Full length paper

Rabies Prevention and Control Program in Bhutan: Self-assessment using SARE Tool

TENZIN TENZIN[1]* | KARMA RINZIN[2] | KINLEY PENJOR[3] | KINZANG DUKPA[1] | RINZIN K. JAMTSHO[4] | YOENTEN PHUENTSHOK[1] | HIRUKA MAHAT[1] | KINLEY CHODEN[5] | KUENZANG GYELTSHEN[6] | JIT B. DARNAL[7]

[1] National Centre for Animal Health, Department of Livestock, MoAF, Thimphu, Bhutan
[2] Animal Health Division, Department of Livestock, MoAF, Thimphu, Bhutan
[3] Military Hospital, Ministry of Health, Deothang, Bhutan
[4] Department of Public Health, Ministry of Health, Thimphu, Bhutan
[5] Wildlife Conservation Division, Department of Forests and Park Services, MoAF, Thimphu, Bhutan
[6] Bhutan Agriculture and Food Regulatory Authority, MoAF, Phuentsholing, Bhutan
[7] Royal Centre for Disease Control, Department of Public Health, Ministry of Health, Thimphu, Bhutan

*_Author for correspondence_: tenzinvp@gmail.com

ARTICLE HISTORY

Received: 26/11/18
Peer reviewed: 17/12/18
Received in revised form: 29/12/18
Accepted: 01/01/19

KEYWORDS

Bhutan
Dog
Human
Rabies
SARE tool

ABSTRACT

Free-roaming dogs and dog bites are a common public health problem in Bhutan. Several control measures were implemented during 1980s including mass killing of dogs by shooting and poisoning. Other control measures such as ad-hoc sterilization and vaccination against rabies, translocation and impounding of dogs were also implemented to reduce dog population and control rabies in the country. From 2009, catch-neuter-vaccinate-release program was initiated to manage dog population and control rabies in the country. Currently rabies outbreaks in animals are commonly reported in southern parts of the country with sporadic incursion into interior rabies free areas. However, no human rabies deaths were reported since 2017. The country is on track to achieve its target to eliminate dog-mediated human rabies deaths by 2030 through One health approach. In this study, we reviewed rabies situation in Bhutan in terms of past and current control measures, gaps and future needs for rabies control using a *"Stepwise Approach towards Rabies Elimination [SARE] tool"*. We highlighted the areas where more attention is required in order to eliminate rabies in Bhutan. The SARE output was used to develop a "Strategic plan for elimination of dog-mediated rabies in Bhutan by 2023" by incorporating all the agreed activities of Global framework for the elimination of dog-mediated human rabies.

1. INTRODUCTION

Rabies is a cross-border issue in Bhutan. Several control measures were implemented in the past and is being undertaken currently to manage dog population and control rabies using One heath approach. There is a global movement to achieve zero human deaths from dog-mediated rabies by 2030 [WHO 2015, WHO 2018]. With the goal of strengthening a One Health-based strategy for rabies control in Bhutan and to achieve zero by 30, technical experts from Ministry of Agriculture and Forests and Ministry of Health held a collaborative meeting on World Rabies day – 28 September 2017 – to evaluate the national rabies control programme and determine future needs for rabies control in Bhutan using the Stepwise Approach towards Rabies Elimination [SARE] tool [https://canineraviesblueprint.org/A-stepwise-approach-to-planning].

2. MATERIALS AND METHOD

We briefly reviewed the rabies situation in Bhutan in terms of rabies incidence in animals and humans, past and current control measures, gaps and future needs for rabies control. This was followed by description of the features of the SARE tool and then conducted rabies control programme assessment by providing scores for the activities implemented and also highlight the areas where more attention is required in order to eliminate rabies in Bhutan. We then presented findings obtained through the SARE assessment to the group. The SARE output was used to develop a "*Strategic plan for elimination of dog mediated* framework for the elimination of dog- *rabies in Bhutan by 2023"* by incorporating all the activities within the broad framework of the agreed activities of global goal to eliminate dog-mediated human rabies deaths [WHO 2015].

2.1 Description of SARE tool

The SARE tool, developed by FAO and the Global Alliance for Rabies Control [GARC] provides a self-assessment guide for the evaluation of the current rabies prevention and control activities and to define what is required to move forward for rabies control programmes in respective countries [FAO 2012, 2013]. The SARE tool provides an "Excel assessment scoresheet" with measurable steps, designed as a logical flow of activities, to progress from Stage 0 to Stage 5, in an efforts towards freedom from dog-transmitted rabies. Countries with no information on rabies start at Stage 0, while others may start further along the scale, and when the country reaches Stage 5, it is free from dog-transmitted rabies [Fig 1]. The SARE tool allows us to provide a '0' [pending activities] or '1' [completed activities] score for each activity that needs to be completed. A SARE score is then calculated automatically. The SARE is an integral part of the Canine Rabies Blueprint [http://caninerabiesblueprint.org], a readily accessible, open source tool which provides practical detailed methods and guidance to implement each activity in the SARE in a progressive and systematic [stepwise] manner [https://caninerabiesblueprint.org/A-stepwise-approach-to-planning].

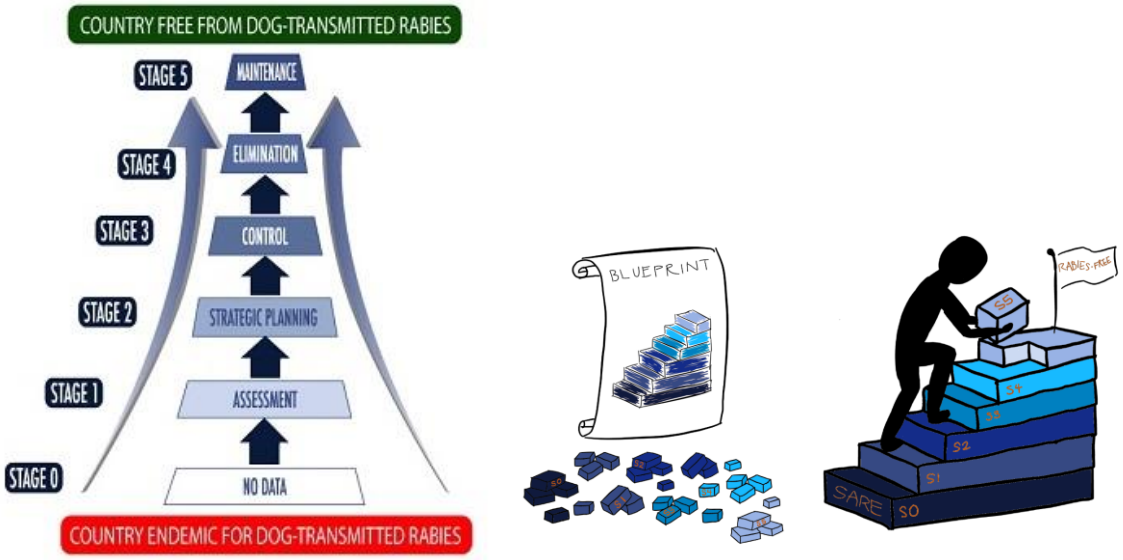

Figure 1: A five stage of SARE steps

The categories of SARE assessment is linked to the agreed activities of Global framework for the elimination of dog-mediated human rabies [STOP-R] developed in 2015 with a STRATEGIC VISION: ZERO HUMAN DEATHS FROM DOG-MEDIATED RABIES BY 2030 [see Table 1] [WHO 2015].

2.2 Description of SARE Stages from 0 to 5

The five Stages of the SARE tools is broadly summarized in Table 2.

Table 1: Global framework for the elimination of dog-mediated human rabies [STOP-R].

S [Socio-cultural]	IEC - Information, education and communication
	DPO - Dog population related issues
T [Technical]	PCO - Prevention and control
	DCA - Data collection and analysis
	LAB - Laboratory Diagnosis
O [Organization]	CCI - Cross-cutting issues
P [Political]	LEG - Legislation
R [Resources]	R - Resources

2.3 Description of 7 Categories and 120 Specific Activities of SARE

The SARE tool is divided into 7 relevant categories with 120 stage-specific activities, viz: legislation [13 specific activities], data collection and analysis [22], laboratory diagnosis [13], information, education and communication [21], prevention and control [26], dog population related matters [13], and cross cutting issues [12]. Each stage-specific activity under each category needs to be addressed and then determined whether a country progresses to the next Stage. The specific categories and number of specific activities under each category comprising the SARE tool are summarized in Table 3.

The above method allows each category to be addressed in a focused and goal-orientated manner. Although each category has detailed stage-specific activities that need to be addressed, implementation of a specific critical activities determines whether a country progresses to the next Stage. Therefore, not all of the activities are mandatory for advancement, but still provide clear guidelines with regards to elements that need to be addressed in order to control and eventually eliminate rabies. These additional elements also allow countries to progress in half increments if more than 50% of the non-critical activities are addressed within a specific stage [Coetzer et al. 2016]. However, there are 4 activities which are considered crucial from the beginning and across all stages and includes [1] Dog vaccination [2] Rabies awareness/communication [3] Accessible PEP and [4] Capacity for rabies diagnosis/surveillance.

Table 2: Description of five Stages of SARE [refer Figure 1].

Stages	Description
STAGE O [No data]	*No information on rabies available, but rabies is suspected to be present:* No systematic recording of clinical rabies or animal bite events occur, but suspicion of rabies being present [any species] is based on episodic clinical description [in animals or humans] or historic confirmation [many years ago]. There is no, or no recent, laboratory diagnosis of rabies [by a laboratory inside the country or by an international reference laboratory]. There are no national rabies control guidelines or, if available, are not implemented or inappropriate to the country's situation.
STAGE 1 [Assessment]	*Assessment of the local rabies epidemiology, elaboration of a short-term rabies action plan:* Situation assessment: At this stage the government assesses existing structures, activities and available resources. Data collection/analysis: The country analyses existing data on rabies, such as animal bite-related events and existing prevention and control activities in at least some parts of the country. Outbreak investigation: Some follow-up of outbreaks and cases has already been conducted or initiated. Collated information and experiences lead to a short-term action plan regarding initial needs and success stories. Stakeholder analysis: It is important to gain insight into the potential stakeholders involved in rabies prevention and control in the country, and to understand the needs of rabies affected communities. Action plan: This stage includes activities to lay the foundation for the elaboration of a future national rabies prevention and control programme and strategy. Resources: Typically, at this stage there is no, or only limited, funding allocated to rabies control.
STAGE 2 [Strategic planning]	*Development of a national rabies prevention and control strategy:* The activities indicated in the previous stage continue to evolve. Based on the short-term rabies action plan there is development of needed capacity and elaboration of SOPs or protocols. Development of a national strategy based on an improved epidemiological understanding and knowledge about the prevailing institutional landscape. Identification of options for funding [national and international].
STAGE 3 [Control]	*Full-scale implementation of the national rabies control strategy:* The capacity to implement the national rabies control strategy is established and functional. Rabies risk is reduced through implementation of the national control strategy. All key stakeholders are engaged in the implementation of the strategy and regular meetings to share information and evaluate progress of rabies control and elimination take place. No human rabies cases are reported.
STAGE 4 [Elimination]	*Maintenance of human rabies freedom, elimination of dog rabies* Maintaining the elimination of dog-transmitted human rabies and elimination of dog rabies. Sustaining implementation of the national elimination strategy including development of plans for the post-elimination phase.
STAGE 5 [Maintenance]	*Freedom from human and dog rabies being monitored:* Monitoring freedom from human and dog rabies. The national post-elimination strategy is developed and implemented.

3. RESULTS AND DISCUSSION

3.1 SARE assessment results

Our assessment indicated that 107 of the 120 Stage-specific activities were accomplished and the country have progressed to Stage 3.5/5 [see Table 4, Figure 2]. However, the following gaps were identified for each category and scored '0' during evaluation since no specific activities were implemented.

3.2 Data collection and analysis

- Have field investigations for all suspected human rabies cases been conducted?

Prevention and control:

- Have modified protocols for PEP administration for rabies-free areas been implemented?
- Has dialogue been initiated with neighbouring countries to prevent the re-introduction of rabies into designated rabies-free zones?

- Has freedom from dog-transmitted rabies in the entire country been verified by the absence of canine variant cases for at least a 2-year period?

Laboratory diagnosis:

- Are wildlife samples submitted for rabies laboratory diagnosis?

Dog population related issues:

- Have dog population management and responsible dog ownership campaigns been continued after the elimination of canine-mediated human rabies?
- Have dog population management and responsible dog ownership campaigns been continued as part of the post-elimination strategy?

Information, education and communication:

- Have awareness programmes focusing on the maintenance of freedom from dog and dog transmitted human rabies been implemented?
- Have human rabies free zones been declared publicly?
- Has national freedom from dog-transmitted rabies been publically declared?
- Has national freedom from canine-mediated human rabies been publically declared?

Cross-cutting issues:

- Has the contribution and role of private sector been clarified and shared with other stakeholders?

Table 3: Description of SARE Categories and Specific activities.

Categories	*Description*	*Activities [# activities]*
Legislation	Focuses on the existing legislation pertaining to rabies control and elimination in the country/region being assessed	- National case definition for animal rabies [2] - National case definition for human rabies [2] - Legal framework [9]
Data collection and analysis	Focuses on assessing the existing surveillance network and capabilities to perform epidemiological analyses within the country/region being assessed	- Surveillance [20] - Health economic studies [2]
Laboratory diagnosis	Focuses on the diagnostic capacity at both national and regional levels of the country/region being assessed	- Specimen referral [2] - Laboratory capacity and testing [11]
Information, education and communication	Focuses on all of the advocacy initiatives being implemented in the country/region being assessed	- Public awareness [8] - Professional education [5] - Advocacy [8]
Prevention and control	Focuses on existing disease intervention strategies that are being implemented in the country/region being assessed	- Human vaccines [7] - Dog vaccines [8] - Outbreak response and other rabies control activities [11]
Dog population related matters	Focuses on all dog population related questions [population size/turnover] in the country/region being assessed.	- Dog population management [13]
Cross cutting issues	Focuses on the collaboration between various stakeholders in the development of control strategies being planned or implemented in the country/region being assessed	- Intersectoral collaboration [6] - National programme and strategy [6]

3.3 Epidemiology and control of rabies in Bhutan

3.3.1 Rabies in animals

Rabies outbreaks had occurred frequently throughout the country until 1992. Mass dog vaccination and dog population management program had reduced the incidence of rabies in the interior parts of the country [Tenzin et al., 2012]. Currently, rabies commonly occurs in the southern parts of the country that share border with India [Tenzin et al., 2011]. However, sporadic outbreaks are reported in some of the rabies free districts in Bhutan as a result of incursion of disease from the bordering areas, and risks establishing endemic transmission [Tenzin et al., 2010, Tenzin et al., 2011; Tenzin et al., 2017]. Between 1996 and 2017, a total of 366 village level outbreaks in animals were reported [average 17 outbreaks/year] and caused death of 1070 domestic animals viz: 551 cattle [51%], 442 dogs [41%], 22 cats [2%], 19 horses [1.7%], 18 goats [1.6%], 16 pigs [1.4%], and 2 sheep [0.2%] [Figure 3] [Tenzin 2017].

Table 4: Summary of the SARE result in Bhutan.

Stepwise Approach towards Rabies Elimination - Bhutan , 2017

STAGE 3.5

ACTIVITY SUMMARY

COMPONENTS	PENDING ACTIVITIES	ACCOMPLISHED ACTIVITIES
Data collection and analysis *Total number of activities = 22*	1	21
Prevention and Control *Total number of activities = 26*	3	23
Laboratory diagnosis *Total number of activities = 13*	1	12
Dog population related issues *Total number of activities = 13*	2	11
Information, Education, Communication *Total number of activities = 21*	4	17
Cross-cutting issues *Total number of activities = 12*	2	10
Legislation *Total number of activities = 13*	0	13

STAGE SUMMARY

STAGE*		PENDING ACTIVITIES	ACCOMPLISHED ACTIVITIES	STAGE COMPLETED?
0	Total number of activities = 6	0	6	COMPLETED
0.5				COMPLETED
1	Total number of activities = 44	0	44	COMPLETED
1.5				COMPLETED
2	Total number of activities = 31	1	30	COMPLETED
2.5				COMPLETED
3	Total number of activities = 23	5	18	COMPLETED
3.5				PENDING
4	Total number of activities = 10	4	6	COMPLETED
4.5				PENDING
5	Total number of activities = 6	3	3	PENDING

* Scores in increments of 0.5 show progress along a particular stage.

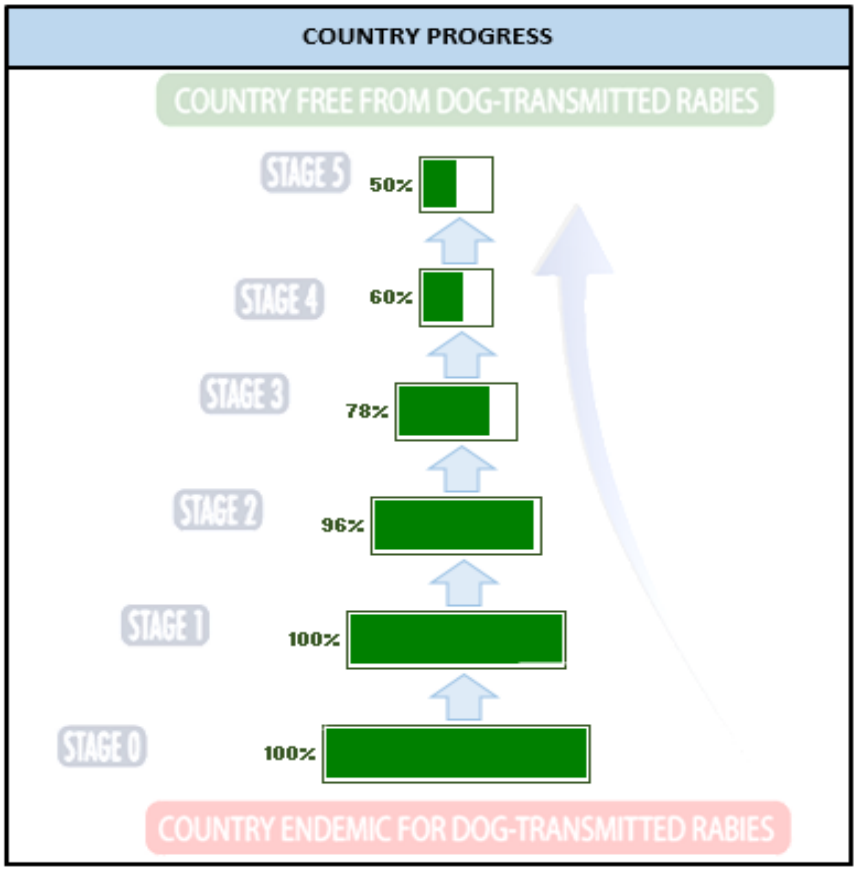

Figure 2: Summary of the five stages of SARE scores in Bhutan**.**

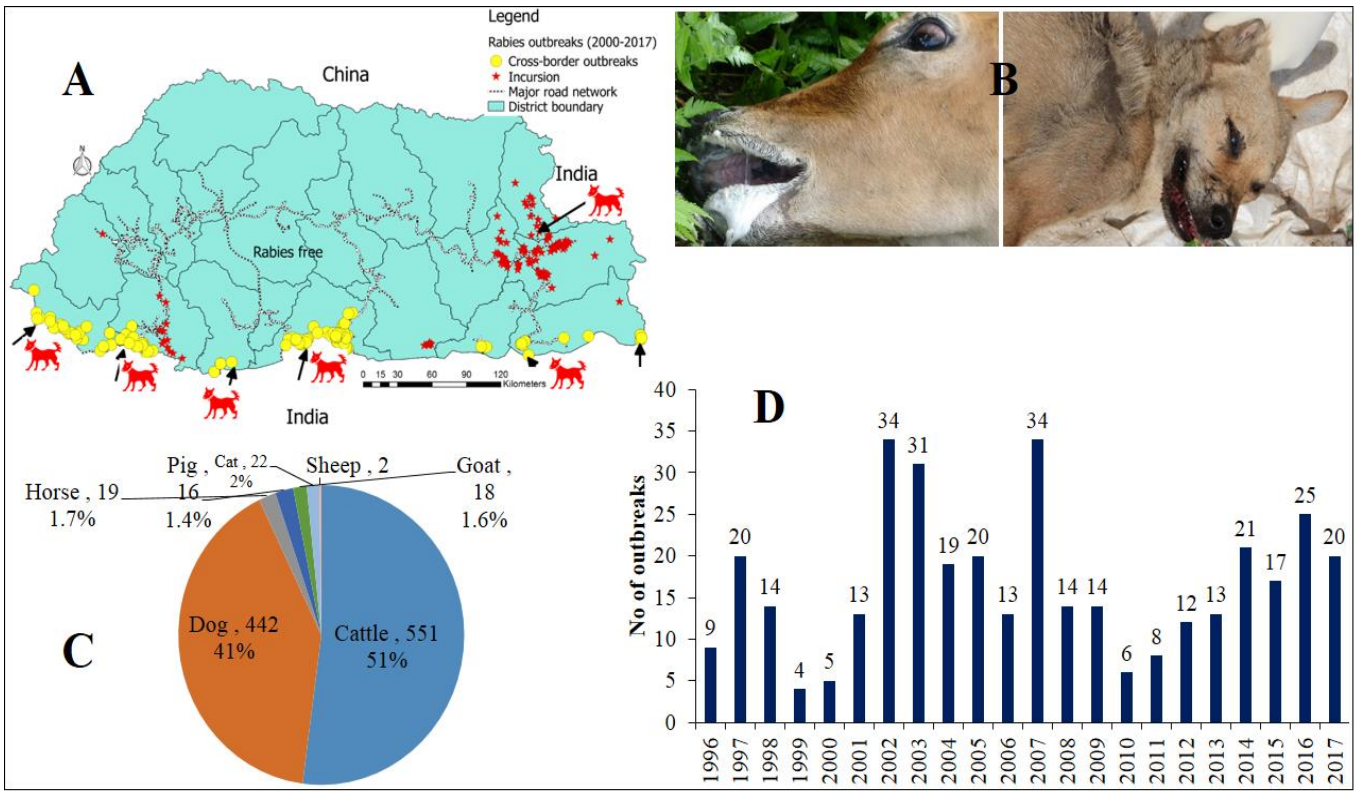

Figure 3: Geographic distribution of rabies in Bhutan [A]; Rabies cases in animals [B]; Distribution of rabies in animals [C] and Temporal distribution of rabies outbreaks in animals [# of outbreaks between 1996-2017] [D].

3.3.2 Rabies in humans

Dog bites in human is a common public health problem in Bhutan. Approximately 7000 dog bites [1026 bites per 100,000 people] are reported annually in the country [Tenzin et al. 2011; Tenzin et al. 2017; Kinley et al. 2019]. However, vast majority of the cases occur in interior rabies free Bhutan and are commonly due to healthy dog bites and poses no risk to rabies infection. Between 2006 and 2016, 17 human deaths attributed to rabies, equating to a cumulative incidence of 0.23 per 10,000 population were reported [Tenzin et al. 2012; Kinley et al. 2019]. However, no human rabies deaths were reported in 2017 and 2018 [Figure 4].

3.3.3 Rabies diagnostic and surveillance system

Rabies is a notifiable disease in Bhutan and any suspect cases are reported for confirmation by laboratory test. Suspect cases in animals are screened against rabies virus using rapid antigen detection test and further confirmed by FAT. Between 2015 and 2017, 178 brain tissue samples from rabies suspect animals [dogs: 103, other animals: 75] were collected and tested positive for rabies virus at the National Centre for Animal Health laboratory [NCAH]. Bhutan currently have two functional FAT facilities at NCAH, Thimphu and Regional Livestock Development Centre [RLDC], Khangma while rapid tests are being conducted by four satellite veterinary laboratories [Deothang, Nganlam, Gelephu and Phuentsholing], RLDCs and district veterinary laboratories. Molecular analyses are also conducted occasionally to determine the rabies virus strains circulating in the country [Tenzin et al. 2011; Jamil et al. 2012]. However, human health does not have rabies diagnostic facilities and suspect cases are diagnosed based on history of exposure and clinical signs/symptoms of rabies. Human cases can be diagnosed in animal laboratory if sample is collected and submitted.

3.4 Legislation on rabies control

Livestock Act of Bhutan 2001 and Livestock Rules and Regulation of Bhutan 2017 clearly specifies zoonoses management including rabies. The national rabies prevention and control plan 2017 [NCAH 2017] and human rabies management guideline 2014 [MoH 2014] is being followed to guide rabies prevention and control activities in the country. To further strategize the national efforts to achieve zero human deaths due to dog-mediated rabies before the global target of 2030, Bhutan One Health Strategy Plan 2017–2021 provide guidelines for the implementation of rabies prevention and control in the country.

3.5 Rabies prevention and control in human - past and present

Rabies prevention and control activities are coordinated at the national level using One Health approach. Post exposure prophylaxis [PEP] and human rabies immunoglobulins are made accessible through network of 30 hospitals and 210 BHUs in the country. All animal-bite victims that visit the hospitals/BHU to seek medical care are provided wound care and PEP

for rabies if necessary, after careful assessment by the clinical staff [Kinley et al, 2019]. Bhutan stopped use of nerve tissue vaccine in 1996 and used Essen regimen [intramuscular vaccination using human diploid cell vaccine] until 2012. Currently, cost-effective updated Thai Red Cross Intradermal regimen [2–2–2-0-2] which requires four visits on day 0, 3, 7 and 28 post-exposure is being adopted and used in Bhutan.

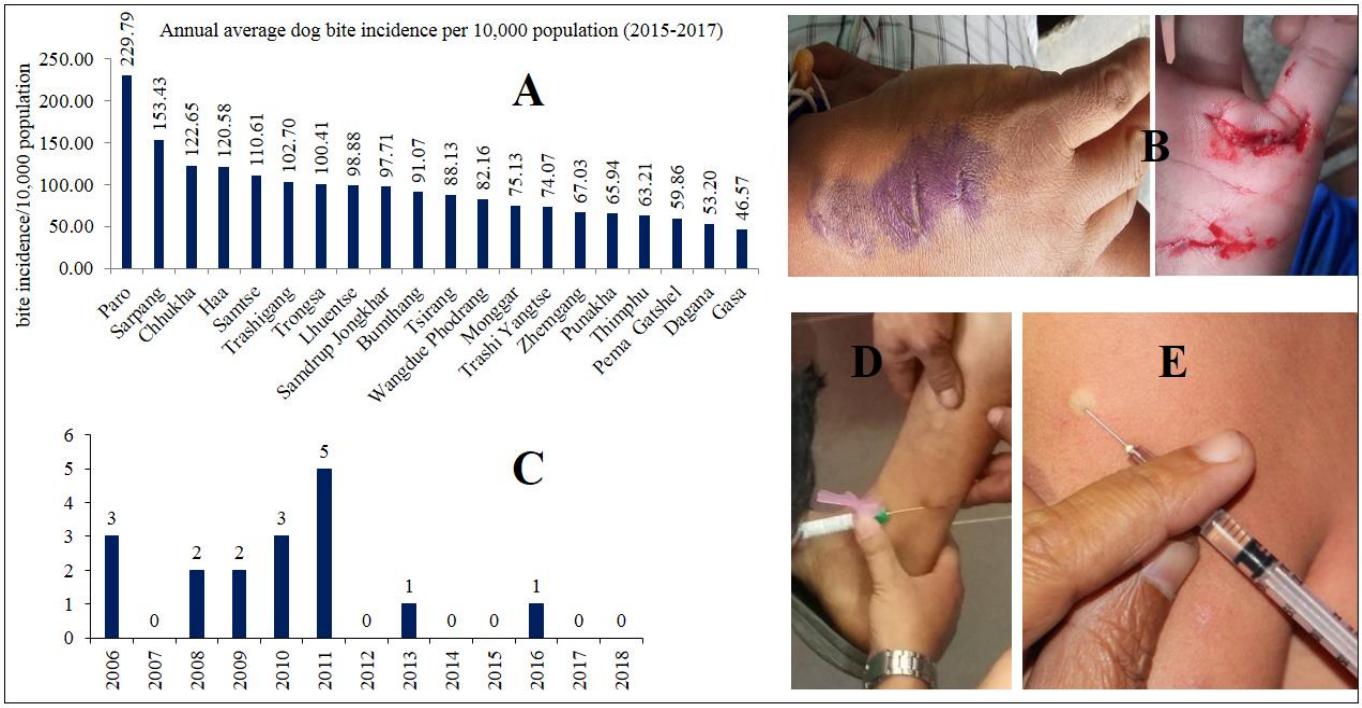

Figure 4: Average annual incidence of dog bites reported to different health centers in Bhutan [2015-2017] [A]; a case of confirmed rabid dog bites in human [B]; human rabies deaths in Bhutan [2006-2016] [C]; and human rabies immunoglobulin [D] and intradermal rabies vaccine being administered in rabies exposed people [E].

3.6 Rabies prevention and control in animal - past and present

3.6.1 Shooting and mass killing of dogs

The frequent outbreaks of rabies in the 1980's in many parts of the country prompted the government and the WHO to initiate rabies control programmes that involved mass killing of stray dogs. The dart guns, syringes and drugs to kill free-roaming dogs were distributed to all districts and several livestock staff were trained in using the equipment in each district. Some trained dog shooters were also employed to shoot dogs in the urban areas/public places as part of rabies control programme; however, it was considered inhumane and was strongly opposed by the general population [Rinzin 2015].

3.6.2 Poisoning and killing of dogs

Dogs were also poisoned using strychnine as part of the rabies and dog population control programme. The strychnine tablets were placed in raw meat and fed to the dogs [Rinzin 2015].

3.6.3 Selective culling of dogs during rabies outbreaks

From 1990 until recently, culling of free-roaming dogs was undertaken only in the rabies outbreak area [Tenzin et al., 2010; Tenzin et al. 2011, Rinzin 2015].

3.6.4 Ad hoc sterilization and vaccination campaigns

Campaigns have been organized in various dzongkhags to sterilize and vaccinate both owned and stray dogs. To increase the effectiveness of such campaigns cash incentives have been given to people who catch and bring in dogs. However, the coverage and frequency of the campaigns have varied between dzongkhags due to a range of constraints including lack of financial resources. Most surgeries were conducted on the ground and in the open with poor facilities [Rinzin 2015].

3.6.5 Translocation of dogs

Although translocation of dogs has not been a recommended strategy to control the dog population, it was implemented in some dzongkhags. Dogs were caught from public places, loaded into trucks and transported to another dzongkhag territory and into the border areas. There was a report of dogs being dropped at Sengor in Mongar dzongkhag by the Bumthang dzongkhag authority. These dogs subsequently attacked and killed some sheep in Sengor which lead to a dispute between the Bumthang and Mongar dzongkhag authorities [Rinzin 2015].

3.6.6 Impounding of dogs

The increasing stray dog population issue was discussed in length during the 87th session of the National Assembly in June 2007 and it was resolved to build dog pounds in all 20 districts to render the towns free of stray dogs by December 2007. Separate dog pounds were built in all districts and impounding of dogs in most of the districts was initiated and were fed and looked after by paid caretakers. It was realized that impounding dogs was not the best solution to control the dog population as it was not affordable and could result in serious welfare issues for the dogs. This approach was discontinued in February 2009 as it was not sustainable [Rinzin 2015].

During the major rabies outbreaks in eastern Bhutan in 2005 and 2006, 900 free-roaming dogs were caught and impounded in 12 temporary shelters constructed in three districts in an attempt to prevent the spread of rabies due to the movement of free-roaming dogs [Tenzin et al. 2011]. The impounding of the free-roaming dogs was adopted in this outbreak in response to religious aversion to the mass culling of dogs by the community in eastern Bhutan.

The Royal Society for the Protection and Care of Animals, Thimphu runs an Animal Welfare Treatment Centre in Serbithang, Thimphu. The RGOB also officially approved the Bhutan Karuna House Program in June 2008 to keep and care stray dogs in Tashigang dzongkhag. When hundreds of dogs were pounded in Memelakha dog pound in Thimphu in 2008, there was criticism by animal welfare organizations and the local community as the pound was overcrowded and did not segregate dogs into different categories such as puppies, lactating bitches, sick, weak and old dogs. This prompted the Brigitte Bardot Foundation to provide funds to the Jangsa Animal Saving Trust [JAST] for the immediate construction of a rescue shelter and the purchase of a vehicle to transport the dogs recovered, particularly the old, disabled and injured animals, and to undertake a food drive in the neighbourhood [restaurants, schools, local donors]. The JAST constructed a treatment shelter adjacent to the RSPCA shelter on land provided by the Government. The shelter is still used for the treatment and care of sick and weak dogs which are subsequently released back to the street once they are healthy [Rinzin 2015]. Dog shelters are also being operated at Paro as Maya Foundation.

3.6.7 CNVR Programme

The animal birth control program and other strategies carried out in the past were not sufficient to reduce the dog population to a manageable level. The Department of Livestock and the Humane Society International, USA initiated a pilot project from February to June 2009 during which 2,846 dogs were sterilized and vaccinated in Thimphu. After a successful pilot project in Thimphu, the Department of Livestock and HSI embarked on a long-term project titled "National Dog Population Management and Rabies Control Programme in Bhutan". The project was officially launched on the 28th September 2009 in Bumthang to coincide with World Rabies Day. Through this project a CNVR programme was carried out where dogs were captured, neutered, vaccinated and released back at their place of origin. More than 85,000 dogs and cats were processed and vaccinated at the end of June 2018 [Figure 5]. Bhutan have an estimated dog human ratio of 1:12.39 with 1:16.3 in the urban and 1:8.43 in rural areas and increasing dog population is still a social and public health issue in the country [Rinzin et al. 2015].

3.6.8 Cross-border rabies control program

Cross-border rabies transmission is a serious problem in Bhutan. Several control measures are being implemented to deal with cross-border rabies transmission including creating immune belt and cordon sanitaria along the borders through annual mass dog vaccination campaign. Mass dog vaccination campaign along the borders was initiated in 2013 and covered 6178, 5462, 2546 and 3042 dogs in 2013 through 2016, respectively. It is important to promote an inter-country collaboration and international partnership through regionally coordinated rabies control programme. A cross-border consultative meeting on animal birth control and rabies control was organized on 8th November 2017 in Phuentsholing between Alipur Duar district West Bengal India and the department of livestock and local government officials.

3.6.9 Advocacy [Information, education and communication] on rabies

Ever since the first World Rabies Day [WRD] was organized by Global Alliance for Rabies Control in 2007, Bhutan also observed the WRD on every 28 September and created mass awareness on rabies through radio and television program, display of posters and banners, distribution of leaflets, education to the students and farmers. Radio and TV program were developed and aired through Bhutan Broadcasting Service. Information on rabies were also shared through print media.

3.6.10 Rabies researches [data collection and analysis]

Although rabies was widespread throughout the country, no detailed studies were conducted and no written document was available on rabies in Bhutan. The first author of this paper [Dr Tenzin] conducted first research on epidemiology and control of rabies in Bhutan as part of his PhD programme in 2009. Since then several scientific papers were published on rabies and dog population management in the country. The study findings provided information to make science-based policy decision on rabies prevention and control in the country [see the list of publications in Table 5].

3.7 Economic impact of dog population management and rabies control

Both dog bites and rabies control cause considerable economic losses to people and government. Rabies can also cause substantial losses to farmers due to death of farm animals as a result of spill-over infection from dogs. The direct outbreak

cost during the rabies outbreak in Chukha in 2008 was estimated to be Nu. 2.75 million [US$ 59,923] [Tenzin. et al. 2010]. This included losses from cattle deaths [Nu. 42,000; 15%], and costs for post exposure prophylaxis of humans [1,516,500; 55%] and implementation of the rabies control programme [Nu. 820,000; 30%]. The government borne expenses during 2016-2018 rabies outbreak in Trashigang [only intervention cost in animal] was estimated to be around 2 million [Tenzin, unpublished]. The economic impact of a small rabies outbreak during 2015 in Orong geog under Samdrup Jongkhar was estimated to be Nu.2,59,703. Of the total estimated cost, Nu. 1,64,872 was borne by the government as direct cost and Nu. 94,831 as indirect cost [income loss for the people, cost borne by people] with a total societal cost [direct + indirect cost] of Nu. 2,59,703 [Tenzin, unpublished]. The total direct cost of rabies and various interventions between 2001 and 2008 was estimated to be Nu. 46.95 million [US$ 1.03 million]. The direct cost for intensified human PET was estimated to be Nu. 5.85 million [US$ 0.11 million] per year with a cumulated estimated cost of Nu. 35.10 million [US$ 0.70 million] at the end of 6 years using Essen treatment regimen. Currently, the annual public health expenditure on human rabies PEP is approximately Nu. 9.3 million [USD 142,000] and the cost is likely to increase with increasing dog bite incidence and elevated level of people awareness on rabies risk [Kinley et al. 2019]. The cost of dog population management is huge [data not available]. Well-planned implemented mass dog vaccination would result in elimination of rabies reservoirs in the domestic dog population and would eliminate human rabies cases. It would also reduce the recurrent expenditure on human post-exposure.

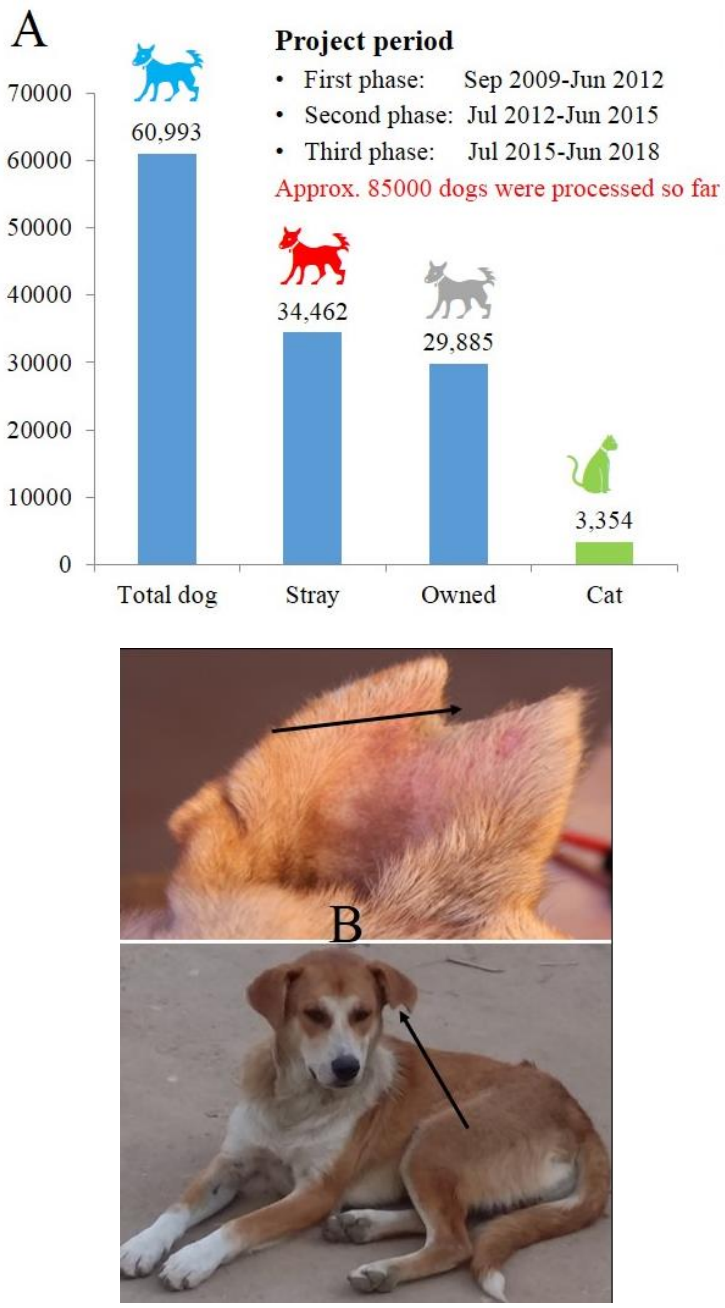

Figure 5: Total number of dogs processed [sterilized and vaccinated] during CNVR programme in Bhutan [2009-2018] [A] and permanently marked dogs with ear-notching of the processed dogs [B].

Table 5: List of papers published in peer reviewed journals [and also list of papers under preparation, submitted and under review].

Year published	Research title and publication
2019	1. Penjor K, Tenzin T, Jamtsho RK [2019]. Determinants of health seeking behavior of animal bite victims in rabies endemic South Bhutan: a community-based contact-tracing survey. *BMC Public Health, 19:237* 2. Rinchen S, Tenzin T, Hall D, van der Meer F, Sharma B, Dukpa K, Cork S [2019]. A community-based knowledge, attitude, and practice survey on rabies among cattle owners in selected areas of Bhutan. *PloS Neglected Tropical Diseases,13[4]: e0007305.* 3. Hampson et al., [2019]. The potential effect of improved provision of rabies post-exposure prophylaxis in Gavi-eligible countries: a modelling study. *The Lancet Infectious disease 19:102–11. WHO Rabies Modelling Consortium [Tenzin Tenzin is a co-author of this publication]*. 4. Yangchen T, Tenzin T, Tenzin S, Lhamo K, Gurung RB, Dukpa K, Gyeltshen T [2019]. Comparison of antibody responses after vaccination with two inactivated rabies vaccines in dogs in Thimphu, Bhutan. Bhutan Journal of Animal Science [3[1]: 79-87. 5. Léchenne M, Tenzin T, Miranda ME, Zinsstag J [2019]. Rabies in East and Southeast Asia - a mirror of the global situation *[One Health Book Chapter, Basel University, TPH, Switzerland]*. 6. Dorji T et al. The preliminary investigation on roaming behaviour of pet dogs in rural and urban community in the periphery of protected area in Bhutan *[under preparation]*. 7. Penjor K, Marquetoux N, Dorji C, Penjor K, Dorjee S, Dorjee C, Jolly PD, Morris RS, McKenziee JS. Clinicians' management of patients potentially exposed to rabies in high-risk areas in Bhutan: A cross-sectional study *[under preparation]*. 8. Dorji T, Tenzin T, Rinzin K, Phimpraphai W, de Garine-Wichatitsky M. Community perception on ecological impacts and epidemiological risks due to free-roaming dogs and management practices in the periphery of a protected area in Bhutan *[submitted]* 9. Rinchen et al. A Qualitative risk assessment of rabies reintroduction into the rabies low-risk zone of Bhutan *[under preparation]*
2018	10. Li AJ, Sreenivasan N, Siddiqi UR, Tahmina S, Penjor K, Sovann L, Gunesekera A, Blanton JD, Knopf L, Hyde TB [2018]. Descriptive assessment of rabies post-exposure prophylaxis procurement, distribution, monitoring, and reporting in four Asian countries: Bangladesh, Bhutan, Cambodia, and Sri Lanka, 2017–2018. *Vaccine. doi: 10.1016/j.vaccine.2018.10.011*. 11. Rinchen S [2018]. Options to control rabies in cattle in Bhutan. *Master Thesis, University of Calgary, Canada* 12. Wangmo K [2018]. Comparison of antibody titres between intradermal and intramuscular rabies vaccination using inactivated vaccine in cattle in Bhutan: *Master Thesis, Massey University, Palmerston North, New Zealand*.
2017	13. Tenzin T; Namgyal J, Letho S. [2017]. Community-based survey during rabies outbreaks in Rangjung town, Trashigang, Eastern Bhutan, 2016, *BMC Infectious Disease, 17:281*. 14. Tenzin T; Wangchuk S, Dorji T, McKenzie J, Jolly P [2017]. Dog bites and Human Rabies: Epidemiological Analysis of post exposure prophylaxis in Bhutan [2009-2012], *Bhutan Journal of Animal Sciences* 1[1]: 57-64.
2016	15. Rinzin K; Tenzin T, Robertson I [2016]. Size and demography pattern of the domestic dog population in Bhutan: Implications for dog population management and disease control. *Preventive Veterinary Medicine, 126:39-47.*
2015	16. Tenzin T, McKenzie J, Rai B, Morris R, Jolly P, Tshering Y, Rinzin K, Dorjee S, Wangchuk S, Dahal N, Dukpa K, Ward MP [2015]. Comparison of mark–resight methods to estimate abundance and rabies vaccination coverage of free-roaming dogs in two urban areas of south Bhutan. *Preventive Veterinary Medicine* 118 [4]: 436–448. 17. Rinzin K [2015]. Population dynamics and health status of free-roaming dogs in Bhutan. *PhD Thesis, Murdoch University, Perth, Australia.*
2013	18. Tenzin T, Wangchuk S, Rai BD, Rinzin K, Dahal N, Dukpa K [2013]. Enhancing rabies control in Bhutan. *Handbook for South Asia Regional One Health Symposium, Massey University, New Zealand.* 19. Tenzin T, Rai BD, Gempo T, Namgyal U [2013]. Home range analysis of free roaming dogs in Gelephu [published report]
2012	20. Tenzin [2012]. Epidemiology and Control of Rabies in Bhutan. *PhD Thesis, University of Sydney, Australia.*

	21. Tenzin T, Ward MP, Dhand NK [2012]. Epidemiology of rabies in Bhutan: Geographic Information System based analysis. The Reality of rabies: setting the scene. Fooks AR [eds] *Compendium of the OIE Global Conference on Rabies Control [OIE eds., 2012]*.
	22. Tenzin T, Dhand NK, Rai BD, Changlo, Tenzin S, Tshephel K, Ugyen P, Singye K, Ward MP [2012]. Community-based study of knowledge, attitude and perception of rabies in Gelephu, south central Bhutan. *International Health* 4: 210–219.
	23. Tenzin T and Ward MP [2012]. Review of rabies situation and its control program in South, South East and East Asia: Past, Present and Prospect for Elimination. *Zoonosis and Public Health*, 59: 451–467
	24. Tenzin T, Dhand NK, Ward MP [2012]. Anthropogenic and environmental risk factors for occurrence of rabies in Bhutan. *Preventive Veterinary Medicine*, 107: 20–26.
	25. Tenzin T, Wangdi K, Ward MP [2012]. Human and animal rabies prevention and control cost in Bhutan, 2001−2008: the cost-benefit of dog rabies elimination. *Vaccine, 31: 260-270.*
	26. Jamil et al. [2012]. Arctic-like rabies virus, Bangladesh. *Emerging Infectious Diseases, 18[12]:2021-24 [Bhutan rabies virus used in this analysis]*
	27. Ahmed et al., [2012]. Evaluation of a monoclonal antibody-based rapid immunochromatographic test for direct detection of rabies virus in the brain of humans and animals. *The American Journal of Tropical Medicine and Hygiene 86[4]:736-40.*
2011	28. Tenzin T, Wacharapluesadee S, Denduangboripant J, Dhand N, Dorji R, Tshering D, Rinzin K, Raika V, Dahal N, Ward MP [2011]. Rabies virus strains circulating in Bhutan: implications for control. *Epidemiology and Infection*, 139:1457−1462.
	29. Tenzin T, Dhand NK, Ward MP [2011]. Patterns of rabies occurrence in Bhutan between 1996 and 2009. *Zoonoses and Public Health*, 58: 463-471.
	30. Tenzin T, Dhand NK, Ward MP [2011]. Human rabies post exposure prophylaxis in Bhutan, 2005–2008: Trends and risk factors. *Vaccine*, 29: 4094–4101.
	31. Tenzin T, Dhand NK, Ward MP [2011]. Surveillance of animal rabies in Bhutan, 1996–2009. *Epidemiologie en sanitarie anaimal*, 59-60, 254–256.
	32. Tenzin T, Dhand NK, Gyeltshen T, Firestone S, Zangmo C, Dema C, Gyeltshen R, Ward MP [2011]. Dog bites in human and estimating human rabies mortality in rabies endemic areas of Bhutan. *PLoS Neglected Tropical Diseases*, 5 [11]: e1391.
2010	33. Tenzin T, Sharma B, Dhand NK, Timsina N, Ward MP [2010]. Re-emergence of rabies in Chhukha District, Bhutan, 2008. *Emerging Infectious Disease*, 16[12], 1925–1930.
	34. Tenzin T, Dhand NK, Dorjee J, Ward MP [2010]. Re-emergence of rabies in dogs and other domestic animals in eastern Bhutan, 2005–2007. *Epidemiology and Infection.* 139, 220-225.
2009	35. Tenzin T, Dorjee J, Rinzin K [2009]. Epidemiologic Investigation of 2005-2007 Rabies outbreaks in Eastern Bhutan. *Journal of Renewable Natural Resources Bhutan*, 5[1]; 105–115.

4. CONCLUSIONS

This review highlights the incidences of rabies in animals and humans, past and current control measures, gaps and future needs for rabies control and also progress made in reducing human rabies deaths in Bhutan. There is good scope for Bhutan to achieve zero human deaths due to dog-mediated rabies before the global target of 2030 and then maintain freedom from dog-transmitted rabies through application of One health approach.

REFERENCES *[most of the references cited in this paper are mentioned in Table 5]*

Coetzer A, Kidane AH, Bekele M, Hundera AD, PieracciEG, Shiferaw ML et al [2016]. The SARE tool for rabies control: current experience in Ethiopia. Antiviral Res. 2016; 135:74–80.

FAO [2012] Developing a stepwise approach for rabies prevention and control, proceedings FAO/GARC workshop, 6-8 November 2012; Rome [Italy] http://www.fao.org/docrep/019/i3467e/i3467e00.htm

FAO [2013]. The Stepwise Approach towards Rabies Elimination: A Planning and Evaluation Tool

GARC http://www.rabiesalliance.org/

National Centre for Animal Health [2017]. National Rabies Prevention and Control Plan, 2nd edition. Serbithang, Bhutan

Ministry of Health [2014]. National Guideline for Management of Rabies. 2nd edition. Thimphu

WHO [2015]. Global Elimination of Dog-Mediated Human Rabies – the time is now! Report of the Rabies Global Conference 10-11 December 2015, Geneva, Switzerland.

WHO [2018]. WHO Expert Consultation on Rabies, third report. Geneva: World Health Organization; 2018 [WHO Technical Report Series, No. 1012]. Licence: CC BY-NC-SA 3.0 IGO.

World Health Organization [WHO], Food and Agriculture Organization of the United Nations [FAO] and World Organisation for Animal Health [OIE], 2018. Zero by 30: the global strategic plan to end human deaths from dog-mediated rabies by 2030.