination tally from the previous campaign in which the vaccination target was achieved.</li> </ol>
Monitoring vaccination efficacy	<ol style="list-style-type: none"> <li>1. Rabies cases in humans and animals should be monitored.</li> <li>2. Integrated Bite Case Management may be used for increasing the sensitivity of detection of animal rabies cases (WHO, 2018a, p. 126).</li> </ol>

*Continued*

**Table 14.2.** Continued

Factor	Description <sup>a</sup>
Response to suspect rabid dogs	<ol style="list-style-type: none"> <li>1. Rapid detection and removal of rabid animals are crucial to reduce the spread of rabies and community impact.</li> <li>2. All persons dealing with suspect rabies cases or entering a field situation where there may be rabid animals should receive a full course of pre-exposure prophylaxis before initiating activity (WHO, 2018a, p. 58).</li> <li>3. Suspect animals should be evaluated and animals demonstrating signs of rabies should be humanely euthanized and submitted for testing as per the WOAHA <i>Manual of Diagnostic Tests and Vaccines for Terrestrial Animals</i> Chapter 3.1.18 (WOAH, 2018).</li> <li>4. Refer to the WHO (World Health Organization), 2018c position paper on rabies vaccines and immunoglobulins for guidance on humans exposed to suspect rabid animals (WHO, 2018c).</li> <li>5. A positive rabies case in an area is an indication for immediate vaccination of the area, including revaccination of previously vaccinated dogs (note that reactive vaccination will have limited impact if not undertaken rapidly, i.e. within the week of the detected animal case, and is not a replacement for comprehensive routine vaccination in endemic settings). Culling should not be carried out.</li> </ol>

<sup>a</sup>CNVR, catch, neuter, vaccinate and return; DPM, dog population management; WHO, World Health Organization; WOAHA, World Organization for Animal Health.



**Fig. 14.4.** Mass dog vaccination and surveillance activities are at the intersection of rabies elimination and dog population management (DPM) programmes. Diagram created by ICAM.

epidemiologically relevant dogs will be particularly difficult for vaccination teams to reach without the help of community members known and trusted by these dogs to find, catch and handle them. As community engagement and action are a foundation of an effective DPM system, locations with already functioning DPM are likely to have stronger communication and support from local communities. In particular,

where DPM systems have involved CNVR, which have the opportunity to recruit community members into accessing and monitoring community dogs, these same individuals can support mass vaccination campaigns of community dogs (see [Box 14.2](#) Case Study 1 about the ManuMitra programme).

By definition, CNVR accesses only epidemiologically relevant dogs that are always free

**Box 14.2. Case studies of synergy between DPM and rabies control.****Case study 1**

ManuMitra ('friend of human') is a comprehensive programme to manage dog populations and control rabies in Kathmandu, Nepal (ICAM, 2019b). One key aspect is the engagement of animal management assistants (AMAs) – local volunteers with a track record of caring for animals in the community. AMAs join a peer-supported training programme covering rabies prevention and control, veterinary first aid and post-operative care for sterilized dogs. They work closely with ManuMitra veterinarians and animal welfare officers to ensure all their local dogs are vaccinated by helping to find, identify and catch dogs that they know. They also identify dogs for sterilization, first gaining consent from an owner or carer for every dog. AMAs provide ongoing monitoring of free-roaming dogs, informing ManuMitra staff when new dogs needing vaccination or sterilization arrive, treating those with minor ailments and skin disease *in situ* and remaining vigilant for suspect rabies cases. AMAs are the experts in their local dogs, and as local residents are best placed to ensure saturation of rabies vaccination and DPM effort in their ward while being continuous advocates for responsible dog ownership and animal welfare.

**Case Study 2**

Help In Suffering has been running a CNVR programme in Jaipur, India, since 1994 complying with the national Animal Birth Control (Dog) Rules, 2001. This involves spaying and vaccinating female dogs, castrating and vaccinating young males and vaccination only of adult males, as castration is expected to make little difference to their behaviour and vaccination only uses fewer resources; each dog is vaccinated once in its lifetime. The vaccine used conveys 3 years of immunity. With a high coverage of the population (> 75%) and these dogs' relatively short lifespan of around 3 years (Reece *et al.*, 2008), this is estimated to maintain immunity in >40% of the dog population. An economic assessment of the period 1994–2017 estimated CNVR had averted over 360,000 dog bites at a cost of US\$5.62 million. In addition, nearly 500 human rabies deaths had been averted by animal birth control (ABC) over the 23-year period. When added to the US\$5.62 million saved from bites averted, this becomes a total societal economic benefit, estimated to be US\$38.48 million. A sizeable financial benefit compared to the US\$658,744 cost of Help In Suffering's ABC work over 23 years; for every US\$1 spent on ABC, US\$8.50 were saved in dog-bite treatment and US\$58.40 in total societal economic losses from both rabies and bites (Larkins *et al.*, 2020).

**Case Study 3**

A fishing community on the outskirts of Karachi, Pakistan, called Ibrahim Hyderi, became the site of Rabies Free Karachi's pilot One Health project. This project involved mass dog vaccination and CNVR of free-roaming dogs, as well as distinctive yellow collars to provide a visual indication that dogs had been treated. The Rabies Free Karachi team also conducted workshops and engaged local people to gain their support in implementing the activities and explain the meaning of the collars. An exploratory follow-up survey of a small sample of local people revealed satisfaction with the project, a more positive perception of the collared dogs and visually more relaxed and friendly behaviour towards these specific treated dogs. Replication of this pilot in other areas of Pakistan is under way with similar results. However, it should be recognized that some people have strongly entrenched opinions of dogs based on previous negative experiences, and for them, the presence of a collar and knowledge of prior treatment may be insufficient to change their perceptions. DPM requires long-term engagement and high population coverage to achieve the changes in the free-roaming dog population required to meet the needs of all citizens. (More details of this case study are provided by Salahuddin *et al.* in Chapter 15, this volume and in WHO, 2018b).

roaming. CNVR is usually running throughout the year rather than as an annual pulse, steadily building the proportion of the free-roaming dogs that are vaccinated and preventing the birth of unvaccinated puppies on the street. Although regular revaccination of 'CNVRed' dogs is the ideal approach, the short lifespan of these

free-roaming unowned or community-owned dogs makes a single vaccination at the time of sterilization sufficient for effective rabies control (Reece and Chawla, 2006) (see Box 14.2 Case Study 2 about Help In Suffering in Jaipur). However, a potential conflict between CNVR and rabies control can occur where vaccination

is tied to sterilization, as this can limit the geographical scope and coverage of mass vaccination. A preferred approach is for vaccination and sterilization to be decoupled, allowing for vaccination only when appropriate, for example with male dogs and during mass vaccination campaigns, with CNVR following up the rest of the year as resources allow.

Some epidemiologically relevant dogs will be behaviourally difficult to catch and handle for vaccination. DPM services present a need and an opportunity to invest in the recruitment and skills development of dog handlers on an ongoing basis; these expert staff can then be utilized for mass vaccination campaigns.

#### 14.6.1 Sustaining herd immunity

The critical percentage of the dog population that must be immune for disease control is related to the basic reproductive number ( $R_0$ ) of the disease; for rabies  $R_0$  is typically between 1 and 2, resulting in a critical percentage of 20–40% (Hampson *et al.*, 2009; Brum, 2019). However, the recommended threshold coverage for an annual vaccination campaign is 70% (Coleman and Dye, 1996; WHO, 2018a, p. 79). This higher target ensures that population turnover between annual campaigns does not allow herd immunity to fall below the critical percentage. While incursions of rabies virus still occur, herd immunity must be sustained above the critical percentage to prevent transmission. DPM can support herd immunity by reducing population turnover and providing services for the vaccination of puppies and newly acquired dogs in the period between annual vaccination campaigns (Table 14.2).

Targeted reproduction control services can reduce the birth of puppies that were likely to go unvaccinated and would have driven herd immunity down. This includes sterilization of community and unowned dogs, and owned dogs identified by their owners as unwanted for breeding. A focus on the spaying of female dogs is likely to have the greatest impact on the production of such ‘at risk’ puppies, as females are the limiting factor in dog population growth. Sterilization coverage should be monitored to check these targets are being met and avoid

reliance on dogs that are easier to access and sterilize but less important for ‘at risk’ puppy production, such as castration of owned and confined male dogs.

The other population turnover process important for herd immunity is the survival of dogs that have been vaccinated. Sterilization may support the survival of vaccinated dogs by removing the energetic costs of reproduction, increased contact rates, and associated disease transmission risk of breeding behaviours. The previously described feedback loop of improved owner behaviour with increasing management investment may also increase survival as the amount and quality of care provided to dogs is likely to be positively correlated with their perceived value.

A critical service of the DPM system is access to veterinary care. Unlike annual mass vaccination campaigns, these services provide year-round access to basic healthcare including rabies vaccination. This provides owners with the opportunity to have puppies and newly acquired dogs vaccinated in the period between vaccination campaigns, an action that should be encouraged through responsible dog ownership education. Veterinary services should also offer humane euthanasia for individual dogs that are suffering from an incurable illness, injury, or a behaviour problem that their owners find unmanageable. This provides an important alternative to abandonment and protects dogs from further suffering. These veterinary services may be private, government, or a combination through government subsidies of private veterinary care.

#### 14.6.2 DPM contribution to rabies surveillance

When rabies outbreaks do occur, their control, and therefore the prevention of human and animal deaths, relies on surveillance and prompt quarantine or humane euthanasia and testing of suspect cases. Where DPM systems exist, the proportion of the dog population that is not under the management of an owner or community carer should be reduced, therefore dogs with signs of rabies are less likely to go unnoticed and accessing dogs for revaccination

in response to an outbreak will be easier. Rabies spread in unmanaged populations of dogs is more likely to go unnoticed until deaths occur in either people or livestock.

Integrated Bite Case Management, or IBCM, is an approach that can improve surveillance and human rabies prevention, including delivery of PEP resulting in faster and more effective management of outbreaks (Suseno *et al.*, 2019; Swedberg *et al.*, 2022). This requires functioning communication channels and a working relationship between human and animal health services, with animal health alerting human health when suspected animal cases occur, and human health alerting animal health when they treat a bite from what is considered to be a symptomatic rabid dog. These alerts include the location and date/time to allow action to be taken by the relevant services. Where DPM systems are in place, animal health services will have greater knowledge of the dog population across their jurisdiction and contacts with owners and carers, allowing them to respond faster and with greater accuracy.

#### **14.6.3 Funding dog-mediated rabies elimination – DPM contribution and conflict**

The elimination of dog-mediated rabies requires widespread vaccination of epidemiologically relevant dogs in all rabies-endemic countries. Resourcing this effort requires funding from local and national governments, supported by donor agencies, pharmaceutical companies and non-governmental organizations (NGOs). In this section, we discuss how DPM systems can contribute to these resources by reducing the costs of rabies control. But there is also the potential for conflict over limited resources and hence resources need to be carefully prioritized, and opportunities are taken to bring in additional funding sources through the wider goals of DPM.

Dogs resort to biting people for a number of reasons. This is usually motivated by fear and has nothing to do with a rabies virus infection. But in an abundance of caution, human health services in countries with endemic rabies may treat these bites as a suspect rabies exposure,

because of the fatal implication of untreated rabies exposure. DPM can help to reduce this costly bite treatment and wastage of PEP by working to remove some of the motivations and contexts that can lead to dog bites. This includes a reduction in maternal defensive aggression (Reece *et al.*, 2013) and a reduction in breeding behaviours, such as competition between males over females in oestrus, which can spill over into aggression towards people. Further, DPM systems may include community and school education initiatives that include bite prevention strategies leading to an avoidance of contexts and human behaviours that may provoke a dog to bite. The use of clear identifying markers for vaccinated free-roaming dogs, such as long-lasting collars, can also support the avoidance of fear-motivated bites. As community members begin to perceive these vaccinated dogs as less of a threat to their health they may treat them with less outward aggression, subsequently avoiding situations where dogs may feel they need to defend themselves by biting (see [Box 14.2](#), Case Study 3 on vaccination collars in Karachi, Pakistan).

We have previously described how DPM can increase vaccination coverage where it matters most through responsible dog ownership and community engagement. Increasing the engagement and the actual action of owners and carers in catching and bringing dogs for vaccination reduces the reliance on expert catchers and handlers, and the cost of hiring these professionals. Payment for vaccination of owned dogs during vaccination campaigns has been shown to reduce coverage (Dürr *et al.*, 2008) and any barriers to achieving high coverage should be avoided during vaccination campaigns. However, outside of vaccination campaigns, owners should be encouraged to access and pay for vaccination through available animal health services, in particular for puppies and newly acquired dogs that come into their care between vaccination campaigns. For owners that can afford vaccination, proactively and independently accessing animal health services for their dogs, leaves government-funded vaccination campaign resources available for those owners that cannot afford these services. Promoting the benefits of other population management interventions may make owners' investment in vaccination more likely, as part of

a package of sterilization and parasite control for their dog.

Conflict can occur where resources that could be used for vaccination alone appear to have been limited to a smaller geographical area by requiring associated DPM measures such as sterilization. Vaccination for rabies should be a priority, as this protects both human and animal health. However, DPM has the potential to achieve additional aims, including: (i) reduced dog bites (in addition to rabies exposures); (ii) improved dog welfare; (iii) reduced free-roaming dogs and associated public safety and public perceptions; and (iv) negative impacts on wildlife and livestock. Hence DPM has the potential to bring in *additional* funding, political support and community engagement that would not otherwise have been available for rabies elimination alone. But this can only be achieved through effective stakeholder engagement and partner collaboration, making clear the collective goals to be achieved and pre-empting their potential for conflict.

## 14.7 Conclusion

Whether the goal of Zero by 30 is achieved will be driven by rabies elimination success in Asia, the continent with the highest burden of human rabies deaths and PEP costs (Hampson *et al.*, 2015). The elimination of dog-mediated rabies is possible, but only by accessing epidemiologically relevant dogs for vaccination and through effective surveillance actions that are supported by DPM. Reflecting on rabies control success in Latin America, we can see this was achieved through widespread and high-coverage dog

vaccination, apparently without additional DPM investment (Vigilato *et al.*, 2013). However, dogs are valued in many parts of Latin America by their owners and community carers (Yue, 2019), and we hypothesize there was already greater investment and action in DPM when rabies control was launched in earnest in the 1980s. This made free-roaming epidemiologically relevant dogs more accessible for vaccination by their owners and carers. In Asia, the lack of DPM systems and associated responsible dog ownership makes these dogs harder to access. This does not mean rabies elimination will fail, but that investment in DPM is likely to be needed, and indeed wanted, by politicians and communities to support rabies elimination and bring additional benefits. It should also be recognized that the scale, investment and political will behind rabies vaccination in Latin America was far greater than anything seen in Asia to date and this greater commitment underpins their success.

Looking long-term, government-funded annual mass vaccination campaigns should not be required as the vast majority of the dog population should be proactively vaccinated by their responsible owners through accessible veterinary services throughout the year. This is the current situation in most high-income countries. DPM systems help achieve this long-term vision of sustainable herd immunity by raising owner expectations of their responsibilities along with investment in the veterinary profession required to service these owned dogs. Achieving this across Asia will be a long process for some countries, but this journey needs to begin with investment in DPM systems.

## Authors' Declaration

All authors declare that they have no conflict of interest.

All authors have approved this manuscript, agree with its submission, and share collective responsibility and accountability.

This manuscript has not been published or is not under review elsewhere.

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