Towards canine rabies elimination: Economic comparisons of three project sites

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Summary
An appreciation of the costs of implementing canine rabies control in different settings is important for those planning new or expanded interventions. Here we compare the costs of three canine rabies control projects in South Africa, the Philippines and Tanzania to identify factors that influence the overall costs of rabies control efforts. There was considerable variation in the cost of vaccinating each dog, but across the sites these were lower where population density was higher, and later in the projects when dog vaccination coverage was increased. Transportation costs comprised a much higher proportion of total costs in rural areas and where house-to-house vaccination campaigns were necessary. The association between the cost of providing PEP and human population density was less clear. The presence of a pre-existing national rabies management programme had a marked effect on keeping infrastructure and equipment costs for the project low. Finally, the proportion of the total costs of the project provided by the external donor was found to be low for the projects in the Philippines and South Africa, but likely covered close to the complete costs of the project in Tanzania. The detailed economic evaluation of three recent large-scale rabies control pilot projects provides the opportunity to examine economic costs across these different settings and to identify factors influencing rabies control costs that could be applied to future projects.

KEYWORDS
dog vaccination, health economics, neglected diseases, post-exposure prophylaxis, rabies, zoonosis

1 | INTRODUCTION

Globally, the majority of human rabies deaths occur as a result of dog bites. It is estimated that approximately 59,000 people die annually as a result of canine rabies, and most victims are in Asia and Africa (Hampson et al., 2015). The global cost of canine rabies has been estimated at $8.6 billion in economic losses, with over half of these losses stemming from premature death and a smaller portion arising from costs of human post-exposure prophylaxis (PEP) (direct costs include vaccine, and RIG while indirect costs include travel time and expense and income lost while seeking PEP), animal tests, dog vaccination and livestock losses (Hampson et al., 2015). Economic losses may approach $120 billion USD in losses if the value of a statistical human life is included (Anderson & Shwiff, 2013; Shwiff, Hampson, & Anderson, 2013). While the disease has a case fatality rate of almost 100%, it is completely preventable through timely intervention with post-exposure rabies vaccine and immunoglobulin. Rabies circulates among animals, canines among them, but transmission in humans is not sustained. Humans are primarily exposed through dogs, and therefore the elimination of canine rabies in dogs is essential to preventing human rabies in the long term (Arechiga Ceballos, Karunaratna, & Aguilar Setien, 2014; Bögel

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Governments and public stakeholder groups, the primary mass campaign investors, need to consider the total benefits and costs of rabies mitigation and possible elimination. Given limited resources, especially in developing countries where canine rabies has the greatest impact, investments in rabies control will depend on a demonstration of the cost and feasibility of the chosen strategy. Rabies management programmes initiated by governments and public stakeholder groups seek to achieve the optimal level of rabies control by factoring in a broader set of components including the impacts to overall disease containment in a region, impacts to canine and human health and market impacts to consumers and the macroeconomy (Sambo et al., 2013).

In the developing world, additional barriers to successful vaccination campaigns include a lack of information about dog populations and their locations, poor surveillance and diagnostic facilities and inadequate resources (Hampson, Cleaveland, & Briggs, 2011; Lembo et al., 2010; Nel, 2013). However, government-led canine rabies elimination strategies have succeeded in many countries around the world, resulting in substantial declines in reported human cases (e.g., Vigilato et al., 2013 and WHO, 2015b). Regardless of who initiates rabies management directed at animal populations, the economically efficient implementation of management efforts requires a comprehensive understanding of the costs associated with animal and human vaccination.

Costs associated with human and animal vaccination are influenced by a variety of factors that can be location-specific. This paper compares the rabies vaccination campaigns across three large project sites: KwaZulu-Natal, South Africa; Cebu, Philippines and South-Eastern Tanzania. In 2010, each location became a canine rabies vaccination demonstration site coordinated by the World Health Organization (WHO) and supported by the Bill and Melinda Gates Foundation (BMGF). Since then, millions of animals have been vaccinated against rabies, and hundreds of thousands of humans have been treated with post-exposure prophylaxis. Here, by comparing the costs of rabies control and the relative contribution of different cost components across the three sites, we attempt to identify factors that influence rabies mitigation costs and explain why costs varied so significantly across the three project sites. The source of funds for these projects is presented to provide insight into the cost sharing between governments, donors and the community itself. This information can inform the expected costs of future rabies control endeavours.

2 | SUMMARY OF THREE CANINE RABIES VACCINATION PROJECTS

The three canine rabies vaccination campaigns began in 2010, running until 2012 in South Africa and the Philippines, and until early 2014 in Tanzania due to some delays in implementing the mass dog vaccination in some regions (World Health Organization (WHO), 2015b). At the start, rabies was enzootic to all three locations (World Health Organization (WHO), 2015a,b), threatening a combined population of almost 30 million people.

2.1 | Philippines

The Philippines passed the Anti-Rabies Act of 2007, which declared a national policy to control, prevent the spread, and eventually eradicate human and animal rabies and mandated responsible pet ownership (Philippines, 2007). Along with the legislation, the National Rabies Prevention and Control Program was also implemented with the express goal of eliminating human rabies by the year 2020 by declaring the Philippines rabies free by the same year (Philipines, 2016). The national rabies programme provides dog vaccinations, and PEP administration to the provinces at subsidized costs for those that can show financial need. Programmatic activities are carried out at the provincial government level. Beyond the ongoing maintenance and prevention activities, the government has also undertaken targeted elimination programmes in high burden areas of the country.

The Philippines project covered three administrative regions, 16 provinces and 31 cities. The project site is home to 17 million people and an estimated nine million dogs (WHO, 2010). Due to the difficulties of compiling complete information from the decentralized delivery system, the cost analysis was only performed for Cebu City, a highly urbanized metro centre, and Carmen Municipality, a more rural setting by comparison, which were assumed to be representative of other urban and rural areas across the project site. Cebu City is a densely populated metro area with a population density of 2,750/km². The population density of Carmen Municipality (527/km²) is similar to the average density of Cebu Province as a whole (780/km²) (Philippine Statistics Authority, 2016). The high human population density throughout the Philippines allows a campaign based on centralized vaccination clinics. Generally, this involves advertising the event beforehand via radio and fliers. On the day of the event, a mobile vaccination clinic is established in a central or accessible location where dog owners are able to bring their animals to be vaccinated and marked.

Within the Philippines project site, and unlike the other sites, dog owners paid for a proportion of the vaccination costs in the form of registration fees, and bite patients contributed substantially towards the cost of their PEP treatment (Miranda et al., 2017).

2.2 | Tanzania

The project administered animal vaccinations in 28 districts (of a total of 169 in the country) over three phases from 2010 to 2014, with a total population of more than 8.8 million people in the project area. The districts were chosen to exploit natural boundaries to facilitate the maintenance of a rabies free area. These boundaries include the coastline to the east, the Udzungwa Mountains to the
west and the Ruvuma River to the south. These districts comprise a variety of cultural settings, including coastal, urban, agro-pastoral and pastoral (World Health Organization (WHO), 2010). The average human population density of the programme area of South-Eastern Tanzania was 54/km², with a wide range of densities across the different districts from a low of 5.3/km² in Liwale to a high of 3,560/km² in Ilala. The low population density requires considerable travel compared with other programmes to reach as many animals as possible. Centralized vaccination clinics were possible only in the larger cities, with field campaigns being required in the more rural areas. Often the field campaigns consisted of vaccination technicians going door-to-door in villages asking to vaccinate the animals in the home.

In Tanzania, the cost of providing PEP to bite victims was reported to be fully covered by the government within the project site (Hatch et al., 2016). However, in general in Tanzania, and previously in the project site area, patients were almost always responsible for all PEP vaccine and associated travel costs (Sambo et al., 2013), which can be very high compared with average incomes. Sambo (2012) found that the average indirect costs of a course of PEP (transportation, accommodation, lost income), which are paid for by the patient, totalled over $20. Considering that the majority of Tanzanians live on less than US $1 per day, these indirect PEP costs represent a significant financial burden.

2.3 South Africa

KwaZulu-Natal had a canine rabies vaccination campaign ongoing before the BMGF-funded project, though funding and awareness increased substantially as the BMGF project began.

The average human population density of KwaZulu-Natal is approximately 109/km², ranging across the municipalities from a low of 41.5/km² in rural areas such as Sisonke to a high of 1,501/km² in urban eThekwini. KwaZulu-Natal is made up primarily of the Zulu ethnic group. The Zulu people tend to be more individualistic than surrounding ethnic groups, leading to a more spread-out and non-centralized village structure (Shwiff et al., 2014). This presented unique challenges to mass dog vaccination campaigns. In contrast with the areas where mass vaccination through central point clinics was possible, vaccination teams needed to implement house-to-house (or local) campaigns in Zulu areas. The teams would generally drive along rural roads with a bullhorn announcing the upcoming vaccination campaign, and providing the date and time of the team’s return. The team would then return on the announced day and vaccinate animals house-to-house. This method of vaccination requires large amounts of fuel and vehicle maintenance (K. Le Roux, 2013, personal communication; Shwiff et al., 2014). In the project area, as in the rest of South Africa, PEP was delivered free to bite patients.

The primary objective of all of the projects was to demonstrate that human lives could be saved through control programmes based on mass canine vaccination campaigns. These projects included the following activities:

1. data collection on human and dog populations and cases of animal rabies,
2. education and training to foster community awareness,
3. improved diagnosis and surveillance in human and animal populations,
4. improved access to human rabies biologicals (post-exposure prophylaxis),
5. design of a long-term sustainable strategy for maintaining freedom from canine rabies, including dog movement and border controls and improved management of dog populations,
6. coordination, implementation, monitoring and evaluation, closely coordinated between the three project areas (World Health Organization (WHO), 2010).

Consequently, data was collated to calculate the costs of the vaccination campaigns and provision of PEP in the different environments (Hatch et al., 2016; Miranda et al., 2017; Shwiff et al., 2014). Table 1 provides the average costs to vaccinate each dog for each of the three vaccination projects, together with figures from a variety of other published vaccination campaigns. This data provides evidence for significant variations in the vaccination cost per dog for different campaign structures, generally related to the amount of travel required (e.g., house-to-house campaigns being more expensive than central point campaigns, different target dog populations [e.g., pets being cheaper to vaccinate than stray dogs]), and different vaccination providers. Scale may also be an important factor, and larger scale projects have been predicted to have a lower cost per dog vaccinated than smaller pilot projects (Kayali, Mindekem, Hutton, Ndoutamia, & Zinsstag, 2006).

While most of the projects listed in Table 1 present detailed data on all relevant costs of the campaign (e.g., for vaccines, consumables, equipment, salaries, accommodation, transportation, cold chain and awareness campaigns), others simply present an aggregated “vaccine administration” cost (for example, Fishbein et al., 1991 and Lapiz et al., 2012) and may have omitted some components in the process.

The detailed economic evaluation of three recent large-scale rabies control pilot projects using the same methods, provides the opportunity to examine economic costs across these different settings and to identify factors influencing rabies control costs that could be applied to future projects.

3 Methodology

3.1 Overall comparisons of the sites

Table 2 compares the demographic characteristics related to population, density and land area of the three project sites presented in this analysis. There are large differences between and within each of the project sites with average human population densities ranging from 54 to 2,750 per square kilometre, and estimated human to dog ratios from 8.5 to almost 70.
Table 3 provides the project-specific vaccination and cost estimates for the animal and human components of each programme, compiled from Miranda et al. (2017), Hatch et al. (2016) and Shwiff et al. (2014). We also calculated a few more summary statistics: the overall dog vaccination coverage (based on the average number of dogs vaccinated per year divided by the estimated dog population); the rate of demand for PEP (the percentage of the human population that presented for PEP following bites over the whole project). Finally, the estimated number of deaths prevented for each project area was calculated, using the proportion of people receiving PEP who would have died without it using data for each country (11.5% for the Philippines, 13.9% for Tanzania and 2.1% for South Africa, from Hampson et al. (2015)), multiplied by the number of people receiving PEP over the course of each project.

At the start of the projects, this estimate reflects the number of lives saved by PEP alone, but as dog vaccination coverage increases this also incorporates an increasing proportion of bite victims for whom exposure to rabies was avoided. Additional project benefits in terms of lives saved will also have occurred among the fraction of bite victims who did not seek PEP, so these are conservative estimates.

Table 1 Collection of cost per dog estimates from various locations. The three BMGF projects are highlighted in bold

<table>
<thead>
<tr>
<th>Location</th>
<th>Published cost per dog ($)</th>
<th>Costs standardized to 2012 ($)</th>
<th>Range reflects</th>
<th>Source</th>
</tr>
</thead>
<tbody>
<tr>
<td>Bhutan</td>
<td>0.99–1.66</td>
<td>1.13–1.89</td>
<td>Pet versus stray dog vaccination</td>
<td>Tenzin, Wangdi, and Ward (2012)</td>
</tr>
<tr>
<td>Cebu, Philippines (City)</td>
<td>1.18–5.79</td>
<td>1.18–5.79</td>
<td>Different phases of campaign</td>
<td>Miranda et al. (2017)</td>
</tr>
<tr>
<td>Carmen, Philippines (rural)</td>
<td>2.15–3.38</td>
<td>2.15–3.38</td>
<td>Different phases of campaign</td>
<td>Hatch et al. (2016)</td>
</tr>
<tr>
<td>Bohol, Philippines</td>
<td>1.62</td>
<td>1.62</td>
<td></td>
<td>Lapiz et al. (2012)</td>
</tr>
<tr>
<td>N’Djamena, Chad(City)</td>
<td>1.47–2.15b</td>
<td>1.67–2.45</td>
<td>Full campaign versus pilot programme</td>
<td>Kayali et al. (2006)</td>
</tr>
<tr>
<td>Serengeti Region, Tanzania</td>
<td></td>
<td></td>
<td></td>
<td>Kaare et al. (2009)</td>
</tr>
<tr>
<td>Agro-pastoralist communities</td>
<td>1.73</td>
<td>2.16</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Pastoralist communities</td>
<td>4.07–6.13</td>
<td>5.08–7.65</td>
<td>Different vaccination strategies</td>
<td></td>
</tr>
<tr>
<td>Tunisia/Thailand</td>
<td>1.30</td>
<td>2.28</td>
<td></td>
<td>Bogel and Meslin (1990)</td>
</tr>
<tr>
<td>Philippines</td>
<td>1.19–4.27</td>
<td>2.31–8.29</td>
<td>Public versus private sector vaccination</td>
<td>Fishbein et al. (1991)</td>
</tr>
<tr>
<td>Flores, Indonesia</td>
<td>2.49</td>
<td>2.54</td>
<td></td>
<td>Wera, Velthuis, Geong, and Hogeveen (2013)</td>
</tr>
<tr>
<td>Tamil Nadu, India</td>
<td>5.00–11.00</td>
<td>5.00–11.00</td>
<td>Oral versus injectable vaccination</td>
<td>Abbas, Kakkar, and Rogawski (2014)</td>
</tr>
<tr>
<td>KZN, South Africa</td>
<td>5.41–6.61</td>
<td>5.41–6.61</td>
<td>Local versus mass campaigns</td>
<td>Shwiff et al. (2014)</td>
</tr>
</tbody>
</table>

*Standardized from the year reported in each source. Where that was unclear, the year of publication was used. The BMGF projects were not standardized because their project timeframes include 2012.

Table 2 Demographic and dog population information for each project area

<table>
<thead>
<tr>
<th>Location</th>
<th>Philippines – Carmen</th>
<th>Philippines – Cebu City</th>
<th>S.E. Tanzania</th>
<th>KwaZulu-Natal</th>
</tr>
</thead>
<tbody>
<tr>
<td>Area (km²)</td>
<td>84.78</td>
<td>315</td>
<td>188,302</td>
<td>94,361</td>
</tr>
<tr>
<td>Human population</td>
<td>44,648²</td>
<td>866,171²</td>
<td>10,224,015³</td>
<td>10,267,300</td>
</tr>
<tr>
<td>Human density/km²</td>
<td>527</td>
<td>2,750</td>
<td>54</td>
<td>109</td>
</tr>
<tr>
<td>Dog population</td>
<td>4,028</td>
<td>67,762</td>
<td>152,045–217,207²</td>
<td>1,200,000⁴</td>
</tr>
<tr>
<td>Dog density/km²</td>
<td>47.5</td>
<td>215.1</td>
<td>0.81–1.15</td>
<td>13</td>
</tr>
<tr>
<td>Human: dog ratio</td>
<td>11.08</td>
<td>12.78</td>
<td>47–67</td>
<td>8.5</td>
</tr>
</tbody>
</table>

3.2 | Explaining variation in the cost per dog vaccinated

The overall project site cost/dog was lowest for the Philippines, and highest for Tanzania (Table 3). This is a very limited number of sites, but across the four sets of data in Table 3, it would appear that overall project cost per dog vaccinated is negatively related to dog density, with the cost per dog several-fold lower when human densities were above 500 people per km². The cost per dog vaccinated had no apparent association with the human: dog ratio (Table 2).

However, where it could be assessed, the cost per animal vaccinated varied considerably within projects and across their phases, from a minimum of $1.18 for Cebu City in 2012 to a maximum of $22.49 for one district of Tanzania in Phase 1 (Figure 1).

There is some suggestion that urban districts have a lower cost per dog than rural districts. Human population density data was not available for every district in Tanzania, but the three districts making up the Dar es Salaam region in Tanzania as well as Cebu City in the Philippines generally displayed lower costs per dog vaccinated than the more rural districts. For other districts, divided into rural and urban segments, the trend was not always the same. Across both the Philippines and Tanzania project sites, however, there was a marked trend of reduced costs per dog vaccinated over time, which would appear to be related to the increase in dog coverage achieved by later campaigns (Figure 2).

3.3 | Costs of each component of dog vaccination campaigns

The costs of the different components of the dog vaccination campaigns were compared across the three project sites (Figure 3a–e).

In all cases, the cost of the vaccine itself was a small fraction of the total cost of vaccinating a dog, ranging from 6% in Tanzania and for the mass campaigns in KwaZulu-Natal to 19% in Cebu City, Philippines (Figure 3a–e).

Labour was the largest cost for all project sites (ranging from 38% for mass campaigns in KZN to 72% in Carmen, Philippines), and included salaries, per diem, training and pre-exposure prophylaxis of personnel where this was specified (Philippines only).

The proportion of the costs spent on transportation (e.g., vehicles, fuel and maintenance) varied, being negligible for the Philippines and rising to 18% for the house-to-house campaigns in KwaZulu-Natal (Figure 3a–e), reflecting the type of campaign structure necessitated by human population density. Similarly, accommodation costs for vaccination staff were negligible in Cebu City and just 3% in Carmen, Philippines, rising to 16% for the mass campaigns in KwaZulu-Natal (Figure 3a–e).

Compared to the other sites, a higher proportion of costs were incurred for fixed assets (e.g., freezers) (12%) and equipment (a proportion of 29%) for the Tanzania project (Figure 3a–e).

3.4 | Explaining variation in the cost per human vaccination

Compared to the cost per dog, the cost per human PEP course delivered was less variable across the sites, ranging from $44.91 to $48.58 for the two Philippines sites to $64.38 for KwaZulu-Natal (Table 3). At the largest scale across sites, lower costs tended to correlate with higher population densities, but within sites this relationship was not always supported. The number of doses patients received also varied, with an average of three doses per patient in KZN (Shwiff et al., 2014) and the Philippines.
2.5 doses per patient in Tanzania (Hatch et al., 2016).

The cost per human PEP treatment (individual medical visit) delivered was very constant across districts in KZN with an average cost of $21.50 per PEP treatment, despite different population densities. In the Philippines, costs in the rural municipality of Carmen were in fact lower than in Cebu City (Figure 4). The most variation within a project was observed in Tanzania, with a low of $12.68 in Morogoro (urban) and a high of $39.71 in Lindi (rural) and Liwale (Figure 4). Across the districts in Tanzania, PEP provision costs tended to decrease as population density increased (Figure 5).

The costs for human PEP treatment were broken down by component (Figures 6). In all cases except Tanzania, the cost of a course of biologics (vaccine and rabies immune globulin) formed the largest proportion of the overall cost. There was a considerably higher proportion of money spent on equipment (combined with vaccination consumables) for the Tanzanian project compared with the other two sites (Figure 6). In the Philippines, but not other sites, surveillance of biting dogs was implemented accounting for a small fraction (1% in Cebu City and 11% in Carmen municipality) of the total cost per PEP course delivered (Figure 6).

### 3.5 Sources of funding across the sites

The total donor funding spent for the three sites is given in Table 3. The project sites differed in the proportion of the total project costs that were covered by the donation.

The most detailed information about funding sources was available for the Philippines project sites. Here, there was considerable financial input from the community in terms of payments for dog registration fees and the costs of two of the four doses of PEP. These contributions totalled 45.1% and 30.5% of all programmatic costs for Cebu City, and Carmen municipality, respectively (Figures 7a and b). The local and national government contributions together comprised 49.0% and 64.6% for Cebu City and Carmen, respectively, leaving only 3.6% and
FIGURE 3  (a) Cost component breakdown of dog vaccination campaigns for Carmen, Philippines. Average cost per dog vaccinated was $2.53 USD. (b) Cost component breakdown of dog vaccination campaigns for Cebu City, Philippines. Average cost per dog vaccinated was $1.52 USD. (c) Cost component breakdown of dog vaccination campaigns for Southeastern Tanzania. Average cost per dog vaccinated was $7.08 USD. (d) Cost component breakdown of mass dog vaccination campaigns for KwaZulu-Natal (KZN). Average cost per dog vaccinated was $6.61 USD. (e) Cost component breakdown of local dog vaccination campaigns for KwaZulu-Natal (KZN). Average cost per dog vaccinated was $5.41 USD
4.8% contributed by the donor, and a further 2.2% and 0.1%, respectively contributed by other donors (Miranda et al., 2017).

For the other project sites the relative contribution of the donation was estimated based on the total project costs as assessed by the economic analyses and the budget spending (Table 3). For KwaZulu-Natal, the donor funds spent during the whole project totalled $2,187,370, comprising 13% of the $16,956,268 total project costs (Shwiff et al., 2014; Table 3).

For Tanzania, the donor funds spent totalled $3,960,508, higher than the total project cost as assessed by the economic analysis ($2,271,668) (Hatch et al., 2016; Table 3). However, while the economic assessment covered the full dog vaccination phases, assessment of PEP costs was only from 2011 to 2013, so this portion of the cost does not cover the entire project period.

## DISCUSSION

Costs associated with field campaigns to control rabies vary widely by region and country. This paper compares three such locations in as consistent a manner as possible to attempt to identify factors contributing to the observed cost variance. It aims to provide information to guide predictions of the costs of providing animal and human vaccination under many different scenarios, and insight into how those costs were covered in these examples. Such generalities may be of benefit to policy makers and others interested in pursuing similar projects to better inform cost predictions.

Comparison across the sites was made more difficult by the different data handling methods employed in each site. Collating the data after the project had been implemented from the multiple sources was a challenge, and for some analyses, data was simply not available for every site. For example, economic data were collected for only two sites within the Philippines project and municipality-level costs were not available for dog vaccination in KwaZulu-Natal. It is possible that differences in data collection across sites impacted the quality of the more detailed data, for example, the costs per PEP course from KwaZulu-Natal show far less variation than those from Tanzania. Various factors identified here that affected the cost per dog vaccinated and the cost per human PEP course delivered may interact with each other. However, here we have data for only four project sites (and only three independent projects). A more accurate multifactorial analysis to examine possible interactions that could influence programmatic costs would need more data than is currently available.

However, some generalities that will be of use to others planning programmatic activities were found. Across project sites, the cost per dog vaccinated was lower where human and dog densities were highest, resulting in a more than 4-fold difference in the average cost per dog. This is due to the effect that human density has on the nature of the dog vaccination campaign that must be applied in order to reach sufficient dogs. Transportation costs comprised the lowest fraction of the total cost per dog in the Philippines sites (with the highest human densities), and the highest fraction where house-to-house campaigns had to be implemented in KwaZulu-Natal to reach the most dispersed populations, with other sites being intermediate.
Where available, the data indicated that the cost per dog vaccinated fell with increases in dog population coverage. While this was driven in part by the increases in coverage achieved as the campaign gained momentum (in later years or phases), there is also likely an effect of human population densities. Economies of scale are hardest to realize in the lowest human population density areas. Additionally, the house-to-house vaccination campaigns necessary in very low human density areas of KwaZulu-Natal were combined with a strategic approach to focus vaccination mostly in high-risk areas which may also contribute to lower coverage levels. This method uses surveillance data to identify lower risk areas which are not important for virus maintenance, and can have much reduced vaccination efforts without compromising the chances of reaching rabies elimination.

The cost of PEP courses did not have such a clear association with human density. Overall, the costs in the Philippines were lower than the sites in Africa; the higher population density in Cebu City did not result in the lowest cost per patient treated. That the cost of PEP across districts in Tanzania fell with higher population density could reflect the economies of scale experienced in more urban areas, but this was not a very strong trend. This may be related to the fact that PEP is something that patients must seek on their own, and that patients in rural areas may face long journeys to receive PEP. Since this analysis focused on the cost of providing a rabies control programme from a government’s perspective, costs incurred by patients in terms of travel to the clinic and missed income (although likely to be high) were not captured. However, it is notable that a much lower proportion of people presented for PEP in Tanzania compared with the other two sites, possibly explained by the lower dog-to-human ratio and a tendency for poorer patients to only seek PEP when the bite is from a genuinely suspect rabid dog, due to the considerable expenses incurred.
The background of the project areas is also of relevance to the total costs per dog vaccinated incurred. The Philippines and KwaZulu-Natal projects both had strong government financial and programmatic input into rabies control prior to the initiation of the BMGF projects. It is likely that the pre-existing rabies management programmes greatly facilitated these projects in terms of experience of staff and advice available to them. In terms of geographic size and population density, the KwaZulu-Natal project is most similar to SE Tanzania, but it experienced lower costs per dog vaccinated. Costs fell during multiyear campaigns, suggesting that projects become more cost efficient with time.

Because of the pre-existing government programmes in KwaZulu-Natal and the Philippines, much of the vaccination infrastructure was already in place when the BMGF project began. This included national and local management, cold chain distribution channels and citizen awareness. The BMGF project was able to utilize much of this infrastructure, allowing the project to reduce the costs that would have been necessary to construct the required infrastructure to build such a project from the start.

In contrast to the pre-existing and ongoing canine rabies elimination programmes that existed in the Philippines and KwaZulu-Natal, Tanzania had no pre-existing government-run mass dog vaccination programmes, with intervention limited to rabies outbreak management. With the exception of one external donor-led project designed to create a buffer zone around the Serengeti National Park (Cleaveland, Kaare, Tiringa, Mlengeya, & Barrat, 2003), routine canine rabies vaccinations have been the responsibility of the owners. In the absence of a national programme, the BMGF project was required to build the necessary infrastructure, leading to significant equipment and fixed assets costs. Along with higher initial fixed costs associated with organising the project, the Tanzania project may have suffered from higher costs stemming from simple inefficiencies that other, more ongoing projects, have already worked through, as evidenced by the delays that were experienced in implementing the dog vaccination campaigns. Certainly the very high costs per dog vaccinated observed in some districts early on in the project reflect very low coverage rates and inefficient programmes. One such challenge has been the provision of an accurate estimate of the dog population in the project area. Dog population estimates directly influence several other costs of the project including canine rabies vaccine and consumables purchases, and required staff forecasts. For the Tanzanian project, the initial overestimation of the dog population led to significant over-purchase of canine rabies vaccines (Hatch et al., 2016).

Despite these differences affecting the breakdown of the costs into components, across all projects, the bulk of the cost of vaccinating a dog was accounted for by labour costs, and the vaccine itself comprised a very small fraction. In contrast, the majority of the cost of providing a course of PEP was the cost of the biologics (vaccine and the limited amount of RIG used).

The different levels of government engagement were also reflected by the proportion of the total project spending that was provided by the donation. Other external donors were not a significant source of funds in any case, and the donor funds comprised just 3.6%-4.8% of the total programmatic costs in the Philippines and 13% in KwaZulu-Natal, but practically all of the funding for the Tanzanian project. This is critically important to consideration of project sustainability after the project period is over. The Philippines and South African governments are expected to be able to sustain the programme into the future, but there are doubts over the future of the Tanzanian project.

The analysis presented here was limited by data not being compiled in a similar way across each site. More robust and in-depth analysis would depend on a wider spectrum of data. However, the results clearly show wide variation in the composition of costs across the three sites, even though the projects were jointly coordinated, demonstrating that rabies control costs will be highly site specific. Major influencers of control programme costs are likely to be the human population density, salary costs for implementing personnel, transportation costs, and whether cost-recovery from the community is likely. Finally, for many rabies endemic situations, initial projects may require that a high proportion of project funding is derived from external donors. Where this is the case, careful consideration of the transition to a government-funded phase to sustain the project’s impact will be necessary.

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REFERENCES


