ECONOMIC CONSEQUENCES OF THE DUTCH BLUETONGUE SEROTYPE 8 EPIDEMIC IN 2006 AND 2007

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SUMMARY

In this study the economic consequences of the bluetongue (BT) epidemic of 2006 and 2007 in the Netherlands were calculated. A deterministic economic model was constructed, reflecting the Dutch livestock production systems for cattle, sheep and goats. The net costs of the BT epidemic in 2006 (BT2006) has been valued at 32.4 million Euros and for the BT epidemic 2007 (BT2007) at 117-128 million Euros. The control measures constituted 91% of net costs of BT2006 and diagnosis costs, 7%. For BT2007, 90% of the net costs were production losses plus veterinary treatment, whereas only 9% was related to control measures. The cattle sector suffered 88% and 76% of the net costs for BT2006 and BT2007, respectively.

INTRODUCTION

Bluetongue (BT) is a viral disease among ruminants, transmitted by biting midges (*Culicoides*) (Verwoerd, 2004). Sheep, and less commonly cattle, can have severe clinical symptoms as a result of the infection and can even die (Elbers and van der Spek, 2008). The disease has been named after the swollen and sometimes cyanotic tongue, which is one of the symptoms of the disease. Because of the economic damage induced by bluetongue, it was listed as a notifiable disease in the 1960's by the World Organization for Animal Health (OIE).

In August 2006, the first BT virus serotype 8 (BTV8) outbreak ever in North-Western Europe was detected in the Netherlands. In that year, a total of 460 Dutch livestock farms were officially registered to be infected with BTV8. In the same period farms in Belgium, France, Germany, and Luxemburg became infected with BTV8 (Elbers et al., 2008a, b). Although a comprehensive set of control measures was put in place at national and at EU level in 2006, the infection reappeared and new outbreaks were reported in the Netherlands and the other originally infected countries in the summer of 2007. The epidemic developed quickly over a large part of North-Western Europe, resulting in the Netherlands in more than 6,000 outbreak farms.

It was clear that the BTV8 epidemic had a large impact, particularly in 2007. However, insight into the economic consequences of the epidemic and control measures was still missing. For the decision-making about the epidemic control it is important to know i) the losses due to BT, ii) the costs of control measures, and iii) the saved losses that resulted from the control

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measures. This economic analysis of the epidemic and the applied control measures contributes to bridging the information gap concerning the impact of the BTV8 epidemic.

A cost-benefit analysis (CBA) is the process of weighing the total expected costs against the total expected benefits of a project, or in this case epidemic control, to optimize control, i.e. choosing the best or the most profitable option to control. Cost-benefit analysis is typically used by governments to evaluate the desirability of a given intervention and the aim is to gauge the efficiency of the intervention. Based on the demographic, epidemiologic and economic information, the costs and expenditures due to the BTV8 epidemic and applied control measures for the different stakeholders can be calculated, but also the possible benefits. The net costs or losses that will be the output of the CBA include costs and expenditures that are corrected for possible profits.

In this paper a CBA of the BTV8 epidemic for the Netherlands is presented. It calculates the losses for different livestock production systems of the BTV8 epidemic from July 2006 to July 2007 (BT2006) and of the BTV8 epidemic from July 2007 to July 2008 (BT2007).

MATERIALS AND METHODS

To evaluate the economic impact of BT in the Netherlands a deterministic economic model was constructed, reflecting the Dutch livestock production systems. In this model the economic impact (the losses and expenditures, corrected for possible benefits) of BT was calculated by an integration of demographic, epidemiologic and economic data. Data from official sources were used as much as possible. Where information was lacking, experts were asked to make estimations. With respect to the model, assumptions and inputs, discussions with several parties from the sectors took place to secure the representativeness of the Dutch practice by the model.

Economic model

The economic consequences of the BTV8 epidemic included the impact on the production of animals due to the disease, the treatment of diseased animals, diagnostic costs, costs of control measures taken during the course of the epidemic (including price changes of animals and animal products due to transport restrictions)Eq.(1).

$$L = \sum_i \sum_j P_{i,j} + T_{i,j} + D_i + M_{i,j} \qquad (1)$$

where L represents the total damage for the entire livestock population due to the epidemic, P the production losses at farm type i and for animal type j, T the corresponding treatment costs, D the diagnostic costs, M the cost of the control measures. The different farm and animal types are given in the section titled Model Input. The different cost categories are explained in more detail in the following paragraphs.

Production losses

The production effects that have economic consequences include mortality (*MT*), early culling (*EC*), reduced milk production (*MP*), weight losses (*WL*), no gestations (*NG*), postponed gestations (*PG*), abortions (*AB*), less fertile rams (*RF*), lower birth weight (*BW*) and stillbirth (*SB*) Eq.(2).

$$P_{i,j} = \sum_i \sum_j MT_{i,j} + EC_j + MP_j + WL_j + NG_j + PG_j + AB_j + RF_j + BW_{i,j} + SB_j \qquad (2)$$

The losses due to mortality were calculated as shown in Eq.(3):

$$MT_{i,j} = mtr_{i,j} \cdot rp \cdot ar_i \cdot \left(v_j - sv_j + rc_j\right), \quad (3)$$

where *mtr* is the mortality rate (in number per 100 animal months), *rp* the period at risk, *ar* the number of animals at BTV8 infected farms, *v* the production value (for ewes it was the difference in the value of an ewe and the replacement lamb and for dairy cattle it was the retention pay-off (RPO value) (Houben, 1995)), *sv* the missed slaughter value and *rc* the costs made to send an animal for rendering.

The cost of early culling was calculated as shown in Eq.(4):

$$EC_j = pt_{EC,j} \cdot mbr_j \cdot rp \cdot ar_j \cdot v_j, \quad (4)$$

where pt_{EC} is the percentage of BTV8 infected cows culled early and *mbr* the morbidity rate (in number of animals per 100 animal months).

The lost revenues due to BTV8 related reduced milk production were calculated as ahown in Eq.(5):

$$MP_j = amp_j \cdot rmp_j \cdot 0.5 \cdot dd_j \cdot VM_j, \quad (5)$$

where *amp* equals the average daily milk production, *rmp* the relative reduction in milk production, *dd* the number of days that the animal was diseased (it was assumed that the milk production is reduced during the first half of this period) and *VM* the value of the milk that was lost.

If an animal is BTV8 infected, clinical symptoms occur that can lead to weight loss. The losses related to weight loss equal the costs of extra feed needed for compensatory growth (Eq.(6)):

$$WL_j = pt_{WL,j} \cdot EF_j, \quad (6)$$

where pt_{WL} is the proportion of animals with a weight loss and *EF* the costs for the extra feed needed for compensatory growth.

If a reproduction animal was not pregnant with a calf or lamb, the animal was culled. The economic consequences included therefore the production value (*v*), the lost value of the calf or lamb ($Price_{calf}$ or $Price_{lamb}$) corrected for the costs on feed and housing saved (*FC*) combined with an increased slaughter value (Δsv) in relation to the average cow or ewe going to slaughter Eq.(7):

$$NG_j = pt_{NG,j} \cdot \left(v_j + Price_j - FC_j - \Delta sv_j\right), \quad (7)$$

where pt_{NG} is the proportion of animals that was not pregnant with a calf or lamb.

If the number of cycles before gestation increased due to a BTV8 infection (*PG*) the losses for dairy cows equalled an extra insemination (AI_2) and the losses of a prolonged calving interval with one cycle (ΔCI_1). The latter included less milk returns, less calves, and a change in feeding costs (Jalvingh and Dijkhuizen, 1997) Eq.(8):

$$PG_{cow} = pt_{PG,cow} \cdot (AI_2 + \Delta CI_1). \tag{8}$$

The losses of having more cycles before gestation for ewes equalled the reduced slaughter value of lambs ($\Delta Price_{lamb}$), since they could not be sold in the right period Eq.(9):

$$PG_{ewe} = pt_{PG,ewe} \cdot \Delta Price_{lamb} \tag{9}$$

The losses of extra abortions due to a BTV8 infection equalled the losses due to a prolonged calving interval for dairy cows for 6 cycles (ΔCI_6) and the costs of two inseminations (AI_1+AI_2) Eq.(10):

$$AB_{cow} = pt_{AB,cow} \cdot (AI_1 + AI_2 + \Delta CI_6). \tag{10}$$

Hereby we assumed that the cows were not culled due to abortions and that two inseminations were needed for the following gestation. For ewes we assumed that they were culled due to abortion and the losses therefore equalled the losses of early culling ($C_{i,j}$) and the missed returns of an average of 1.5 the lambs that cannot be sold ($Price_{lamb}$) Eq.(11):

$$AB_{ewe} = pt_{AB,ewe} \cdot (C_{ewe} + 1.5 \cdot Price_{lamb}). \tag{11}$$

During the BT epidemic it was observed that BTV8 infected rams were less fertile or infertile for a certain period. The losses corresponding to this category equal the costs made to buy an extra breeding ram Eq.(12).

$$RF_{ram} = pt_{RF} \cdot Price_{ram} \tag{12}$$

Calves with lower birth weight (*BW*) and stillbirths (*SB*) were observed on BTV8 infected dairy farms. The losses due to a lower birth weight equalled the lower price the dairy farmer received for the calf from the veal calf farms ($\Delta Price_{calf}$). However, the losses for the veal calf farm equalled the costs of extra feed needed for compensatory growth (*EF*) minus the reduced price he had to pay for the calf Eq.(13):

$$\begin{aligned} BW_{dairyfarm} &= pt_{BW} \cdot \Delta Price_{calf} \\ BW_{vealcalffarm} &= pt_{BW} \cdot (EF_{calf} - \Delta Price_{calf}) \end{aligned} \tag{13}$$

The losses due to stillbirths equalled the missed price of a calf or lamb ($Price_{calf}$ or $Price_{lamb}$) corrected for the costs that were not made until the selling moment of a young calf, i.e. the feed costs (*FC*). For lambs these costs are zero since they are fed by the ewe, Eq.(14).

$$SB_j = pt_{SB,j} \cdot (Price_j - FC_j) \tag{14}$$

Treatment costs

BTV8 diseased animals could have been treated with pain killers (*pk*), antibiotics (*ab*) or corticosteroids (*cs*) to relieve the suffering of the diseased animal and to prevent secondary infections as a result of reduced immunity. However, a treatment to fight a BTV8 infection does not exist. The treatment costs included only the costs of the veterinary medicines and the application materials (*mt*). The costs of the veterinarian were not included, since most animals were treated at the first visit of the farm to make a BT diagnosis and those costs were included in the diagnostic costs. The treatments later in time were assumed to be applied by the farmer. The treatment costs were calculated as shown in Eq.(15):

$$T_i = mbr_j \cdot (pt_{pk,j} \cdot Price_{pk,j} + pt_{ab,j} \cdot Price_{ab,j} + pt_{cs,j} \cdot Price_{cs,j} + pt_{treated} \cdot Price_{mt}), \quad (15)$$

where $pt_{pk}, pt_{ab}, pt_{cs}$ represent the proportion of diseased animals that are treated with pain killers, antibiotics and corticosteroids, respectively, and $pt_{treated}$ the total proportion of animals treated. The price of the veterinary drugs and materials are represented by $Price_{pk}, Price_{ab}, Price_{cs}$ and $Price_{mt}$, respectively. If a dairy cow was treated with antibiotics an additional loss due to the milk that couldn't be delivered for 5 to 8 days was included in the calculations.

Diagnostic costs

The diagnostic costs included the costs of the veterinarians (state and own or private veterinarian), the materials for taking blood samples, and the test costs (including the submission costs to the lab). All tested farms and animals were included, so also the test-negative farms, the (screening) farms that were monitored to follow the spread of the epidemic and the animals to be exported. Until September 2007, the diagnostic costs were calculated as shown in Eq.(16):

$$D_i = VET_{own} + VET_{state} + samples \cdot (Price_{mt} + pt_{PCR} \cdot Price_{PCR} + pt_{ELISA} \cdot Price_{ELISA}) + sc, \quad (16)$$

where VET_{own} represents the costs of the own veterinarian, VET_{state} the costs of the state veterinarian, *samples* the number of samples taken, $Price_{mt}$ the price of the materials, pt_{PCR} the proportion of samples tested with the PCR, $Price_{PCR}$ the price of the PCR test, pt_{ELISA} the proportion of samples tested with the ELISA for the price of $Price_{ELISA}$, and *sc* the submission costs to the lab. As from September 2007, the official diagnosis of BT was allowed to be based entirely on the clinical inspection of a veterinarian, bringing the VET_{state} to zero. However, a number of samples were still submitted, that were included in the calculations.

Costs of control measures

During the BTV8 epidemic, control measures were put in place for animal holdings in different control zones around infected farms. The control measures included obligatory indoor housing of ruminants (*OH*), treatment of animals, stables and lorries for animal transport with insecticides (*TI*), extra testing and controls of animals for export (*EX*), and animal movement restrictions. The losses due to the animal movement restrictions were considered to be price changes of animals and animal products (*PC*) as an effect of market influences Eq.(17).

$$M_{i,j} = OH_{i,j} + TI_{i,j} + EX_{i,j} + PC_{i,j}. \quad (17)$$

In a 20 kilometre area around infected farms (20km-zone) all ruminants had to be housed at all times from August 17 till September 26, 2006. These animals had to be housed indoors during the evening and night from September 26 till October 13, 2006. The costs of obligatory indoor housing included feed, water, bedding materials and the costs for spreading of the extra manure produced on the fields during the first 14 days and the costs of removing the manure from the farm for the last 42 days. The latter costs were due to the regulation on minerals, which indicate that from September 1st the manure cannot be spread over the fields. The calculation is shown in Eq.(18):

$$OH_{i,j} = pt_{outdoor,i} \cdot na_{i,j} \cdot ((40 + \tfrac{1}{2} \cdot 17) \cdot EF_j + EBM_j + MP_{1,i} \cdot CSM_j + MP_{2,i} \cdot CMS_j), \qquad (18)$$

where $pt_{outdoors}$ is the proportion of animals that is usually in the fields in between August and November, *na* the number of animals, *EF* the costs of extra feed per day, *EBM* the costs of extra bedding materials, MP_1 the extra manure produced during the first 14 days, *CSM* the costs of spreading the extra manure on the fields, MP_2 the extra manure produced during the last 42 days and *CMS* the costs of removing the extra produced manure.

The farms that had to house the ruminants indoors also had to treat their animals and stables with insecticides. During the BTV8 epidemic officials regulated that lorries and the animals to be transported also had to be treated with insecticides. The corresponding costs are calculated as shown in Eq.(19):

$$TI_{i,j} = pt_{IT} \cdot (sa_i \cdot Price_{IS} \cdot nsa + na_{i,j} \cdot Price_{IA,i,j} \cdot nna_j) + nl \cdot Price_{IL} + nat_j \cdot Price_{IA,j}, \qquad (19)$$

where pt_{IT} is the proportion of farmers that obeyed the insecticide control measures, *sa* is the stable area, $Price_{IS}$ the price of insecticides for stables, *nsa* the number of treatments needed in 56 days, *na* the number of animals treated, *nna* the number of treatments per animal in 56 days, $Price_{IA}$ the price of the insecticides for animal treatment, *nl* the number of lorries treated, $Price_{IL}$ the price of insecticides per lorry, and *nat* the number of animals transported and treated.

The extra testing related to the export of dairy heifers includes the testing needed to find BTV8 negative farms and the extra testing of heifers to be exported. These costs were calculated as shown in Eq.(20):

$$EX_{exporters} = NFT \cdot (price_{PCR2} + VET_{own} + sc) + NEH \cdot Price_{testEH} + \Delta NEH \cdot REV_{EH}, \qquad (20)$$

where *NFT* is the number of farms tested, $price_{PCR2}$ the price of a PCR test at a non-accredited lab, *sc* the submission costs, *NEH* the number of export heifers, $Price_{testEH}$ the total test costs of an export heifer, ΔNEH, the decrease in number of export heifers due to the BTV8 epidemic, and REV_{EH} the revenues earned per exported heifer. The number of dairy farms tested increased during the epidemic, since more farms were positive and therefore not suitable for export. For the BT2007 epidemic it was assumed that for each farm that had exported two heifers, three farms were tested on BTV8. Furthermore, each exported heifer had been tested twice before export until October 2007, whereupon it was tested three times (to reduce the risk of exporting BTV8 positive animals). The cost of testing a BTV8 positive heifer on an export stable was also included. This situation happened 20 times and the costs included the decrease in value of the positive heifer, an extended quarantine period of the other heifers in the stable, and an extra test for the other heifers. The cost of testing a BTV8 positive heifer in the importing country was not included, since the probability of this situation was low (although it has happened) and the consequences were complex.

Price changes

Due to the BTV8 epidemic some export streams of animals (and animal products) were banned for set periods. Furthermore, movement restrictions within a country can disturb the supply and demand so that the price of animals can change for a certain period. To study the effects of the size of the 20km zone on the average market prices of production animals per month an Autoregressive Integrated Moving Average model was used. For export heifers no data were available and therefore experts on export heifers were asked to estimate the required input based on their experiences. The economic effect of price changes is calculated as shown in Eq.(21):

$$PC_{i,j} = NA_{i,j} \cdot \Delta Price_{i} \qquad (21)$$

where *NA* is the number of animals sold or bought, and $\Delta Price$ the change in price.

Model input

Sector information

The CBA included the cattle, sheep and goat sector. For each sector different farm types with average herd or flock size were considered (Table 1). Since farm numbers and sizes differed between the Northern (the provinces Friesland, Groningen, Drenthe and North Holland), Middle (the provinces Overijssel, Flevoland and Utrecht) and Southern regions (the provinces North Brabant, South Holland, Zealand and Limburg) of the Netherlands and because of the fact that mortality and morbidity rates differed between these regions due to the spread of the BTV8 epidemic in 2006 and 2007 from the Southern to the Northern regions, the CBA model differentiated between these regions. The information for the goat sector about different farm numbers and sizes over the different regions was not available.

Table 1. Demographic data about the Dutch cattle, sheep and goat sectors

	# Holdings				Average # animals/year/farm	
	N[1]	M[1]	S[1]	Total	Total[2]	for reproduction
Cattle holdings						
Dairy farms	6,863	11,361	4,077	22,301	116	64
Veal calf farms	599	1,818	757	3,174	133	0
Other cattle farms	1,838	4,961	2,927	9,726	37	16
Total				35,201	3,745,000	2,991,000
Sheep holdings						
Dairy sheep farms	11	14	5	30	245	240
Traditional herding	15	19	6	40	2015	448
Breeding farms	3,820	4,952	1,660	10,432	147	51
Fattening farms	732	949	318	2,000	157	0
Hobby farms	18,999	24,625	8,256	51,881	8	4
Total				64,383	4,286,091	1,325,092
Goat holdings						
Dairy goat farms				351	612	447
Fattening farms				45	297	0
Hobby farms				74,824	4	3
Total				75,220	502,540	369,756

[1] North (N), Middle (M), South (S)
[2] At a farm count in May 2007 for cattle and in November 2004 for sheep and goats, excluding the new born lambs and calves that were born and slaughtered within one year.

Reconstruction of the restriction zones

During the BTV8 epidemic different restriction zones were put in place, where different control measures were applied. The area within a 20 kilometres radius around infected farms – reflecting the area where most control measures were applied - was called the 20km zone. The area between the radii of around 100 and 20 kilometres around the infected farm was called the protection zone. In this area fewer control measures were in place than in the 20km zone. The remainder of the Netherlands is called the free zone, in which no control measures were in place. Based on the press publications of the Dutch Ministry of Agriculture, Nature and Food Quality the size of the different zones per month per half a province was reconstructed. By multiplying the number of farms per province by the size of the different zones in time the number of farms affected by different control measures was determined per unit of time.

Epidemiological input

Since the first detection of BTV8 in the Netherlands, different epidemiological studies have been conducted. For our model we used epidemiological input from different studies. Table 2 summarizes the input. Due to different estimates of the morbidity and mortality rates for cattle from different studies, we distinguished two scenarios in our model for the BT2007 epidemic. The morbidity and mortality rates in the first scenario (BT2007-A) were based on a longitudinal study of 585 officially BTV8 infected cattle farms ((Elbers & van der Spek, 2008)). The rates in the second scenario (BT2007-B) were based on a longitudinal study on 72 dairy farms in the Netherlands ((Bartels et al., 2008; Berends, 2008)). The information needed to calculate the losses due to the effects of BTV8 on animal production is summarized in Table 3.

Table 2. Morbidity, mortality, percentage adult animals with clinical symptoms, period at risk, and percentage and number of infected farms for the different animal types, regions and years

Description	Var.	Cattle			Sheep			Goats
		N[1]	M[1]	S[1]	N[1]	M[1]	S[1]	-
Morbidity rate (#/100 animal months)	*Mbr*							
BT2006		-	-	0.42[2]	-	-	1.30[2]	-
BT2007-A		1.66[3]	6.48[3]	4.65[3]	3.24[3]	6.48[3]	7.99[3]	1.30[4]
BT2007-B		1.42[5]	0.81[5]	1.03[5]	3.24[3]	6.48[3]	7.99[3]	1.30[4]
Mortality rate (#/100 animal months)	*Mtr*							
BT2006		-	-	0.04[2]	-	-	0.70[2]	-
BT2007-A		0.03[3]	0.23[3]	0.17[3]	0.79[3]	1.23[3]	1.60[3]	0.00[4]
BT2007-B		0.28[8]	0.26[8]	0.40[8]	0.79[3]	1.23[3]	1.60[3]	0.00[4]
Diseased adult animals (%)	pt_{adult}	88[2]	88[2]	88[2]	80[2]	80[2]	80[2]	-
Period at risk (months)	*Pr*	6	6	6	6	6	6	6
% Infected farms								
BT2006		0.0[2]	0.0[2]	100.0[2]	0.0[2]	0.0[2]	100.0[2]	100.0[2]
BT2007		82.7[6]	99.4[6]	99.9[6]	70.0[7]	70.0[7]	70.0[7]	100.0[7]
Estimated # Infected farms								
BT2006		0	0	200	0	0	270	0[4]
BT2007		7196	16224	6997	16505	21391	7172	25

[1] North (N), Middle (M), South (S), [2] (Elbers et al., 2008), [3] (Elbers & van der Spek, 2008), [4] (Dercksen et al., 2007), [5] (Bartels et al., 2008), [6] A study of the Animal Health Service on screening farms, [7] (Elbers et al., 2008), [8] (Berends, 2008)

Input for the cost calculation on diagnostics

For the calculation of the diagnostic costs, data from the official BTV laboratory (i.e. the Central Veterinary Institute) were used to calculate the input. The model differentiated between the number of samples taken on positive and negative tested farms, and farms tested for export (Table 4). Not all samples were tested by PCR or ELISA, the proportion tested with the different tests differed between years and farm types (Table 4). The economic input for the calculation of the diagnostic costs of BTV8 is summarized in Table 4.

Table 3. Input for the cost calculations on the production effects caused by BTV8

Description	var.	Cattle		Calves		Sheep		Goats	
		2006[1]	2007[1]	2006	2007	2006	2007	2006	2007
Days diseased (#)	*Dd*	18	21	-	-	18	21	18	18
BT related early culling (%)	pt_{EC}	3	3	-	-	3	0	0	0
BT related no gestation (%)	pt_{NG}	5.2	9.9	-	-	5.0	9.8	-	-
BT related postponed gestation (%)	pt_{PG}	36.9	53.5	-	-	0.0	10.0	-	-
BT related abortion (%)	pt_{AB}	2.0	6.2	-	-	1.9	3.2	-	-
BT related reduced fertility rams (%)[2]	pt_{RF}	-	-	-	-	0.0	75.0		
BT related reduced birth weight (%)	pt_{BW}	2.6	6.7	-	-	-	-	-	-
Average daily milk production (kg/day)	*amp*		26.90		-		2.00		2.48
Relative reduction milk production (%)	*rmp*		20		-		20		80
Value missed milk (€/kg)[3]	*VM*		0.06		-		1.13		0.41
Feed costs related to weight loss (€/a)	*EF*		5.60		19.93		-		-
Costs 1st artificial insemination (€/a)	AI_1		23.75		-		-		-
Costs 2nd artificial insemination (€/a)	AI_2		13.85		-		-		-
Costs postponed gestation (1 cycle) (€/a)	ΔCI_1		9.00		-		6.00		-
Costs postponed gestation (6 cycles) (€/a)	ΔCI_6		101.90		-		-		-
Feed costs until sale (€/animal)	*FC*		-		3.57		-		-

[1] BT2006 or BT2007

[2] Percentage of sheep farms that need one extra ram

[3] Due to the quota system for dairy milk equals the value of dairy milk the variable costs of milk produced.

Table 4. Average # of samples taken per farm and average proportion of samples tested with PCR or ELISA for farms tested positive, negative or for export, and economic input for calculation of the diagnostics costs

Description	Var.	Cattle		Sheep		Goats	
		BT2006	BT2007	BT2006	BT2007	BT2006	BT2007
Number of samples taken (#/farm)	*Samples*						
		11	4	3	2	-	8
		12	4	13	3	24	3
		44	81	6	4	52	683
Proportion samples tested PCR (%)	pt_{PCR}						
		100	100	100	100	-	100
		58	88	91	100	12	55
		80	90	27	100	27	51
Proportion samples tested ELISA (%)	pt_{ELISA}						
		70	94	40	96	-	100
		100	100	100	78	100	100
		100	100	100	32	100	100
				BT2006			BT2007
Veterinary cost for BTV8 diagnosis							
Own veterinarian	VET_{own}			78.67			78.67
State veterinarian	VET_{state}			183.32			183.32
Price of PCR (€/sample)	$Price_{PCR}$			87.58			33.2
Price of ELISA (€/sample)	$Price_{ELISA}$			5.83			6.13
Price materials for sampling (€/sample)	$Price_{mt}$			0.02			0.02
Submission costs (€/farm)	*Sc*			9.52			9.52

Input for the cost calculation on control measures: The input used for the cost calculations of the obligatory indoor housing is based on a Dutch handbook on livestock production ((ASG, 2006)) (Table 5).

Table 5. Input for the cost calculations on obligatory indoor housing

Description	Var.	Farm type			
		Dairy	Other cattle	Sheep	Goat
Proportion animals outdoor	$pt_{outdoor}$	85%	75%	100%	0%
Manure produced (m^3/farm in first 14 days)	MP_1	*70*	37	-	-
Manure produced (m^3/farm in last 42 days)	MP_2	*164*	46	-	-
ANIMAL TYPE		COW	CALF	SHEEP	GOAT
Extra feed costs - obligatory indoor housing (€/animal/day)	*EF*	€ 0.53	-	€ 0.04	-
Extra bedding materials (€/animal/day)	*EBM*	€ 0.06	€ 0.03	€ 0.08	-
Costs spreading manure on own fields (€/m^3)	*CSM*	€ 4.30	€ 4.30	€ 0.00	-
Costs removal of manure from the farm (€/m^3)	*CMS*	14.00	€ 14.00	€ 0.00	-

For the cost calculations of the treatment of stables and animals with insecticides, input was based on internet information and prices of insecticides were suggested by the Dutch Ministry of Agriculture, Nature and Food Quality (Table 6).

Table 6. Input for the cost calculations on treatment of stables and animals with insecticides

Description	Var.	Value
Proportion farmers obeying insecticide treatment measure	pt_{IT}	75%
Stable area	*sa*	
Dairy, veal calf, traditional herding		500
Other cattle farm, dairy sheep and goat farm		250
Sheep breeding and fattening, goat fattening, hobby farms		50
Costs treatment stall (100 $m^{3)}$	$Price_{IS}$	€ 27.55
Number of treatments	*nsa*	1.5
Costs treatment animal	$Price_{IA \cdot nna}$	
Cattle		€ 1.09
Sheep and goats		€ 0.58
Number of animal treatments	*nna*	
Cattle		2
Sheep and goats		4

Sensitivity analysis

A sensitivity analysis was performed on the variables that were assumed to be most influential, i.e. the number of BTV8 infected farms, the number of farms that had to obey the obligatory indoor housing in 2006, mortality rates, morbidity rates and the proportion of reproduction animals with a postponed gestation or an abortion.

RESULTS

Reconstruction of the restriction zones

Figure 1 shows the relative number of farms in the different BTV8 restriction zones. The 'free zone' disappeared within one month after the detection of the first outbreak farm. The number of farms in the 20km zones increased quickly to more than half of the farms in the period between January 2007 and August 2007, after which all farms were located in the 20km zone. From November 2007 the whole area of the Netherlands was officially a protection zone until July 2008.

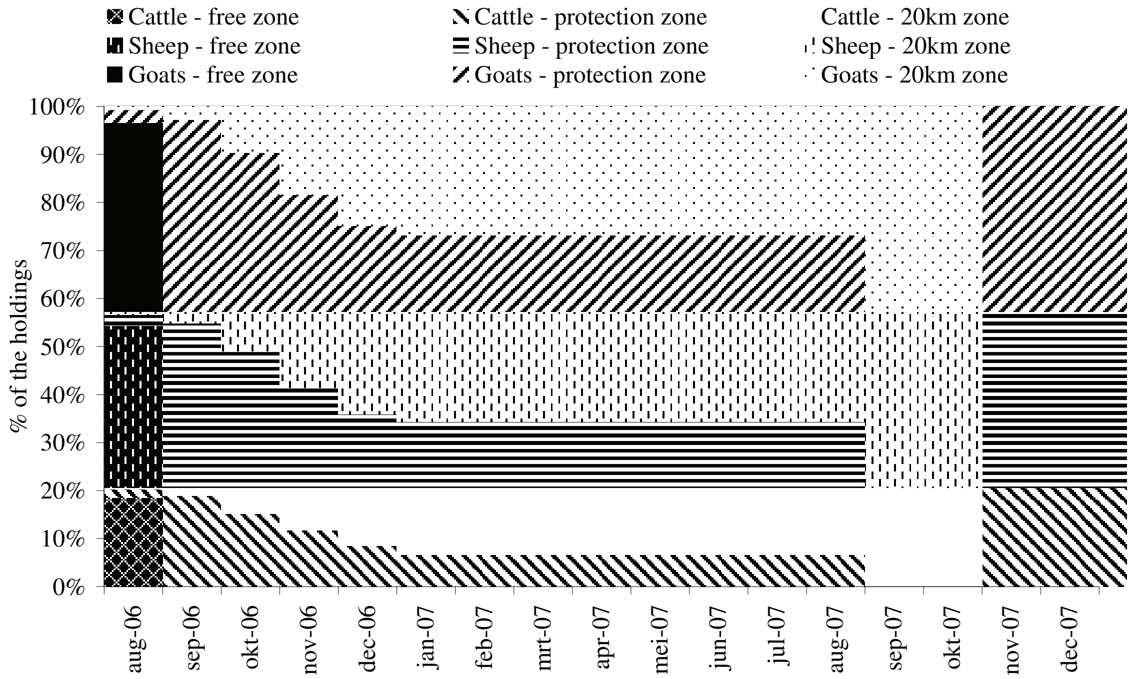

Figure 1. Relative number of cattle, sheep and goat farms in the different restriction zones.

Net costs BT2006 and BT2007 epidemics

The net costs of the Dutch BT2006 epidemic were more than 32 Million Euros and 117.1 to 128.4 million Euros for the BT2007 epidemic, depending on the applied epidemiological estimations (scenario A or B: Tables 5 and 6). The compulsory indoor housing determined 55% of total economic impact in 2006, transport restrictions 36%, diagnosis costs 7%, and the production losses plus treatment less than 2%. In 2007, 90% of total economic impact was caused by the production losses and treatments and only 9% by the transport restrictions. The distribution of the losses over the different components in 2007 differed from 2006. This is because the compulsory indoor housing did not take place in 2007, the rules of diagnosis were relieved from September 2007, and the higher number of farms and animals that were infected with BTV8 during the BT2007 epidemic.

Table 5. Net costs (*1000 Euros) of the BT2006 epidemic per farm type, sector and in total

FARM TYPE SECTOR	PRODUCTION LOSSES	DIAGNOSIS	TREATMENT	CONTROL MEASURES	TOTAL
Dairy	371.8	185.9	5.4	14,940.5	15,503.6
Veal calf	0.7	-	-	303.0	303.7
Other cattle	22.6	75.9	0.6	916.9	1,016.1
Susp. test neg[1]	-	196.8	-	-	196.8
Screening	-	1,313.8	-	-	1,313.8
Export	-	-	-	10,086.3	10,086.3
Cattle subtotal	395.0	1,772.5	6.1	26,246.7	28,420.3
Dairy sheep	0.1	0	0	9.5	9.6
Trad. Herding	0.5	0.2	0	97.8	98.5
Breeding	59.4	46.4	2.9	1,954.4	2,063.2
Fattening	4.3	8.9	0.5	414.7	428.4
Hobby	5.4	94.9	0.3	598.3	699.0
Susp test neg.	-	99.3	-	-	99.3
Screening	-	120.2	-	-	120.2
Export	-	-	-	19.4	19.4
Sheep subtotal	69.7	367.0	3.7	3,094.1	3,537.6
Dairy goat	0	0	0	54.8	54.8
Fattening	0	0	0	0.9	0.9
Hobby	0	0	0	225.8	225.8
Susp. test neg	-	6.2	-	-	6.2
Screening	-	120.2	-	-	120.2
Export	-	-	-	5.6	5.6
Goat subtotal	0	126.5	0	287.1	413.5
Transport subtotal				1.9	1.9
Total	464.8	2,268.9	9.8	29,629.8	32,373.3

[1] Suspected farm but tested negative

Comparison economic impact of subsectors

The cattle sector suffered the greatest economic impact, i.e. 88% of total economic impact in the 2006 epidemic and 76% of the impact in the 2007 epidemic. Within the cattle sector, the economic impact for the dairy farmers was highest (55% of the total economic impact for the cattle sector in 2006, and 77% in 2007). Thereafter, the exporters and the quarantine farms for export experienced most economic impact (35% of the total economic impact in the cattle sector in 2006 and 11% in 2007). Within the sheep sector, the sheep producers suffered most economic impact (58% of the total economic impact for the sheep sector in 2006 and 71% in 2007). The small-scale sheep farms experienced an economic impact that corresponded to 20% of the total economic impact for the sheep sector in 2006 and 5% in 2007.

Table 6. Net costs (*1000 Euros) of the BT2007 epidemic per farm type, sector and in total.

FARM TYPE SECTOR	PRODUCTION LOSSES		DIAGNOSIS	TREATMENT		CONTROL MEASURES	TOTAL	
	2007-A	2007-B		2007-A	2007-B		2007-A	2007-B
Dairy	55,463.3	71,621.9	354.5	8,821.5	2,123.8	1,493.4	66,132.6	75,593.6
Veal calf	257.2	257.2	-	-	-	0.1	257.2	257.2
Other cattle	8,100.6	11,253.3	158.0	1,641.6	314.5	0.1	9,900.3	11,725.9
Susp. test neg	-	-	154.1	-	-	-	154.1	154.1
Screening	-	-	182.2	-	-	-	182.2	182.2
Export	-	-	-	-	-	9,414.8	9,414.8	9,414.8
Cattle subtotal	63,821.0	83,132.3	848.8	10,463.1	2,438.4	10,908.3	86,041.3	97,327.8
Dairy sheep	5,344.2	5,344.2	0.0	12.8	12.8	0.2	5,357.2	5,357.2
Trad. Herding	327.8	327.8	1.2	419.4	419.4	0.5	749.0	749.0
Breeding	14,771.3	14,771.3	324.9	2,671.4	2,671.4	43.8	17,811.4	17,811.4
Fattening	2,408.8	2,408.8	62.3	1,980.8	1,980.8	15.7	4,467.7	4,467.7
Hobby	1,076.5	1,076.5	339.8	142.2	142.1	1.8	1,560.3	1,560.3
Susp. test neg.	-	-	91.7	-	-	-	91.7	91.7
Screening	-	-	26.0	-	-	-	26.0	26.0
Export	-	-	-	-	-	1.8	1.8	1.8
Sheep subtotal	23,928.7	23,928.7	846.0	5,226.5	5,226.5	63.9	30,065.1	30,065.1
Dairy goat	199.6	199.6	311.8	311.8	311.8	54.8	823.2	823.2
Fattening	0.0	0.0	0.0	4.9	4.9	0.9	4.9	4.9
Hobby	0.0	0.0	2.8	101.3	101.3	225.8	104.1	104.1
Susp. test neg	-	-	3.3	-	-	-	3.3	3.3
Screening	-	-	26.0	-	-	-	26.0	26.0
Export	-	-	-	-	-	18.1	18.1	18.1
Goat subtotal	199.6	199.6	344.0	418.0	418.0	18.1	979.7	979.7
Transp.subtotal						0.7	0.7	0.7
Total	87,949.4	107,260.6	2,038.9	16,107.6	8,082.9	10,991.0	117,086.8	128,373.4

Sensitivity analysis

The net costs of the BT2006 epidemic were most sensitive to a change in the number of farms that had to obey the indoor housing obligation (Table 7). The net costs of the BT2007 epidemic was most sensitive to the number of BTV8 infected farms, but was also sensitive to the mortality rate and less sensitive to the morbidity rate and fertility variables.

Table 7. Relative change in net costs due to a 10% change of an input variable.

VARIABLE	CHANGE	RELATIVE CHANGE IN NET COSTS	
		BT2006	BT2007
# BTV8 infected farms	-10%	-0.28%	-6.46%
# BTV8 infected farms	+10%	0.13%	5.92%
# Farms compulsory indoor housing	-10%	-5.43%	-
# Farms compulsory indoor housing	+10%	5.43%	-
Mortality cattle and sheep	-10%	-0.03%	-3.02%
Mortality cattle and sheep	+10%	0.03%	3.02%
Morbidity cattle and sheep	-10%	-0.01%	-1.44%
Morbidity cattle and sheep	+10%	0.01%	1.44%
Proportion animals postponed gestation	-10%	-	-1.51%
Proportion animals postponed gestation	+10%	-	1.44%
Proportion animals abortion	-10%	-	-2.05%
Proportion animals abortion	+10%	-	1.19%

DISCUSSION

This cost benefit analysis focussed on a sector point of view. Although the different farm types, the distribution of the farm types over the Netherlands, as well as the presence of unregistered hobby sheep and goat farms are taken into account, it calculated the average economic impact (net costs) due to a BTV8 infection for the average farm. This research is suitable to support decision-making at sector level on, for example, the retrospective evaluation of implemented control measures, like the transport restrictions. It can also be used to evaluate future control measures, like vaccination strategies. However, assumptions have to be made on the size of the epidemic in the future. An evaluation of vaccination strategies in the epidemic year of 2008 (July 2008 till July 2009) has been made and will be published soon.

The cost benefit analysis is not suitable to support decisions at individual farm level on, for example, voluntary vaccination or the treatment of animals for several reasons. Each farm is unique and is not described by the average farm demographics as used in this study. Moreover each farm has a specific financial situation that puts the losses due to BTV8 infection in a unique risk perspective. Furthermore, an individual farmer does not make decisions purely on economic criteria, but also on the BTV8 history of the farm in the previous year(s). Thereby, experienced emotional impact can influence the BTV8 related decisions at farm level.

The net costs related to the BTV8 epidemic (until July 2008) were between 150 to 160 million Euros. At the start of the epidemic (i.e. in BT2006) the majority of losses were due to control measures, whereas in the second year of the epidemic (i.e. in BT2007) the majority of the losses were due to the production losses and treatment of diseased animals.

Epidemiological variables (e.g. morbidity and mortality) had a relative big influence on the net costs, especially when the epidemic has affected a large number of farms (BT2007). This study used two scenarios of morbidity and mortality estimates for cattle. The net costs were 11 million Euros (about 10%) higher in scenario B than in scenario A. Looking more in detail it showed that the production losses in scenario A were 22% lower, whereas the treatment costs were 50% higher compared to scenario B. In scenario A the morbidity rates were higher causing higher treatment costs, whereas in scenario B the mortality rates were higher, which caused (even) higher production losses.

The results showed that the net costs for the cattle sector were much higher than for the sheep sector or the goat sector, while the number of sheep and goats were much higher and the morbidity and mortality rates of sheep were much higher. The difference in net costs was due to the fact that the value of cattle (and therefore also the losses in case of diseases) was much higher.

Summarizing, this study shows that an introduction of an exotic disease in the Netherlands can cause very high losses, due to the disease and due to the control measures taken.

ACKNOWLEDGEMENTS

This study was funded by the joint commission on cattle health and quality (DKR) of the Product Boards for Livestock and Meat and the Dutch Dairy Board. We gratefully acknowledge Chris Bartels, Inge Berends, Lammert Moll, Gerdien van Schaik and Piet Vellema (Animal Health Service) for their input.

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