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Cost analysis of bluetongue virus serotype 8 surveillance and vaccination programmes in Austria from 2005 to 2013

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ABSTRACT

This study was designed to evaluate the costs between 2005 and 2013 of the national bluetongue virus (BTV) surveillance and vaccination programmes before, during and after the BTV serotype 8 (BTV-8) outbreak in Austria commencing in 2008. In addition to an assessment of the temporal development of costs, a spatial cost analysis was performed. Within the context of this study, the term 'costs' refers to actual financial expenditure and imputed monetary costs for contributions in-kind. Costs were financed directly by the private–public sectors, by the European Commission (EC), and (in-kind) by responsible national institutions and individuals (e.g. blood sampling by veterinarians).

The total net cost of the BTV-8 surveillance and vaccination programmes arising from the outbreak amounted to €22.8 million (0.86% of the national agricultural Gross Value Added), of which 32% was allocated to surveillance and 68% to the vaccination programme. Of the total programme costs, the EC supplied €4.9 million, while the remaining costs (€18 million) were directly financed from national resources. Of the latter, €14.5 million was classed as public costs, including €2 million contributions in-kind, and €3.4 million as private costs. The assessment of the costs revealed heterogeneous temporal and spatial distributions. The methodology of this analysis might assist decision makers in calculating costs for other surveillance and intervention programmes. The assessment of contributions in-kind is of importance to public authorities as it increases visibility of the available resources and shows how they have been employed. This study also demonstrates the importance of tracking changing costs per payer over time.

Introduction

Economic assessment of animal health surveillance programmes is an important aspect of veterinary medicine and is attracting increasing attention. Bluetongue virus serotype 8 (BTV-8) was reported in Europe for the first time in 2006 (Müller et al., 2010; Saegerman et al., 2011; Coetzee et al., 2013). Initial cases emerged in the border regions between The Netherlands, Belgium, Germany and Luxembourg (Gloster et al., 2007; Elbers et al., 2008; Saegerman et al., 2008; Kirschvink et al., 2009), and the first Austrian case of BTV-8 was detected in November 2008 (Loitsch et al., 2009).

In 2008, the European Union (EU) mobilised approximately €165 million[1] for BTV control programmes in Member States, with a further €66 million in 2009. While substantial EU contributions for large-scale vaccination programmes (e.g. rabies) have previously been documented,[2] analyses focusing on resource allocation of surveillance programmes are limited (Rich et al., 2013). One reason for this is the difficulty in obtaining accurate information on costs and tangible benefits of surveillance programmes (Drewe et al., 2013a). Moreover, it is essential to consider changes in costs over time, as surveillance programmes will differ in duration, according to the objectives and goals of decision makers (Rich et al., 2013). Recently, Häsler et al. (2012) retrospectively estimated the costs and benefits of the BTV surveillance and intervention programmes in Switzerland between 2008 and 2009, which indicated that the mean cost of these programmes amounted to approximately €102,000–106,000 and €18–19 million, respectively.

In the present study, we conducted a cost analysis of the Austrian BTV-8 surveillance and vaccination programmes between 2005

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[1] €1 = approx. US$1.08, £0.73 as at 1 April 2015.

[2] See: http://ec.europa.eu/food/animal/diseases/docs/report_2007-2011_2013-10941_en.pdf (accessed 24 July 2015).

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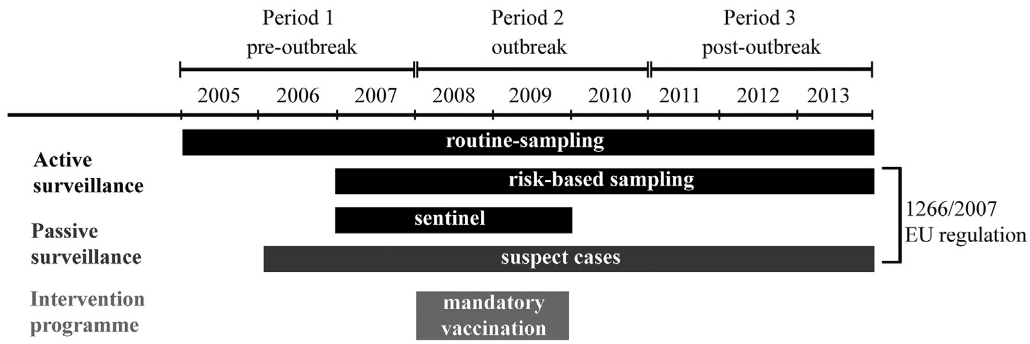

Fig. 1. Timeline of Austrian BTV surveillance and intervention activities: Period 1 (pre-outbreak) represents the costs that arose from the beginning of the surveillance period to the first detected BTV-positive animal; period 2 (outbreak) covers the years from the first to the last officially confirmed BTV case, up to the achievement of BTV-free status. Period 3 (post-outbreak) starts at the date of BTV-free status (March 2011) and continued until the year 2013.

and 2013. Within the context of this study, the term 'costs' refers to actual financial expenditure and imputed monetary costs for contributions in-kind. The objectives were to estimate the cost of the programmes before, during, and after the disease outbreak and, where the highest costs were incurred, to define the proportion of costs financed by the public and private sectors and the European Commission (EC), and to analyse the proportion of costs directly financed and the proportion provided as contributions in-kind by various national authorities and individuals. Linear regression models were applied to analyse whether costs could be predicted using information readily available in the public domain (e.g. animal populations).

Materials and methods

Description of the surveillance and intervention programmes

Prior to the European BTV-8 outbreak in 2006, only marginal BTV surveillance activities were conducted in Austria. From 2007 onward, both active and passive BTV surveillance programmes were implemented in accordance with EU regulation 1266/2007[3] (Fig. 1). Routine BTV sampling was also undertaken based on imports, exports and national trade of livestock.

Samples were collected in designated BTV areas, according to a risk-based sampling plan. Geographical areas were classified according to the expected BTV risk, using criteria such as livestock density, vector activity and climate. The country was divided into 28 geographical units, from which 91 animals per unit were tested each month between 2007 and 2010. From 2011, the country was divided into four units, from which a total of 301 animals were tested from mid-September to December (see Appendix: Supplementary Table S1).

As part of sentinel surveillance, 150 cattle per geographical unit per month were tested (maximum of 10 cattle per farm). In 2008, bulk milk samples from routine milk testing were tested by ELISA for the presence of antibodies to BTV,[4] although milk testing was discontinued once animals had been vaccinated. Serological assessment of blood samples was undertaken at the official laboratories of the Austrian Agency for Health and Food Safety (Österreichische Agentur für Ernährungssicherheit, AGES) and by various regional veterinary authorities.

Due to the apparent risk of BTV transmission from neighbouring countries and identification of the first BTV-positive case in Austria, a mandatory nationwide BTV vaccination campaign was introduced in 2008 for all ruminants, using a commercially available inactivated BTV-8 vaccine (Steinrigl et al., 2010).[5] All goats and sheep ≥4 weeks and all cattle ≥3 months of age were vaccinated. Sentinel animals and breeding bulls were excluded from the compulsory vaccination programme. In cattle, vaccination was carried out twice with an interval of 4 weeks, whereas sheep and goats were vaccinated once. The vaccination rate during the mandatory period was around 80% (Loitsch et al., 2009).

In mid-2009, the mandatory vaccination programme was replaced by a voluntary scheme. To demonstrate the success of vaccination with respect to disease mitigation and to maintain BTV disease-free status (granted in March 2011), surveillance remains in place at the current time. The surveillance and vaccination programmes are summarised in Appendix: Supplementary Table S1.

[3] See: http://eur-lex.europa.eu/legal-content/EN/TXT/HTML/?uri=CELEX:32007R1266&from=EN (accessed 25 July 2015).
[4] See: http://www.ages.at/fileadmin/AGES2015/Service/Tiergesundheit/JahresBerichte/BTV-Abschlussbericht_2008.pdf (accessed 24 July 2015).
[5] See: http://www.efsa.europa.eu/it/scdocs/doc/479.pdf (accessed 24 July 2015).

Cost calculation

For the retrospective cost analysis, the years 2005–2013 were divided into three periods as described in Fig. 1. The major cost factors were determined by analysing the activities needed to establish and maintain surveillance and vaccination programmes, as detailed elsewhere (Pinior et al., 2015). We investigated whether these major cost factors had been documented or could be based on legal decrees, e.g.

Table 1
Net costs of the surveillance and vaccination programmes for the period 2005–2013.

Major costs (€)		
Surveillance programme	Absolute values	Relative values
Implementation costs		(47.53%)
Call out charges	1,970,700	
Samples taken	1,163,010	
Dispatch of samples	315,312	
Diagnostic costs		(52.34%)
Risk based sampling	1,276,851	
Sentinel	292,478	
Routine	2,222,753	
Passive	6325	
Other costs		(0.13%)
Office supplies	5997	
Travel	2241	
Purchase of sentinel animals	900	
Total costs	7,256,567	(31.82%)
Financed by the European Commission	566,460	(7.81%)
Financed by national resources	6,690,107	(92.19%)
Vaccination programme		
Implementation costs		(81.51%)
Injection (€2)	7,199,088	
Call-out charge (€30)	3,175,050	
Call-out charge for beef suckler herd (€40)	2,200,200	
Call-out charge for alpine pasture herds[a] (€60–120/h)	100,860	
Other costs		(18.49%)
Vaccination doses ordered[b]	2,850,000	
Ear tag	18,280	
Information material	1667	
Dispatching vaccine	1367	
Court fees[c]	2600	
Travel	1621	
Total costs	15,550,733	(68.18%)
Financed by the European Commission	4,322,322	(27.80%)
Financed by national resources	11,228,411	(72.20%)

[a] Veterinarians received a call-out charge of €60/h for alpine pasture holdings up to 1300 m above sea level, €90/h at 1300–1700 m, and €120/h above 1700 m.
[b] Note that the number of vaccine doses ordered does not necessarily correspond to the number of doses used.
[c] A number of farmers initiated legal proceedings against the Austrian authorities alleging vaccine adverse reactions having a detrimental effect on their livestock.

Table 2
Costs in the surveillance programme over the three time periods.

Surveillance	Price €/unit	Period 1 Pre-outbreak	Period 2 Outbreak	Period 3 Post-outbreak	Total number	Total costs
Diagnostic methods						
ELISA (milk)	5.6	0	41,151	4999	46,150	258,440
ELISA (blood)	6.8	39,349[a]	72,664	90,509[a]	202,522	1,377,150
PCR	15.0	658	72,577	69,982	143,217	2,148,255
Serum neutralisation	52.6	0	141	0	141	7417
Serotyping	45.0	0	49	0	49	2205
Genome neutralisation	95.0	0	52	0	52	4940
Total number		40,007	186,634	165,490	392,131	–
Total costs		277,443	1,827,778	1,693,186	–	3,798,407
Implementation						
Call out charge (COC)[b]	50.0	6948	21,469	10,997	39,414	1,970,700
Samples taken	5.0	30,370	93,805	108,427	232,602	1,163,010
Dispatch of samples[c]	8.0	6948	21,469	10,997	39,414	315,312
Total number		44,266	136,743	130,421	311,430	–
Total costs		554,834	1,714,227	1,179,961	–	3,449,022

[a] For ELISAs carried out in Periods 1 and 3, the sample type (milk or blood) was not always recorded. For the cost calculation, the ELISA price for blood was therefore used. If initial ELISA testing proved BTV-positive, results were confirmed by PCR.
[b] Veterinarians were budgeted to receive €50 (net) per holding visited based on official agreements with the responsible parties (e.g. a legal decree relating to official veterinary fees); this fee included the costs for the collection of five samples. Each additional sample cost €5. If COC data for a given year were incomplete, but the number of samples was known, then the missing data were estimated based on full datasets from other years.
[c] The dispatch of samples per farm cost €8 (assumption).

veterinarians' fees for specific activities. To collect data on major costs, access to the accounts of the federal veterinary authorities was granted.

The net costs of the surveillance and vaccination programmes were divided into those directly financed and those provided as contributions in-kind from national public institutions, such as the Federal Ministry of Health (Bundesministerium für Gesundheit, BMG), AGES and the veterinary authorities. The latter was considered hidden costs, based on official agreements with the responsible parties. Data were collected between May 2013 and August 2014 (Appendix: Supplementary Table S2).

Surveillance activities included costs for the call-out charges of veterinarians, taking milk/blood samples, and dispatching samples from the farm to the laboratory for BTV diagnostic testing. All of these costs were contributed as payments in-kind by the veterinary authorities and are detailed in Table 1. If the data for a given year were incomplete, but the number of samples was known, then the missing data were estimated based on full datasets from other years. In addition, we considered the costs of consecutive laboratory tests for BTV detection.

Within the vaccination programme, costs arose for veterinary call-out fees and the administration of vaccines. The call-out fee paid to a veterinarian was dependent on whether a beef suckler herd, an alpine pasture holding with different altitudes, or another farm type was visited (see Appendix: Supplementary Fig. S1, showing the distribution of alpine pastures by altitude).

The costs for the surveillance and vaccination programmes were analysed by year to demonstrate how resource allocation differed over time. These costs were further analysed according to national (private and public) and EC costs, and the level of reimbursement provided by the EC per year. The decision to vaccinate all ruminants in Austria was taken within days of the first BTV case being reported. The whole of Austria was then declared a single restriction (vaccination) zone with respect to BTV and only minimal additional costs were incurred with respect to movement restrictions at that time. For this reason, it was not necessary to take the costs of restriction zones into account, in contrast to assessments undertaken in other countries (Tago et al., 2014).

In addition to the temporal analysis of the costs, all invoices received during both programmes were considered according to their geographical location. For ease of comparison, all calculated spatial costs for each political district were normalised with regard to the total number of animals divided by the number of holdings per political district (referred to as 'average herd size'), based on animal population data from the year 2009. The actual distribution of the ruminant population per species and the associated number of holdings in each district are shown in Appendix: Supplementary Fig. S2. These data were extracted from the official Austrian database (VIS, Veterinary Information System).

A further method of normalisation that we used was to express the programme costs in livestock units (Drewe et al., 2013b). In Austria, one livestock unit (LU) is equivalent to a 500 kg adult cow, or approximately 6.7 adult sheep or goats.[6] Livestock units were calculated based on the Austrian ruminant population in 2009.

A linear regression model was used for both programmes to quantify the expected effect of the ruminant (cattle, sheep and goats) population (PC, PS, PG) and the average ruminant herd size (HC, HS, HG) on the total costs per political district. As such, the costs of vaccination were calculated as follows:

$$\text{Vaccination costs} = \beta_0 + \beta_1 PC + \beta_2 PS + \beta_3 PG + \beta_4 HC + \beta_5 HS + \beta_6 HG$$

For the model describing the surveillance costs, model diagnostics revealed not normally distributed model residuals. Thus, the surveillance costs were log-transformed as follows:

$$\log(\text{surveillance costs}) = \beta_0 + \beta_1 PC + \beta_2 PS + \beta_3 PG + \beta_4 HC + \beta_5 HS + \beta_6 HG$$

We aimed to reduce the models to include only the most relevant factors and used the Akaike information criterion (AIC) to determine the best model. The AIC uses the parsimony principle to reduce the number of factors analysed and incorporates both the complexity of the estimated model and how well the model fits the data (Akaike, 1973). We calculated the root-mean-square error (RMSE) to evaluate the predictive goodness-of-fit of the final models. The models and maps of Austria were implemented using the R statistical computing environment.[7]

Results

Total costs of the surveillance and intervention programme

Taken together, the BTV-8 programmes in Austria cost €22.81 million, of which 31.8% (€7.25 million) was allocated to surveillance and 68.2% (€15.55 million) to the vaccination campaign. These costs represent 0.86% of the Austrian Gross Value Added (GVA) for agriculture. The total spending on livestock surveillance and vaccination combined was €14.14 per livestock unit, whereby €4.50 per livestock unit was spent on BTV surveillance and €9.64 on vaccination. If only the financed costs across both programmes were taken into account (i.e. in-kind contributions were excluded) then €12.82 per livestock unit was funded directly. A detailed allocation of the surveillance and vaccination costs can be found in Table 1.

Temporal and spatial analyses of the surveillance and vaccination costs

Table 2 shows that the largest proportion of the surveillance costs were incurred during the BTV outbreak with a share of 48.9% (€3.54 million), followed by the post-outbreak period with 39.6% (€2.87 million) and prior to the outbreak with 11.5% (€832,277). The level of reimbursement of surveillance costs over time is shown in Fig. 2.

[6] See: http://noe-bbk.lko.at/?+Merkblatt+Mehrfachantrag+Flaechen+2014+&id=2500%2C2159860%2C%2C%2Cc2V0PTI%3D (accessed 25 July 2015).

[7] See: http://www.r-project.org (accessed 2 April 2015).

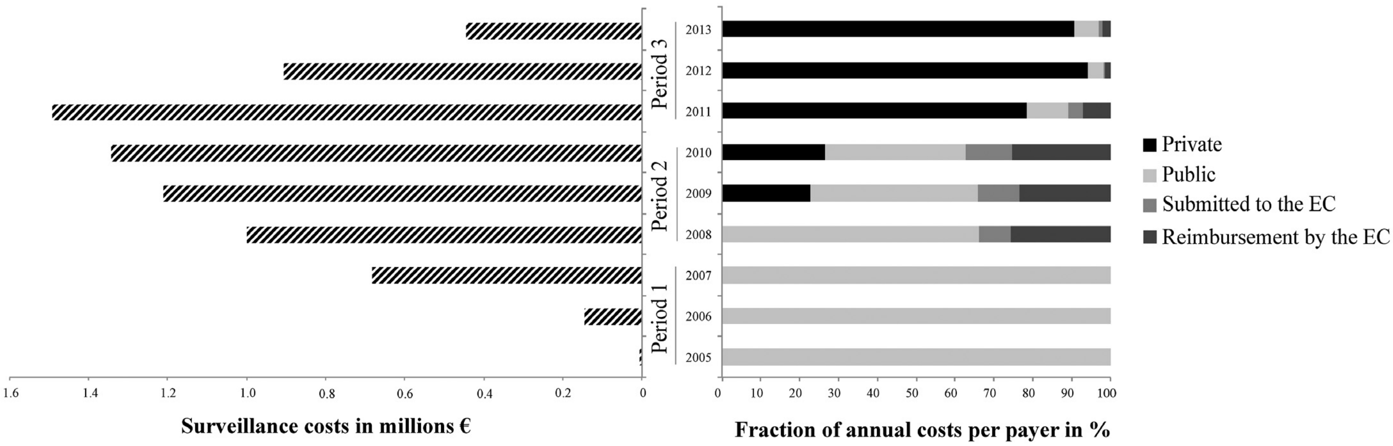

Fig. 2. Timeline of the surveillance costs and fraction of the reimbursement of costs per payer (%).

The greatest normalised total diagnostic costs were reported in the political districts of Innsbruck Land (13.4%), Melk (7.2%) and Ried im Innkreis (5.8%) (Fig. 3a). These districts also incurred the highest surveillance implementation costs, which, for all three districts together, accounted for 21.8% of the total implementation costs and 31.4% of the total diagnostic costs.

Approximately 1594 million cattle, 344,000 sheep and 65,000 goats were vaccinated during the mandatory vaccination programme. In 2009, the cost of vaccines, injection administration and call-out charges totalled around €11.77 million (75.7%). If call-out charges are excluded, 88.6% of the total vaccination costs were allocated to cattle, followed by sheep (9.6%) and goats (1.8%). The

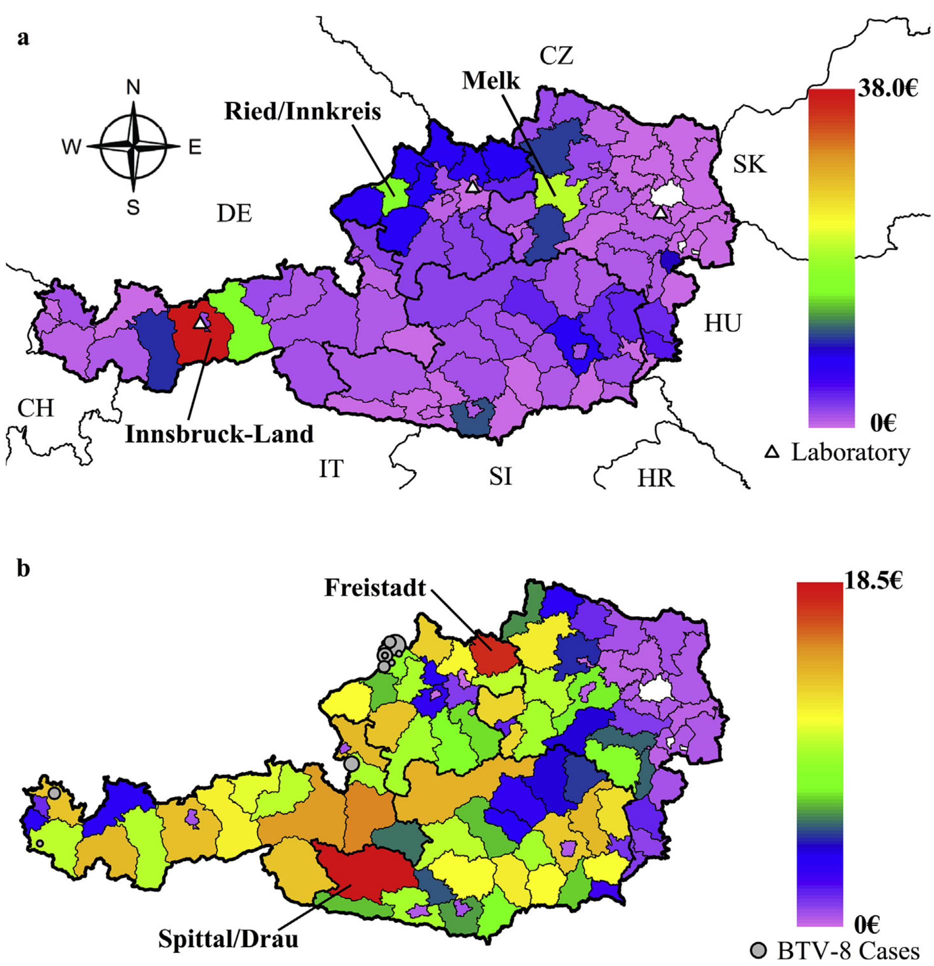

Fig. 3. (a) Total normalised surveillance costs in each political district (€000s). (b) Total normalised vaccination costs in each political district (€000s). Costs were normalised by number of animals and number of holdings per political district. No data on the serological costs per political district were available for the years 2005–2010; these data were therefore extrapolated from data collected between 2011 and 2013. This figure illustrates data and analysis for 96/99 political districts in Austria; the remaining three districts (Vienna, Eisenstadt and Rust) were excluded due to their extremely low ruminant stocking densities (0–2.05 head/km^2) and are labelled white.

Table 3
Tabular summary of the final linear regression model for the surveillance and vaccination costs.

	Estimate (β)	Standard error (SE)	*t* value	*P* value
Vaccination				
Intercept	4.42E+04	7.62E+03	5.803	<0.0001
Cattle population	5.77E+00	1.36E-01	42.388	<0.0001
Sheep population	5.95E+00	6.11E-01	9.731	<0.0001
Cattle herd size	−1.26E+03	2.30E+02	−5.458	<0.0001
Goat herd size	−3.41E+02	2.04E+02	−1.668	0.0987
Surveillance				
Intercept	8.68E+00	2.03E-01	42.836	<0.0001
Goat population	3.03E-04	1.63E-04	1.816	0.0662
Cattle population	4.93E-05	8.10E-06	6.096	<0.0001

NB: for the model describing the surveillance costs, model diagnostics revealed not normally distributed model residuals. Therefore, the surveillance costs were log-transformed.

highest normalised vaccination costs can be found in the districts of Spittal an der Drau and Freistadt, which together make up 5.8% of the total vaccination costs (Fig. 3b).

Regression models

Vaccination costs increased significantly with increasing cattle and sheep population, and decreased with an increasing mean cattle herd size within a district (Table 3). The coefficient of determination expressed a high level of goodness-of-fit ($R^2 = 0.97$) and the mean error made by the model was RMSE = €20,521.77 per political district. The model was found to be less suitable to describe the surveillance costs, as the goodness-of-fit of this model was lower than that determined for vaccination costs, namely, $R^2 = 0.45$, with an RMSE = €137,131.90 per political district.

Discussion

The results of this study show that considerable costs were incurred by both the BTV-8 surveillance (€7.25 million) and vaccination programmes (€15.55 million) in Austria between 2005 and 2013. Assessment of the costs revealed heterogeneous temporal and spatial distributions. Overall, our analyses indicate that public costs have decreased by a factor of 9.6 since Austria achieved 'freedom from disease' status with respect to BTV, compared with the outbreak period, and that private costs have increased by a factor of 3.1. Assuming no further outbreaks are reported in Europe, it seems reasonable to presume that public costs and EC co-financing of BTV surveillance will continue to decline in the future. The main reason for high private costs after the outbreak was the large number of animals exported to other countries,[8] as BTV screening of animals was necessary to promote such exports.

An estimate of the cost of the BTV surveillance and vaccination programmes exists for Switzerland (Häsler et al., 2012) where it was found that the costs for serological surveillance were around six times lower than those incurred in Austria (excluding implementation costs), although both countries have similar numbers of animals and BTV prevalence. In contrast, vaccination costs in Switzerland were around 1.2× higher than those reported here. Total BTV surveillance costs in Austria were calculated at €4.50 per livestock unit, with €9.64/LU spent on the vaccination programme. This compares favourably with the results reported in the UK by Drewe et al. (2013b), where the average cost of surveillance across all livestock species was £4.00 per LU (approximately €5.48). However, it should be noted that the costs reported for all ruminant species in Austria were specific to BTV surveillance only and superficial comparisons of such studies are difficult, due to differing study assumptions and methodology, political aims, and veterinary authority infrastructure.

Data were available for 96/99 political districts in Austria and the spatial analysis revealed a heterogeneous distribution of costs. The greatest diagnostic costs were found in the district of Innsbruck Land. This can be explained by the presence of a large livestock market and a number of private livestock traders in this district, leading to a requirement for BTV testing prior to animal export (to neighbouring Italy, in particular), comprising 12% of the total diagnostic costs in Innsbruck Land. The high serological costs in some political districts in Upper Austria can also be explained by the high level of exports. For example, approximately 80% of the breeding cattle exported from Upper Austria in 2011 were transported to Turkey.[9]

The greatest vaccination costs occurred in the districts of Spittal an der Drau and Freistadt. Since most of the Austrian alpine pasture (12.5%) is located in Spittal an der Drau, veterinarians in this district received relatively high call-out fees per hour, as charges increase with altitude (Table 1). The cost differences between the federal state of Lower Austria and the states of Styria, Carinthia, Salzburg and Vorarlberg can also be explained by the additional alpine call-out fees. Around 75% of all Austrian alpine pastures (>1300 m above sea level) are found in these latter federal states, whereas only around 0.9% of pastures in Lower Austria reach alpine altitudes.[10] The districts of Spittal an der Drau and Freistadt also contain the greatest proportion of beef suckler herds in Austria, leading to elevated operational costs.

The spatial differences in vaccination costs may have been caused by the differing number of injections administered per species and varying fees per farm type and location. The first BTV outbreak in Austria occurred in the district of Schaerding in the province of Upper Austria (representing 24/28 of all Austrian cases), which had the greatest stocking density of cattle nationally (92 head/km^2). This is comparable with the stocking densities of other European countries experiencing BTV outbreaks such as Belgium (84.9 head/km^2) and The Netherlands (113 head/km^2) (Caporale and Giovannini, 2010).

Our results from this study have demonstrated that differences existed between the incurred costs in Austria, the costs submitted to the EC and the costs reimbursed by the EC. Costs associated with diagnostic testing, undertaken as part of the routine surveillance programme, were not (or were only partially) submitted to the EC for reimbursement. Furthermore, the EC only funded certain costs up to a maximum value. The difference between the active and passive surveillance programmes (approximately €7.23 million) can be explained by the fact that only a small number of suspected BTV cases were reported by farmers. It has previously been suggested that active farmer participation in surveillance programmes can be a cost-effective method of reporting disease incidence (Souza Monteiro et al., 2012), but it appears that Austrian farmers may not have been actively involved in the BTV programmes.

The veterinary authorities in Austria experienced difficulties in explaining the need for compulsory BTV-8 vaccination to the farming community and there were a number of legal cases alleging adverse reactions following vaccination and negative articles in the farming press at the time of the outbreak. Thus, the farming community as a whole may not have engaged fully with the surveillance and intervention initiative as might have been expected when faced with

[8] See: http://www.statistik.at/web_de/statistiken/aussenhandel/ (accessed 30 March 2015).

[9] See: http://wirtschaftsblatt.at/home/nachrichten/oesterreich/1204238/index (accessed 25 July 2015).

[10] See: http://www.gruenerbericht.at/cm3/download/finish/142-almstatistik/415-almstatistik-2009/0.html (accessed 25 July 2015).

an outbreak of infectious disease that can cause severe economic and production losses.

The quantification of costs in an analysis of this kind is primarily dependent on the information available. As expected, there was a lack of documentation pertaining specifically to contributions-in-kind. The greatest level of payments-in-kind was recorded during implementation of the surveillance programme, in contrast to the vaccination programme where the activities were directly financed. Nonetheless, our study has shown that a significant proportion of the visible costs were avoided by relying on national resources (unreported costs).

Overestimation and underestimation are common issues associated with this type of retrospective cost analysis. Combining the implementation activities of both programmes may have led to an overestimation of the costs, e.g., if veterinarians combined their surveillance visits with vaccination of animals, or carried out tasks for different surveillance programmes at the same time. This was the case in 2013 when BTV and Schmallenberg virus surveillance schemes were in operation simultaneously. In addition, a number of activities considered to be contributions-in-kind, such as planning, were not taken into account, due to lack of data. As reported elsewhere, planning and documentation activities made up 13% of the total BTV vector monitoring costs (Pinior et al., 2015). In contrast with other countries (e.g. Switzerland), costs associated with creating a vaccination databank were negligible, because existing databases were already available in Austria. In Switzerland, these costs were estimated at approximately €460,000 (Häsler et al., 2012).

A further study limitation is that the analysis did not include the private and public costs of voluntary vaccination in the post-outbreak period from 2011 onwards. Consequently, although uptake of voluntary BTV vaccination appears to be low (A. Loitsch, unpublished data), the proportion of costs incurred by the private and public sector post-outbreaks may be underestimated. A degree of bias might have arisen through the extrapolation of spatial costs from 2011–2013 to 2005–2010. Due to the BTV disease situation in Germany, it is likely that more diagnostic tests were carried out in the border region between Austria and Germany in 2007–2009 than were extrapolated.

Another limitation of the study is that the benefits of the surveillance and vaccination programmes have not been quantified in economic terms. The benefits of surveillance programmes, in particular, are known to be difficult to quantify (Drewe et al., 2013b; Pinior et al., 2015). While the low number of BTV-8 cases reported in Austria at the height of the European outbreak appears to support the success of the vaccination programme, a formal investigation has not been carried out. Given the relatively large number of BTV cases seen in neighbouring countries (e.g. 11,485 cases in Germany in 2007) and subsequent economic losses associated with these, the Austrian government made the decision to implement a mandatory vaccination programme (Caporale and Giovannini, 2010). Opinions are divided as to the best form of intervention, with some studies suggesting targeted vaccination in high risk areas, whereas others prefer to vaccinate all susceptible animals nationwide (Caporale and Giovannini, 2010; Velthuis et al., 2011). However, quantification of vaccination outcome, such as an assessment of income generated through continued animal export, was beyond the scope of the current study.

We believe that the study findings will be useful for decision makers, who seek to calculate costs of surveillance and vaccination programmes. While it is clear that vaccination costs rise with an increasing number of animals, serological costs are less predictable, because factors such as type and number of diagnostic tests (e.g. ELISA or PCR) per animal can substantially influence these costs. For this reason, the mean error made by the linear model for surveillance (RMSE: €137,131.90 per district) demonstrated a larger error in cost estimation than the RMSE for vaccination (€20,521.77). A further benefit of our study is that the assessment of contributions in-kind makes these resources visible and shows how hidden investments have been used.

Conclusions

The assessment of costs with respect to the BTV surveillance and vaccination programmes in Austria revealed heterogeneous temporal and spatial distributions. The study demonstrates the importance of tracking changing costs over time and being aware that it is not only epidemiological models which are dynamic, but also the economic factors associated with monitoring infectious disease.

Conflict of interest statement

None of the authors of this paper has a financial or personal relationship with other people or organisations that could inappropriately influence or bias the content of the paper.

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Appendix: Supplementary material

Supplementary data to this article can be found online at doi:10.1016/j.tvjl.2015.07.032.

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