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Paper

Economic comparison of the monitoring programmes for bluetongue vectors in Austria and Switzerland

B. Pinior, K. Brugger, J. Köfer, H. Schwermer, S. Stockreiter, A. Loitsch, F. Rubel

With the bluetongue virus serotype 8 (BTV-8) outbreak in 2006, vector monitoring programmes (according to EU regulation 1266/2007) were implemented by European countries to obtain information on the spatial distribution of vectors and the vector-free period. This study investigates the vector monitoring programmes in Austria and Switzerland by performing a retrospective cost analysis for the period 2006–2010. Two types of costs were distinguished: costs financed directly via the national bluetongue programmes and costs contributed in-kind by the responsible institutions and agricultural holdings. The total net costs of the monitoring programme in Austria amounted to €1,415,000, whereby in Switzerland the costs were valued at €94,000. Both countries followed the legislation complying with requirements, but differed in regard to sampling frequency, number of trap sites and sampling strategy. Furthermore, the surface area of Austria is twice the area of Switzerland although the number of ruminants is almost the same in both countries. Thus, for comparison, the costs were normalised with regard to the sampling frequency and the number of trap sites. Resulting costs per trap sample comprised €164 for Austria and €48 for Switzerland. In both countries, around 50 per cent of the total costs can be attributed to payments in-kind. The benefit of this study is twofold: first, veterinary authorities may use the results to improve the economic efficiency of future vector monitoring programmes. Second, the analysis of the payment in-kind contribution is of great importance to public authorities as it makes the available resources visible and demonstrates how they have been used.

Generally, vector-borne diseases present a (re-)emerging threat to Europe (Schaffner and others 2013), the most prominent recent example of this is bluetongue disease, an arboviral disease among ruminants, transmitted by biting midges of the genus *Culicoides*. In 2006, bluetongue virus serotype 8 (BTV-8) emerged for the first time in Europe between the neighbouring countries the Netherlands, Belgium, Germany and Luxemburg (Gloster and others 2007, Mehlhorn and others 2007, Elbers and others 2008, Saegerman and others 2008) and tens of thousands of farms were affected (Robin and others 2014). In order to provide information about BTV-8 transmission dynamics or the freedom of BTV-8 in the European countries, monitoring and surveillance programmes were initiated in 16 regions in accordance with EU regulation 1266/2007 (Häsler and others 2012). In general, both monitoring and surveillance systems include a systematic data collection and provide valuable information for veterinary authorities about transmission, distribution of or freedom from diseases (Vazquez-Prokopec and others 2010). A monitoring programme, in contrast to surveillance, does not contain possible subsequent interventions (Drewe and others 2013b, Hoinville and others 2013). In the context of BTV-8, for example, a vector monitoring programme was implemented by a number of European countries. The midges were captured by light traps to obtain information on their distribution and seasonal activity. Nonetheless, the limited resources in the veterinary public health sector raise the question whether the information gained from such monitoring programmes is in adequate balance with the associated costs (Stärk and others 2006, Drewe and others 2013b, Hoinville and others 2013). For example, in the study by Drewe and others (2013a), gaps in the resource allocations for livestock health surveillance programmes in Great Britain were identified.

It is well recognised that an evaluation of such programmes is important for public authorities (Haghparast-Bidgoli and others 2014): first, to analyse whether the objectives of monitoring have been achieved (effectiveness), and second, whether the objectives of monitoring activities have been realised in an efficient manner (Drewe and others 2013b) without wasting

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resources (Hoinville and others 2013). Under ideal conditions, the economic evaluation is an integral part of the evaluation process (Drewe and others 2012). Although the evaluation of monitoring and surveillance systems is considered highly important, most of the existing evaluation frameworks neglect an economic analysis. This lack of economic analyses is mainly based on the difficulty to access or to identify economic data (Drewe and others 2013b).

According to Hoinville and others (2013), three types of economic evaluation in programmes can be distinguished: (1) economic optimisation, (2) economic acceptability as assessed by a cost-benefit analysis and (3) a cost minimisation analysis (CMA). Generally, it is necessary to compare different systems in economic terms to determine the lowest costs preferred by decision makers (Rutten and others 2012).

So far, no economic evaluations of vector monitoring programmes have been conducted in depth, although cost estimations for observed and simulated BTV-8 outbreaks have been previously published (Hadorn and others 2009, Velthuis and others 2010, Häsler and others 2012). In general, CMA is rarely used in the veterinary field (e.g. by Rutten and others 2012), but frequently utilised in the human healthcare sector (Keith and others 2014, Mariño and others 2014, Russell and others 2014, Wermeling and others 2014).

The aim of this study was to perform a cost analysis of the Austrian and Swiss vector monitoring programmes between the years 2006 and 2010. The objectives were (1) to estimate how much the information gained from vector monitoring costs, (2) to analyse which proportion of costs were financed directly by the national bluetongue monitoring programmes and which proportion were contributed as payments in-kind by responsible institutions and agricultural holdings towards the total cost and (3) to compare the costs of both vector programmes with a CMA to conclude how efficient the national monitoring activities were. This knowledge provides the opportunity to deliver potential economic improvements, for example, by the identification of areas where costs can be reduced or by a rational allocation of scarce resources. This enables decision makers, on the one hand, to conclude which kind of monitoring is preferred and, on the other hand, to increase the efficiency of future vector programmes.

Materials and methods

Vector monitoring programmes in Austria and Switzerland

In both countries, Austria and Switzerland, the national vector monitoring programmes were established in accordance with EU regulation 1266/2007 (http://eurlex.europa.eu) to investigate the occurrence and geographical distribution of midges in European countries. A review of *Culicoides* species distribution in Europe is provided, for example, by Goffredo and others (2004), Ander and others (2012) and Brugger and Rubel (2013a).

This was the first vector monitoring programme in Austria. Consequently, at the time of the BTV-8 outbreak in Europe in 2006, only rudimentary knowledge about the vectors was available (Anderle and others 2008). In order to obtain information on the abundance, the geographical distribution (particularly of *Culicoides obsoletus* as the main vector for transmission of BTV-8) and the vector-free period, a total number of 54 trap sites were selected in Austria (Fig 1). Trap sites were chosen by the application of 40×40 km^2 grids, within which one farm with at least 10 cattle was allocated. The responsible institutions were the Federal Ministry of Health (Bundesministerium für Gesundheit (BMG)), the International Research Institute of Entomology of the Natural History Museum Vienna (NHM) and the Austrian Agency for Health and Food Safety (Agentur für Gesundheit und Ernährungssicherheit (AGES)). After the initiation of the planning phase in October 2006, the monitoring began in June 2007 and continued until June 2010. Midges were collected weekly on Mondays from dusk till dawn with black-light traps from the Onderstepoort Veterinary Institute (Sehnal and others 2008). The official veterinarians of each Austrian district were instructed to operate the traps and to send the collected midges to the NHM for morphological determination and counting. Results of the Austrian monitoring programme were summarised in the project reports (Loitsch and others 2009, 2010).

In Switzerland, the vector monitoring programme was run by the Swiss Veterinary Office (Bundesamt für Lebensmittelsicherheit und Veterinärwesen (BLV)) and the Institute of Parasitology at the University of Zurich (IPZ). In contrast to Austria, the light traps in Switzerland were operated by farmers who sent the samples to the IPZ for morphological determination every second week. Midges were collected once a week using the same trap type as in Austria from a total of 19 traps from October to May (34 weeks) each year. This is the most significant difference between the two monitoring programmes. Since species composition and distribution were already known in Switzerland, the Swiss veterinary authorities were exclusively interested in determining and documenting the vector-free period. Sampling only during the cold months reduces the workload due to the shorter sampling period and lower numbers of trapped midges. The determination of the vector-free period enables trade of livestock out of a restricted zone because both countries have been affected by BTV-8. Results of the vector monitoring programme in Switzerland were published by Zaugg

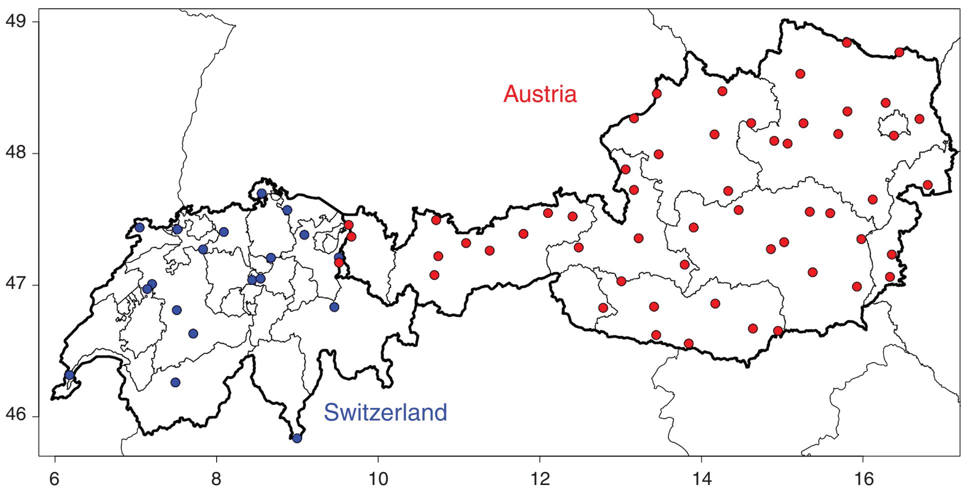

FIG 1: Locations of the 55 Austrian (red dots) and 19 Swiss trap sites (blue dots). Note that each programme also operated a trap in Liechtenstein. With an area of around 83,850 km^2, Austria is more than twice as large as Switzerland (41,200 km^2), whereas the size of the human population is rather comparable (Austria: 8.43 million; Switzerland: 8.04 million). Altogether there are around 2.39 million ruminants (cattle, sheep, goats) in Austria and 2.07 million in Switzerland. Climate zones and *Culicoides* species were described by Brugger and Rubel (2013a)

and others (2008), BVET (2009) and Schorer and Schwermer (2012). Each year a trainee uninstalled seven traps after the catching period and reinstalled the traps at the beginning of the next catching period in Switzerland. These and other differences between the two monitoring systems in Austria and Switzerland are summarised in Table 1. It should also be noted that both Austria and Switzerland operated one additional light trap in the neighbouring country of Liechtenstein.

Cost calculations

In a first step, the major cost factors were determined by analysing the activities needed to establish and run a vector monitoring programme (see online supplements). These comprised costs for planning C_B implementation C_I, analysis C_A, documentation C_D and finalisation C_F. Generally, this study differentiated the major costs into labour, material and other costs. Cost calculations for the five monitoring stages are summarised in Table 2 and explained in more detail in the following.

The net labour costs were calculated by the number of man-hours multiplied by the official hourly wage rate. In Austria, two different hourly wage rates were applied. The first hourly wage rate of €45.00 was based on the signed contract for employees of the NHM, the second hourly wage rate of €71.70 represents the average for an Austrian veterinary officer of BMG, AGES and federal states, estimated from the national pay grade level. Time sheets of the involved employees (as far as available) were used for calculating the labour costs for specific activities. If data were missing, values from the staff involved were used. Corresponding hourly wage rates in Switzerland were €19.80–25.70 for non-academic staff and €72.60 for academic staff.

Labour costs for the planning phase C_P comprised costs for budget calculation, review of literature and selection of trap locations, procurement and distribution of traps and related equipment, training events for employees from involved institutions and meetings. Labour costs for the implementation stage C_I comprised costs for installation of new traps, maintenance and repair of traps, collection and preparation of samples, as well as meetings. Labour costs for the analysis phase C_A comprised costs for morphological determination of midges and virus detection. Additional labour costs arose for documentation C_D and finalisation C_F of the vector monitoring. The latter included, for example, labour costs for dismantling traps after the collection period.

Material costs arose for planning, implementation and analysis, respectively. For the implementation stage, they were divided into costs for traps and related equipment, thermometers, climate data and packing material. Insight into the accounting system of the federal governments allowed us to estimate these costs. However, other costs comprised mainly callout charges for official veterinarians and costs for transport, electricity and catering, which were explicitly displayed for the implementation and included in the lump-sums for planning and finalisation. The calculation of these costs can be found in the online supplements.

Additionally, it was distinguished between costs financed by the bluetongue monitoring programme according to the EU regulations and the payment in-kind contribution of national public institutions such as BMG, AGES, BLV, veterinary offices and agricultural holdings. The latter were considered as hidden costs, generally not declared in official reports. Further, the cost fraction co-financed by the EU was estimated, although it is only relevant for the member state Austria. For both programmes, equal effectiveness is assumed, for example, an equally good chance of catching midges.

In the second step, the costs of the programmes were normalised according to trap samples, as both the number of trap sites and the number of sampling weeks differed between the two countries. It should be noted that sampling areas of 1600–2100 km^2 per trap are similar in both countries. Further, the Bray-Curtis dissimilarity measure $BC_{mA,mS}$ (Bray and Curtis 1957, Clarke 1993) was used to compare the monitoring costs of Austria C_{mA} and Switzerland C_{mS} for the five monitoring stages introduced above. If $BC_{mA,mS}(a)=0$, the activity costs (a) within a monitoring stage are similar. Maximal differences in the activity costs were estimated for $BC_{mA,mS}(a)=1$. The Bray-Curtis dissimilarity measure for each monitoring stage is defined as follows:

$$BC_{mA,mS}(a) = \frac{1}{2}\sum |C_a, m_A - C_a, m_S| \quad (1)$$

where the sum of all cost activities (a) is calculated for a specific monitoring stage listed in Tables 2 and 3.

Results

The net total costs for the Austrian bluetongue vector monitoring amounted to €1,414,583 and are depicted in Table 2. A total of €689,660 (48.8 per cent) can be allocated to the national bluetongue monitoring programme and the remaining €724,923 (51.2 per cent) as in-kind contributions of the participating institutions. The costs mainly accrued from the implementation stage with a share of €661,472 (46.8 per cent), followed by analysis costs of €566,948 (40.1 per cent) and to a much lesser extent by documentation costs of €122,269 (8.6 per cent). The lowest costs were calculated for planning with €63,567 (4.5 per cent) and finalisation with €327 (0.02 per cent), respectively. Considering the cost allocation divided by labour, material and others, the largest amount of €1,287,012 (91.0 per cent) was attributed to labour costs, followed by €71,862 (5.1 per cent) for others and €55,709 (3.9 per cent) for material. All material was officially financed by the national bluetongue monitoring programme, but 51.6 per cent of the labour costs and 85.2 per cent of the other costs were estimated as national in-kind support.

In contrast to Austria, a significant lower financial effort was calculated for the bluetongue monitoring programme in Switzerland, resulting in total costs of €93,039 (Table 3). As in Austria, about half of these total costs were accounted for payment as in-kind contributions. The Swiss analysis costs of €37,350 were followed by implementation costs of €35,763 causing together >75 per cent of the total costs. The Swiss costs for labour, material and others were allocated as follows: labour €79,365 (85.3 per cent), material €8,130 (8.7 per cent) and others

TABLE 1: Comparison of the Austrian and Swiss vector monitoring programmes for the period 2006–2010

Criteria for comparison	Austria	Switzerland
Responsible institutions	BMG, AGES, NHM	BLV, IPZ
Aims of the monitoring	Obligatory EU regulation	Voluntary EU regulation
Previous expert knowledge	Low	High (monitoring since 2003)
Exclusive national monitoring	Yes	No
Combined with sentinel surveillance	No	Yes
Virus detection in midges	Yes	No
Planning period	October 2006–May 2007	March 2007–September 2007
Monitoring period	June 2007–June 2010	October 2007–May 2010
Catching period	52 weeks/year	34 weeks/year
Number of trap sites	55	19
Take care of traps	Veterinary officer	Farmers
Training for trap care	Yes	No
Dispatching frequency of samples	4/month	2/month
Number of trap site changes	5	3
Dismantling of traps	After three years	Each year

Note that Switzerland is not a member state of the EU, but signed a bilateral agreement for the implementation of EU regulation 1266/2007
AGES, the Austrian Agency for Health and Food Safety; BLV, the Swiss Veterinary Office; BMG, the Federal Ministry of Health; IPZ, the Institute of Parasitology at the University of Zurich; NHM, the International Research Institute of Entomology of the Natural History Museum Vienna

TABLE 2: Specification of net costs for the Austrian bluetongue vector monitoring 2006–2010

Activities	Financed	In-kind	Subtotal
Planning costs C_P	22,681	40,886	63,567
Labour	15,840	40,886	56,726
Budget calculation	2678	2367	
Review of literature and selection of trap sites	2250	2367	
Procurement and distribution of equipment	1530	9899	
Training events	4252	12,911*	
Meetings	5130	13,342*	
Material	2000	–	2000
Other	4841	–	4841
Implementation costs C_I	39,839	621,633	661,472
Labour	765	560,427*	561,192
Installation, maintenance and repair of traps	–	7532	
Collection and preparation of samples	–	550,456	
Meetings	765	2439	
Material	33,586	–	33,586
Black-light traps and related equipment	26,570	–	
Thermometers and climate data	739	–	
Packing material	6277	–	
Other	5488	61,206	66,694
Callout charges for veterinarians	–	39,151	
Transport	5488	21,880	
Electricity	–	175	
Catering	–	–	
Analysis costs C_A	563,363	3585	566,948
Labour	543,240	3585	546,825
Determination of midges	543,240	–	
Detection of bluetongue virus	–	3585	
Material	20,123	–	20,123
Documentation costs C_D	63,450	58,819*	122,269
Labour	63,450	58,819	122,269
Finalisation costs C_F	327	–	327
Labour	–	–	–
Other	327	–	327
Total costs C_{Total}	689,660	724,923	1,414,583
Financed by the EU	266,772	–	266,772
Financed by national resources	422,888	724,923	1,147,811

*Labour costs partially/completely estimated by involved staff

€5,544 (6.0 per cent). In this context, the national in-kind payment of Switzerland comprises 50.1 per cent of the labour and 64.3 per cent of the other costs.

The comparison of the relative costs from Austria and Switzerland shows a similar cost allocation for the specific monitoring stages (Fig 2). The monitoring costs are normalised in order to account for the different number of trap sites and the number of sampling weeks between the two countries. The normalisation shows that the Austrian monitoring resulted in much higher costs (€164) than the Swiss monitoring (€48) per week and trap. These 3.4 times higher costs per week and trap in Austria can be broken down as follows: Austrian costs for documentation were 4.3 times higher, followed by implementation and analysis costs that were 4.2 and 3.4 times higher than in Switzerland. However, if the analysis costs were related to the number of collected midges, the costs per midge in Austria (0.07 cent) were 12 per cent of those in Switzerland (0.57 cent). The highest Bray-Curtis dissimilarity of the cost composition per monitoring stage can be found in the finalisation of the monitoring with $BC_{mA,mS}=0.76$, up to similar compositions of the costs, which can be found in all other monitoring stages. The values of the latter ranged between 0.00 and 0.17.

Discussion

The results show that the vector monitoring programmes incurred considerable costs in Austria (€1,414,583) and Switzerland (€93,039). These costs must be contrasted with a relatively small number of 28 BTV-8 positive cattle on 14 Austrian farms (Brugger and Rubel 2013b) and 160 infected animals reported on 70 Swiss farms (Schorer and Schwermer 2012). It should also be noted that this small number of cases may be the result of vaccination in the neighbouring Germany, but also to a lesser extent in Austria and Switzerland. Therefore, the question arises whether the costs of these vector monitoring programmes are justified. Specifying these costs, as presented here, may contribute to answering this question.

Our study has shown the financial effort necessary to collect information on the spatial distribution of vectors, their abundance and the vector-free period. In principle, such economic data are rare and difficult to obtain (Drewe and others 2013b). To date, no cost analyses have been carried out for the Austrian monitoring and surveillance systems. In Switzerland, these costs have recently been published by Häsler and others (2012). The costs of the vector programme in Switzerland were calculated to be 3.9 times lower than in this study (Häsler and others 2012). It is important to note that the quantification of the costs is mainly dependent on the provided documents. A certain lack of documentation was found for all in-kind contributions, particularly in the present study. A better documentation of the in-kind performance would be preferable in order to demonstrate the total financial effort in a more convincing way. In this context, the in-kind contribution can also be considered as fixed costs. In contrast to the variable costs, the fixed costs are rarely quantified in the literature (personal communication, 2013). However, the demonstration of the in-kind contribution is beneficial for two reasons. First, it could help to increase the country's bargaining power vis-à-vis the European Commission with regard to the maximum co-financing rate of the costs for a programme compared with when only the financed costs are shown. Second, the presentation of in-kind contributions is of great importance to public authorities as it makes the available resources/capacity visible and demonstrates how they have been used. Analysing the costs by payment source reveals that the Austrian in-kind contributions were mainly covered by the public (99 per cent) and were primarily allocated to staffing costs (91 per cent). In Switzerland, on the other hand, 26 per cent of the costs were

TABLE 3: Specification of net costs for the Swiss bluetongue vector monitoring 2006–2010			
Activities	Financed	In-kind	Subtotal
Planning costs C_P	–	5340	5340
Labour	–	5310*	5310
Budget calculation	–	726	
Review of literature and selection of trap sites	–	1452	
Procurement and distribution of equipment	–	771	
Training events	–	–	
Meetings	–	2361	
Material	–	–	–
Other	30	–	30
Implementation costs C_I	8130	27,633	35,763
Labour	–	24,069*	24,069
Installation, maintenance and repair of traps	–	4541	
Collection and preparation of samples	–	11,286	
Meetings	–	8242	
Material	8130	–	8130
Black-light traps and related equipment	6384	–	
Thermometers and climate data	99	–	
Packing material	1647	–	
Other	–	3564	3564
Callout charges for veterinarians	–	219	
Transport	–	3198	
Electricity	–	37	
Catering	–	110	
Analysis costs C_A	37,350	–	37,350
Labour	37,350	–	37,350
Determination of midges	37,350	–	
Detection of bluetongue virus	–	–	
Material	–	–	–
Documentation costs C_D	2250	4208*	6458
Labour	2250	4208	6458
Finalisation costs C_F	1950	6178*	8127
Labour	–	6178	6178
Other	1950	–	1950
Total costs C_{Total}	49,680	43,359	93,039
Financed by the EU	–	–	–
Financed by national resources	49,680	43,359	93,039

*Labour costs partially/completely estimated by involved staff

borne by the farmers operating the traps. Presumably these costs are underestimated because the income, and thus the hourly wage rate of farmers, can vary widely, for example, depending on the market price performance of agricultural goods offered. In Austria, the proportion of reimbursement by the public is presumably overestimated, on occasion it was found that some farmers operated the traps for the veterinarians (personal communication, 2013). In general, the normalised results show that an almost equal large amount of human resources (88 per cent on average) is needed for monitoring vectors (Fig 2). The allocation of costs in each monitoring stage is quite similar in both countries, with the notable exception of the finalisation of the monitoring (Fig 2). This is expressed by the high Bray-Curtis dissimilarity index and can be explained by the fact that the activities vary significantly in this stage. One example of this is that the traps were dismantled every year after the collecting period (34 weeks) in Switzerland, while the traps in Austria were dismantled only once after three years.

Furthermore, the results of this study indicated that the monitoring in Switzerland was 3.4 times more efficient than in Austria. This could imply that the Swiss programme should be followed in the future, based on the CMA. However, this conclusion and therefore the comparability of the costs of the two programmes is limited for several reasons: first, the Swiss institutions (BLV, IPZ) have previous experience in vector monitoring carried out from 2003 to 2006, which may have affected the C_P and C_A in this study. The information available from the previous programme led to the need for less information in the present study, reducing its costs (personal communication, 2013). Hence, it is not surprising that the absolute costs for planning and analysis are more than 90 per cent lower than in Austria (Tables 2 and 3), although the surface area of Switzerland is only half the area of Austria (Fig 1). These numbers demonstrate that increased cooperation, including the exchange of information and previous experience, between neighbouring countries could considerably reduce monitoring

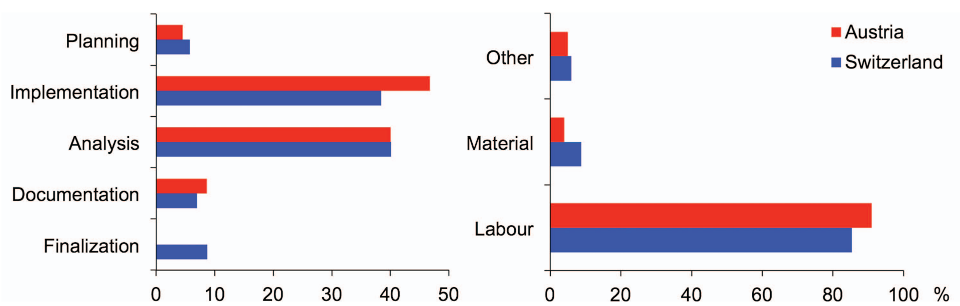

FIG 2: Allocation of the relative costs of the bluetongue monitoring programmes in Austria and Switzerland. Units: per cent

costs in the future. Second, both programmes fulfil the same legislative requirements, but use different sampling strategies. These may have an effect on the outcome of the monitoring. In contrast to the Swiss programme, the determination of the vector-free period was not the primary goal in Austria, where information on geographical distribution and vector abundance were equally important. A quantification of the outcome, such as the assessment of the quality and quantity of collected data, would be necessary to estimate the value of each country's programme and to put the value in relation to its costs in order to offer conclusions as to whether costs and benefits are in adequate proportion to each other. In our study, the value of the information has not been quantified in monetary terms, because the monitoring programme did not lead to damage limitation, to a reduction of costs of other surveillance systems (e.g. by identifying risk areas for targeted sampling), to intervention measures or to trade facilitation. The major benefits of the vector monitoring programme are the information about the existence of vectors, their spatial distribution and information on the vector-free period. However, a comparison of the outcome of both programmes could provide a different conclusion about the preferred vector programmes in the future.

Conclusions and recommendations

This paper provides insight into the allocation of costs of monitoring systems and assesses the efficiency of such programmes by comparing the costs. It also opens up the opportunity to derive potential economic improvements to increase the efficiency of future vector programmes. However, the comparability of the costs is limited for several reasons. First, the Swiss institutions have substantial experience of vector monitoring through past programmes, which were not captured by the present study. Second, both countries use different sampling strategies, based on their objectives. Third, absolute monitoring costs in each country are influenced by the surface area and the environmental conditions (Mehlhorn and others 2007, Saegerman and others 2008). Therefore, relative (normalised) costs, that is, costs per trapped midges or costs per week and trap, were calculated for comparison.

Recommendations for future vector monitoring programmes, especially in Austria, are (1) to estimate the likely benefits and costs of programmes and to ensure that both are in adequate balance before monitoring programmes are implemented. (2) To better document the in-kind contribution in order to increase the country's bargaining power vis-à-vis the EC with regard to the maximum co-financing rate of the costs for a vector programme. Our study has shown that a significant proportion of the visible costs was avoided by relying on national resources (unreported costs). (3) To determine only a statistically significant sample of the collected midges morphologically. Dealing with pools considerably reduces the costs without any loss of accuracy. (4) To focus time-wise on specific monitoring programmes and train staff on these. (5) Veterinary authorities should cooperate closer with research institutes, which have an interest in monitoring data. This measure would significantly improve data quality. The Austrian monitoring data, for example, have been shown to be inappropriate for quantitative analyses due to poor data quality (Pacheco 2009). Thus, they may not be used to develop models for midge dynamics and subsequently for epidemic models, a precondition for simulation studies to optimise control strategies.

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Contributors Conceived and designed the study: BP and JK. Provided and interpreted basic documents on the vector monitoring programmes: BP, SS, HS and AL. Collected and analysed the data: BP. Supervised the data analysis: FR. Wrote the paper: BP, FR, KB and HS.

Competing interests None.

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