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Evaluation of a voluntary passive surveillance component in cattle through notification of excess mortality

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ABSTRACT

Passive surveillance can be most effective in the early detection of disease outbreaks given that farmers observe their animals daily. The European Animal Health Law states that unexplained excess mortality should be reported to the veterinary authorities. In the Netherlands, in addition to notifications to the competent authority, Royal GD is commissioned a passive surveillance component that consists of a veterinary helpdesk and post-mortem examination for early detection of emerging diseases. The aim of this study was to evaluate this voluntary passive surveillance component through excess mortality in cattle.

Weekly on-farm mortality was calculated using the cattle Identification and Registration records. Mortality was assessed on regional level for dairy, veal and other beef cattle using a Generalized Linear Model (GLM) (log-link, negative binomial). We used a cumulative sum of the model residuals to identify periods of excess mortality. The mortality was defined as excessive when above five times the standard error. The analysis was also conducted on herd level, but these models did not converge.

We checked for an association between the two passive surveillance components elements and excess mortality. A GLM (log-link, negative binomial) with the number of contacts or submissions per region as the dependent variables and excess mortality per region and year as independent variables was carried out.

Overall, the models showed significantly higher use of passive surveillance components in periods of excess mortality compared to non-excess periods. In dairy cattle the odds for contact or submission were between 1.72 (1.59–1.86) and 2.02 (1.82–2.25). For veal calves we found the odds of 2.19 (1.18–4.04) and 2.24 (1.78–2.83) relative to periods without excess mortality. Beef cattle operations, other than veal, showed only an increased odds for postmortem submissions in calves of 3.71 (2.74–5.01), submissions for cattle and contact in general was not increased for this farm type.

In conclusion, the voluntary passive surveillance component in the Netherlands is used more often in periods of excess mortality in cattle. The chance of getting a timely response is highest for dairy farms. For veal calf operations the chance of receiving a timely response is more likely for postmortem submissions. A comparison with passive surveillance for excess mortality in other countries was not possible because no literature could be found. However, the method of this study can be used by other countries to evaluate their passive surveillance. This would make comparison of the performance of passive surveillance in different countries possible.

1. Introduction

Early detection of infectious diseases in animals is important for prevention of disease transmission between farms and countries. In this study passive surveillance is defined as, observer-initiated provision of animal health related data (e.g. discuss clinical signs including mortality) or the use of existing data for surveillance. Decisions about whether information is provided, and what information is provided from which animals is made by the observer (Hoinville et al., 2013; RISKSUR, 2013). In contrast, in active surveillance data collection is initiated by the investigator. Potentially, passive surveillance can be the most effective way for early detection of disease outbreaks, because the

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coverage and frequency (most farmers observe their animals daily) outperform what can be afforded by active surveillance (Cameron, 2011). However, effectiveness and timeliness in disease detection depends on the collaboration of farmers and veterinarians, as well as on the ability to recognize clinical symptoms (Cameron et al., 2020). If disease symptoms are very generic, subtle or absent, the farmer may not be able to recognize diseased animals. Detection of disease can be enhanced by increasing their knowledge on emerging diseases and their trust in the executing institution or authority (Cameron et al., 2020; Elbers et al., 2010). Although of importance, evaluation of passive surveillance components is not straight forward. Objective quality parameters such as sensitivity and timeliness are difficult to determine as information on farmers and veterinarians, who did not notify suspicion of disease while the herd was infected, is most often missing (Cameron, 2011).

A recent example of disease detection using passive surveillance, is the bluetongue virus (BTV) serotype 3 epidemic in the Netherlands, which was detected early September 2023 (Holwerda et al., 2023). This epidemic was notified to the veterinary authority, the Dutch food and consumers safety authority (NVWA), and also reported to the veterinary helpdesk of the private organization Royal GD (Gezondheidsdienst voor Dieren, Deventer, Netherlands) (Vredenberg et al., 2022). These are the two passive surveillance components in place in the Netherlands. In case of notifiable disease it is obligatory by Dutch law to report the suspicion to the NVWA, which can take measures in case tests turn out to be positive (NVWA, 2024). The veterinary helpdesk of GD can be contacted directly by farmers and vets to discuss a variety of animal health related topics (Vredenberg et al., 2022). Between 4th September and the 31th of October in 2023 an excess of 37 thousand sheep died from the disease (Santman-Berends et al., 2023). Besides BTV, there are more infectious diseases causing elevated mortality rates. Other examples of infectious animal disease with high mortality rates are highly pathogenic avian influenza (HPAI) in poultry and classical and African swine fever in pigs (OIE, 2024).

In the European Union, regulations for identification and registration of cattle have been implemented in 2000 (Regulation (EC) No 1760/2000, 2000). As a result, in most European countries cattle mortality is well registered which makes this data accessible for surveillance purposes. Additionally, the European Animal Health Law (AHL), implemented in 2021, mandates the reporting of deviating mortality to the authorities. Despite this obligation, the exact definition of 'deviating mortality' for cattle is not further defined in the AHL. Several studies have shown that syndromic surveillance on mortality data was valuable for early disease detection (Struchen et al., 2015; Torres et al., 2015). These studies used algorithms for detection and prediction of excess mortality based on the data from the identification and registration systems (Faverjon et al., 2021; Fernandez-Fontelo et al., 2020; Struchen et al., 2015; Torres et al., 2015). However, none of the studies evaluated whether notifications of excess mortality through passive surveillance would support early detection of disease.

In the Netherlands, the voluntary passive surveillance component is commissioned to Royal GD by the Ministry of Agriculture and the industry and includes a veterinary helpdesk and postmortem examination (Vredenberg et al., 2022). The voluntary passive surveillance component is subsidized, on a 50–50 basis by the government and cattle industry for all cattle farms. The passive surveillance component provides farmers and veterinarians with expert information when they have animal health related questions. At the same time, the information provided by the farmer or the veterinarian is collected and analyzed with the purpose of early detection of emerging diseases. In this study we aimed to evaluate the voluntary passive surveillance component through excess mortality in cattle.

2. Method

2.1. Available data

The study included data from July 2017 to July 2022. In this period no notifiable diseases associated with increased mortality rates were recorded. The first dataset, cattle identification and registration, contained the registration of birth, movements and removal from all cattle in the Netherlands (Table 1). Calves were included as long as they have been ear-tagged. In the Netherlands calves have to be tagged within three days after birth. Mortality of perinatal calves (<3 days, not ear-tagged) was beyond the scope of our study (Santman-Berends et al., 2019). The data was extracted from the national identification and registration system (I&R). The reason of removal dataset described the reason for removal from the registration, being slaughter, export or death. Death was defined as on-farm mortality resulting in the collection and registration of the carcass by the authorized rendering company Rendac (Son, Netherlands). The third dataset from the I&R system, farm registration, contained farm ID, the start date, and the stop date if the farm quitted its activities. The farm registration dataset was supplemented with the farm information dataset containing the anonymized farm ID, farm size, farm type and first two digits of the postal code (PC2) of the farm (Fig. S1). Farms with more than one farm type, had an ID for each farm type and were therefore already in the data separately.

The information of the veterinary helpdesk and the postmortem submissions was provided by Royal GD for the whole study period. The veterinary helpdesk data contained information on the farm ID, veterinarian ID, location of farms and veterinary practices on PC2 level, topic of the contact and the date. Possible topics for contact were udder, gastro-intestinal tract, mortality, respiratory tract, lameness, birth, production, fever, fertility, nerve system, stragglers, eye, skin and miscellaneous (Vredenberg et al., 2022). The postmortem data contained the farm ID, age of the cattle and the date.

2.2. Data editing

Based on the cattle identification and registration dataset, the age of the animals which were coded as on-farm death (Reason of removal), was assigned as calf when the age was <365 days and cow at >365 days. The number of cows was aggregated to farm level based on farm ID, week number and year, after which the farm size, farm location (PC2) and farm type were matched to the data. Farm type was categorized to dairy farms, veal calf operations, and other beef cattle operations (e.g. young stock, suckler). Farms were allowed to switch farm type within the study period. In that case, farms were in their start category until the time they switched and entered the new category for the remaining time period.

The veterinary helpdesk data was aggregated to farm level counting the number of contacts of a farm within a week. The total number of contacts per farm per week was counted, with in addition the registration of the topics mastitis, miscellaneous or mortality related topics (e.g. sudden death, dead calf, increased mortality, abortion). The submitted postmortems were also aggregated to farm level counts based on the

Table 1
Overview of the available datasets with their content.

Name dataset	Content dataset
Cattle identification and registration	Birth date, movement date, removal date
Reason of removal	Slaughter, export, death, date
Farm registration	Farm ID, start date, stop date
Farm information	Farm size, farm type, location[1]
Veterinary helpdesk	Farm ID, veterinarian ID, location[1] farm, location[1] veterinary practice, contact topic, date of contact.
Postmortem	Farm ID, age of cattle, date of submission

1 location defined as the first two digits of the postal code.

farm ID, week number and year. The veterinary helpdesk data and postmortem data was added to the previously described set containing the on-farm mortality.

The final dataset for analysis was aggregated to region level based on the PC2. Regions with few farms were combined (Fig. S1). The aggregation from farm to region level followed by the combination of regions was necessary to prevent lack of power in the outcome variable being mortality, because many weeks without mortality resulted in models that did not converge. A pre-analysis showed that for dairy farms and veal calf operations at least 20 farms had to be within a region, for other beef cattle operations this was 100 farms. Regions below these numbers of farms were aggregated to the largest geographical neighbor until the required numbers of 20 and 100 farms were reached. Regions 22 and 23 were excluded from the veal analysis, because the low number of farms still resulted in a not converging model, which causes false positive periods of excess mortality while there were no registered deaths within those periods. Region 25 was excluded from the dairy farm and veal operation analysis, because no farms of this type were registered in this region.

2.3. Modelling excess mortality

To model excess mortality, first a generalized linear model was fitted for each region separately. We used the *glm.nb* function of the "MASS" (version 7.3–58.1) package in R to fit the models. Fitting separate models allowed the baseline to be different for regions, as regions can have different baseline mortality due to differences in numbers of farms and herd sizes. The models contained only year as independent variable and mortality as dependent variable, α represents the intercept of the model, β1 the estimated coefficient for year and ∈ is the random error term. (Eq. (1)). Because of the right-skewness of the mortality distribution we used a negative binomial distribution with a log-link. Although there were some seasonal effects on national level, including week, month or quarter in instead of year did not result in significantly better models on regional level based on Akaike's Information Criterion (AIC) (Akaike, 1973). For all farm categories, calf (cattle younger than or equal to 365 days) mortality was analyzed. For dairy farms and other beef cattle operations also cow (cattle older than 365 days) mortality was analyzed. Regions were included in the analysis if they had, within the whole study period, at least one week with more than 3 reported cow deaths in a week or more than 4 calves. This step was necessary to prevent non-converging models. As the aim of the research was the evaluation of surveillance for early detection, mortality of less than 3 cows or 4 calves were assumed to be "normal" mortality due to chance. These thresholds were not completely arbitrary chosen. In another study we conducted a survey containing the question at which level of weekly cow and calf mortality they contact the veterinary helpdesk based on a herd size of 100 cows (Vredenberg et al., In preparation). The chosen thresholds of 3 dead cows or 4 dead calves in a week are based on the results of the survey. Although this question was at farm level, using the threshold on region level guarantees that a farm with excess mortality in the regions would not be missed in the analysis.

$$Mortality = \alpha + \beta 1 * Year + \in \quad (1)$$

The linear models as described in the previous section resulted in baseline mortality models for every region separately. In order to find periods of excess mortality we performed a cumulative sum (CUSUM) for all regions within all five analyses (three herd types and one or two age categories). The residuals of the regional linear models, were used as input data for the CUSUM. A CUSUM analysis is a statistical technique which can be used to detect deviation in sequential data. It is often used to analyze and monitor the standard performance of industrial processes, but can also be used in other scientific fields. It analyses the cumulative sum of differences between data points and a reference value, identifying trends in data over time. The plotted points should fluctuate randomly around zero. If an upward or downward trend develops, the process mean has shifted and the process may be affected by special causes. First, the deviation of the sequential datapoints (x_j) around the group mean ($\widehat{\mu}$) is calculated (Novoa and Varela, 2020). The process is "in control" if the deviation ($x_j - \widehat{\mu}$) fluctuates randomly around zero. However when the cumulative sum of the deviation moves away from zero and exceeds a pre-set upper (UB) or lower bound (LB), the process is "out of control". In other words, the mean of the process has shifted. Eqs. (2) and (3) show the mathematical notation of the CUSUM (Yu and Cheng, 2022). C_j represents the shift in the positive (equation1) and negative direction (Eq. (2)) for timepoint *j*. T_j is the shift corresponding to timepoint *j* and is summed with the previous timepoint (C_{j-1}) to obtain C_j. The definition and calculation of the T_j varies.

$$C_j^+ = \max\{0, \quad T_j + C_{j-1}^+\} \quad (2)$$

$$C_j^- = \min\{0, \quad T_j + C_{j-1}^-\} \quad (3)$$

$$T_j = \frac{(x_j - \widehat{\mu})}{\frac{\sigma}{\sqrt{n}}} - \left(\frac{se.shift}{2}\right) \quad (4)$$

We used the *cusum* function (version 2.7) of the "qcc" package in R (version 4.2.2) (Scrucca, 2004). In the *qcc* package the deviation is expressed in standard errors of the mean. Eq. (4) shows how T_j in this package is calculated. The allowed deviation before detecting a shift, can be adjusted by changing the value of argument *se.shift*. The threshold for a process being out of control can be regulated by the *decision.int* argument of the *cusum* function. For both we used the package's default setting of 1 for the *se.shift* and 5 std. errors for *decision.int*.

As mentioned earlier the residuals of the glm models were used as input data for the CUSUM. If the process is "in control", there is no excess mortality of cattle found for that region for these weeks. When the CUSUM value exceeds the threshold of the UB, the process is "out of control" and these weeks were denoted as weeks with excess mortality. In this study, only violations of the upper bound were evaluated, as we were only interested in excess mortality and not in less than expected mortality, which was caused by consecutive weeks without mortality.

A period was defined as a succession of weeks with excess mortality. The first week of every period of excess mortality was denoted in a separate column. Before a CUSUM exceeds its threshold there was already mortality causing the cusum to rise, so the actual start of the excess mortality period was considered to start at least a week before the period indicated by the cusum. Every analysis resulted in a separate dataset for every region containing the week number, week of excess mortality (0/1) and start period (0/1). All graphs of the cusum results were visually inspected to confirm the models fitted well enough to continue analysis. Fig. 1A. shows an example of a model which was considered a converging model. There was mortality registered in the two periods exceeding the UB, and the graph came back under the threshold after both periods. Fig. 1B. shows an example of a not converging model. Although the first part of the graph would still have been plausible, the last linear increase was typical for non-converging models. Although the graph shows excess mortality, no actual mortality was registered in that period. As previously described only combined regions 22 and 23 were excluded from the veal calf operations analysis based on the violations identified by the cusum of the model, without any mortality in the data for these periods. The remaining regions and combinations of regions were, based on the CUSUM graphs, considered valid for further analysis.

2.4. Analysis of helpdesk contact and postmortem submissions

The results of the excess mortality modelling were merged with the number of helpdesk contacts and number of postmortems for the corresponding weeks and PC2 regions. Generalized linear mixed models (GLMM) were used to check for an association between the number of

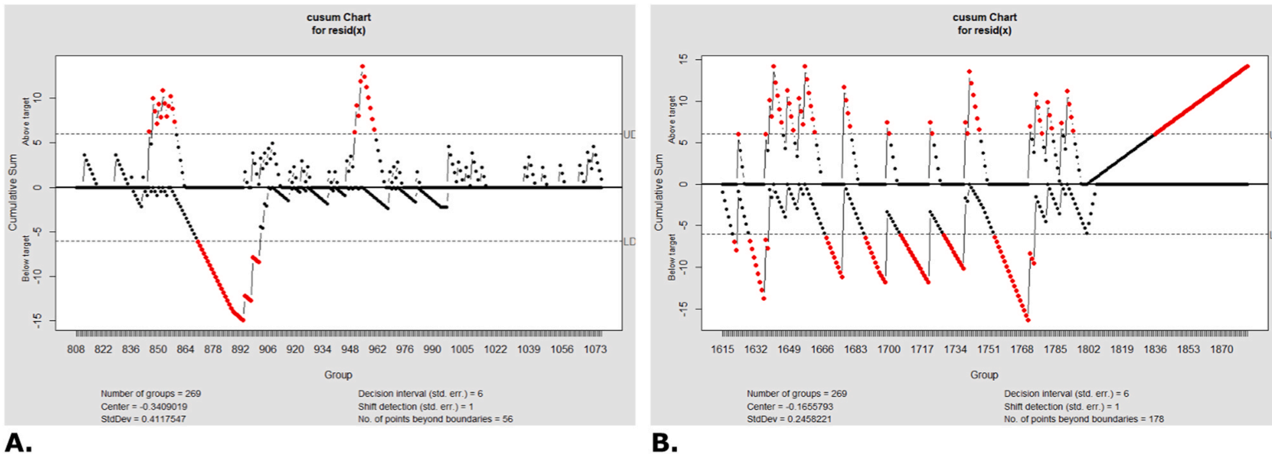

Fig. 1. Example of visual examination of the CUSUM of a converging (A.) and a non-converging model (B).

helpdesk contacts or postmortem submissions within weeks of excess mortality. The models contained the total number of helpdesk contacts or postmortem submissions as dependent variable and week with excess mortality (0/1) and year as independent variables. The Odds ratio's (OR's) and 95 % confidence intervals (95 % CI) were calculated from the output. A significant OR>1 suggested that contact or postmortem submissions were increased within the period of excess mortality. Additionally the same analysis was done once without contacts about mastitis and once without contacts registered as miscellaneous. Mastitis is not considered related to emerging diseases and it is hypothesized in a previous study that miscellaneous is neither (Vredenberg et al., 2022). The content of the miscellaneous contacts is unknown, but the registration for cattle lacks a general advice category unlike the comparable registration for pigs. Therefore the miscellaneous contacts were expected to contain similar topics as the general advice category for pigs (e.g. lab results, information on eradication programs).

In order to assess the timeliness of the passive surveillance, number of weeks between the start of the period of excess mortality and the first moment of contact, postmortem or at least one or the other, was analyzed. Additionally, the number of periods without any contacts or submissions were identified. First by descriptives of the period, mean time of the period, mean and median time to first signal (contact or postmortem) and no contact at all. Secondly the median survival time was calculated using the *survfit* and *Surv* function of the "survival" package (version 3.5–8) in R. The follow-up time was the time from the start of the period being zero until the first signal. If the first signal was in the same week as the start of the period the follow-up time was zero. In case of no signal within the period, that period was censored at the end of its follow-up time. The event was the first signal from the start of the period and farm type was added as an independent variable to estimate the median survival time for each farm type separately. The survival function was executed for the cow and calf data separately. The differences in timeliness between the farm types were determined using a Cox proportional hazard models with the same parameters as the survival function. The R functions *coxph* and *Surv* of the "survival" package (version 3.5–7) were used for the Cox proportional hazard models. The function *ggsurvplot* of the "survminer" (version 0.4.9) package was used for the graphs.

3. Results

3.1. Descriptives

In this study the mortality rates of, on average 15,457 dairy farms, 2587 veal calf operations, and 8574 other beef cattle operations were analyzed (Table 2). The average absolute mortality per farm per year for cows (4.5 cows) and calves (5.0 calves) was fairly similar. Veal calf operations had a much higher absolute yearly calf mortality of 22.8 calves and other beef cattle operations had a low absolute mortality of 0.7 cows and 1.0 calves. Fig. 2 shows the frequency over time of the helpdesk contacts and postmortem submissions between July 2017 and July 2022. In the fourth quarter of 2019 the veterinary helpdesk was contacted almost 600 times about dairy farms. In the same quarter of 2020, most cattle for postmortem which were submitted came from dairy farms. The trend over the years seems to be stable.

3.2. Analyses

Table 3 contains the number of contacts and postmortem submissions within weeks with excess mortality, which were compared to weeks without. For cows and calves on dairy farms there was an increased odds for contact in weeks with excess mortality of 1.88

Table 2
Number of farms, farm size, cow and calf mortality from July 2017 to July 2022 for dairy farms, veal calf operations and other beef cattle operations.

		2017* (Q3-Q4)	2018	2019	2020	2021	2022* (Q1-Q2)	Yearly mean	Mean mortality per herd n (%)
Dairy farms	Farms	16,364	16,314	15,692	15,239	14,857	14,273	15,457	
	Mean Farm size	166	159	160	166	170	176	166	
	Cow mortality	35,858	68,626	66,074	71,861	70,418	31,264	68,820	4.5 (2.7 %)
	Calf mortality	45,807	89,750	73,625	71,172	69,990	32,817	76,632	5.0 (3.0 %)
Veal calf operations	Farms	2501	2744	2737	2689	2541	2307	2587	
	Mean Farm size	482	460	457	446	464	514	469	
	Calf mortality	34,533	66,577	60,661	54,400	51,507	27,681	59,071	22.8 (4.9 %)
Other beef cattle operations	Farms	7985	8717	8863	8797	8792	8290	8574	
	Mean Farm size	55	51	47	47	48	48	49	
	Cow mortality	2965	6328	5772	6091	6228	2917	6060	0.7 (1.4 %)
	Calf mortality	4747	9194	8000	7795	7909	3850	8299	1.0 (2.0 %)

* In 2017 only 3th and 4th quarter of the year and in 2022 the 1st and 2nd quarter.

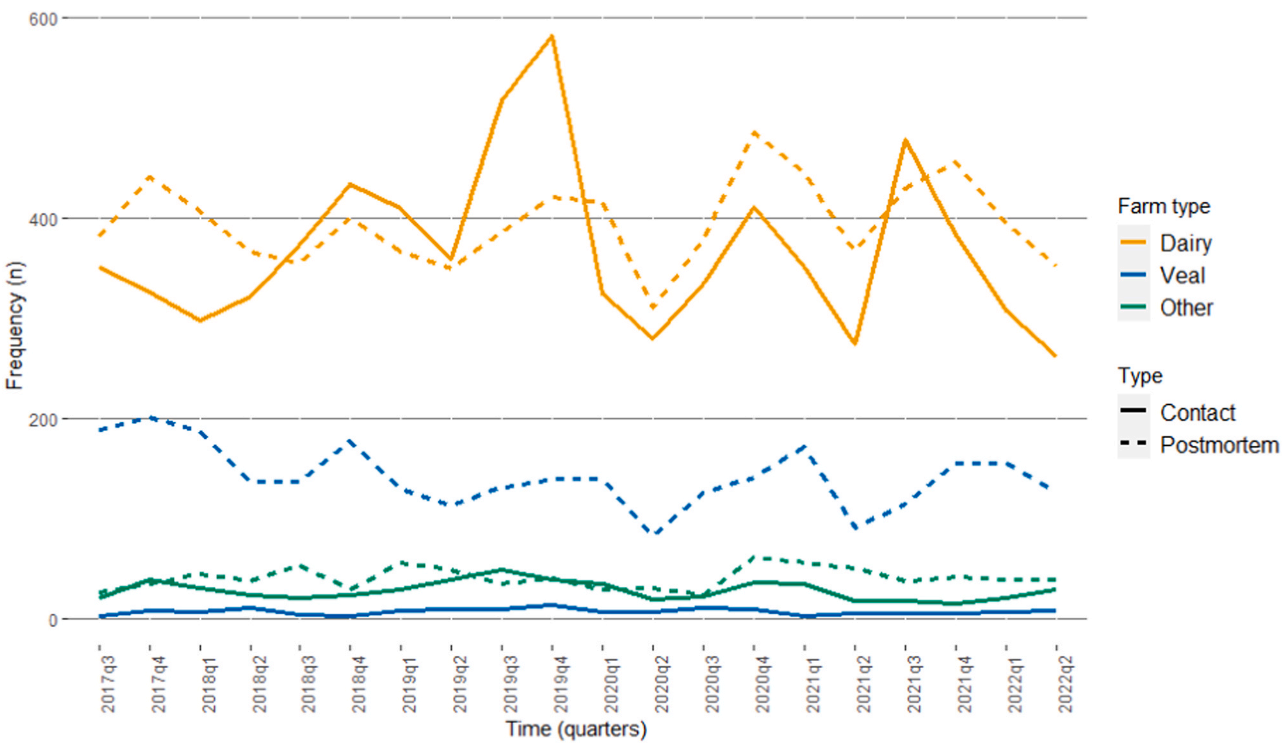

Fig. 2. Helpdesk contact and postmortem submission from third quarter of 2017 until second quarter of 2022 for dairy farms, veal calf operations and other beef cattle operations.

Table 3
The number of helpdesk contacts and postmortem submissions in periods with excess mortality identified by the cusum of the model residuals. The Odd Ratios (OR) compare the number of contacts and postmortems in weeks with excess mortality (1) compared to weeks without excess mortality (0). The percentages were calculated by the number of contacts and postmortems per week.

		Excess mortality (0=No, 1= Yes)	# weeks	# contact	%	OR	95 %CI	#Postmortem	%	OR	95 %CI
Dairy farms	Cow	0	20,822	6456	31.0			7233	34.7		
		1	966	917	94.9	1.88	1.69–2.09	671	69.5	2.02	1.82–2.25
	Calf	0	19,534	5811	29.7			6480	33.2		
		1	2254	1562	69.3	1.72	1.59–1.86	1424	63.2	1.92	1.79–2.07
Veal calf operations	Calf	0	14,795	140	0.9			2528	17.1		
		1	806	21	2.6	2.19	1.18–4.04	307	38.1	2.24	1.78–2.83
Other beef cattle operations	Cow	0	19,504	535	2.7			791	4.1		
		1	401	22	5.5	0.73	0.35–1.53	23	5.7	1.41	0.87–2.29
	Calf	0	19,038	519	2.7			738	3.9		
		1	597	37	6.2	1.39	0.87–2.12	73	12.2	3.71	2.74–5.01

(1.69–2.09) and 1.72 (1.59–1.86), respectively, compared to weeks without excess mortality. In periods of excess mortality the submissions of postmortems were also increased with an odds of 2.02 (1.82–2.25) for cows and 1.92 (1.79–2.07) for calves. For veal farm operations, which we only analyzed for calves, the absolute numbers and percentages of contact were much lower compared to dairy farmers. However for both, contact (OR= 2.19 (1.18–4.04)) and postmortem submissions (OR = 2.24 (1.78–2.83), significant differences were found in weeks with excess mortality compared to other weeks. The number of contacts for other beef cattle operations is fairly low. Of all farm types, “other beef cattle operations” had least submissions for postmortem examination. Other beef cattle operations was the only farm type for which the association between contact and excess mortality for cows (OR= 0.73 (0.35–1.53) and calves (OR= 1.39 (0.87–2.12)) were not statistically significant. Postmortem submissions for cows (OR= 1.41 (0.87–2.29)) and calves (OR=3.71 (2.74–5.01)) had an increased odds of which the latter was statistically significant.

The results in Table 3 were based on total number of contacts with the veterinary helpdesk. As a sensitivity analysis we examined the effect on the odds ratios when contacts about mastitis or contacts classified as miscellaneous were excluded from the analysis (Table S1). The effect of excluding contacts on one of these topics did not change the direction of the associations described in the previous paragraph.

The results shown in Table 3 compared number of weeks to number of contacts or postmortem submissions. These numbers do not provide information on the timeliness of the signals (contacts or postmortem), these results are shown in Table 4, Fig. 3 and Fig. 4. Table 4 shows the descriptive values on timeliness including the number of periods with excess mortality without any signal. Figs. 3 and 4 show the results of the survival analysis for calves and cows, respectively. The graphs show the survival time in weeks from the start of a period with excess mortality until the first signal (postmortem and contact combined). The dotted vertical lines at survival probability 0.5 indicate the median survival time. Periods were censored if no signal was received within the period.

In general, dairy farms showed the shortest period between the start of the period and the first signal with a median time of zero weeks, a mean between 0.63 and 1.63 weeks and a median survival time of zero being a contact within one week of excess mortality. The number of

Table 4
Description of the timeliness of receiving the first contact, postmortem submission or both in periods of excess mortality of three different farm types.

			# Weeks	#Period	Mean time in weeks of excess mortality period (min-max)	Mean time in weeks to first signal	Median time in weeks to first signal	# No of periods without signal (%)
Dairy farms	Cow	Combined	966	146	6.62 (2–25)	0.63	0	13 (9)
		Contact				1.15	1	34 (23)
		Postmortem				1.08	1	23 (16)
	Calf	Combined	2254	256	8.83 (2–42)	0.80	0	32 (13)
		Contact				1.63	1	59 (23)
		Postmortem				1.40	1	57 (22)
Veal calf operations	Calf	Combined	806	118	6.83 (2–38)	1.72	1	57 (48)
		Contact				1.70	2	108 (92)
		Postmortem				1.75	1	58 (49)
Other beef operations	Cow	Combined	401	83	4.83 (2–21)	1.90	1	63 (53)
		Contact				3.00	1.5	77 (65)
		Postmortem				1.65	1	66 (56)
	Calf	Combined	597	102	5.85 (2–38)	3.90	2	73 (62)
		Contact				6.86	4.5	88 (75)
		Postmortem				4.60	2	77 (65)

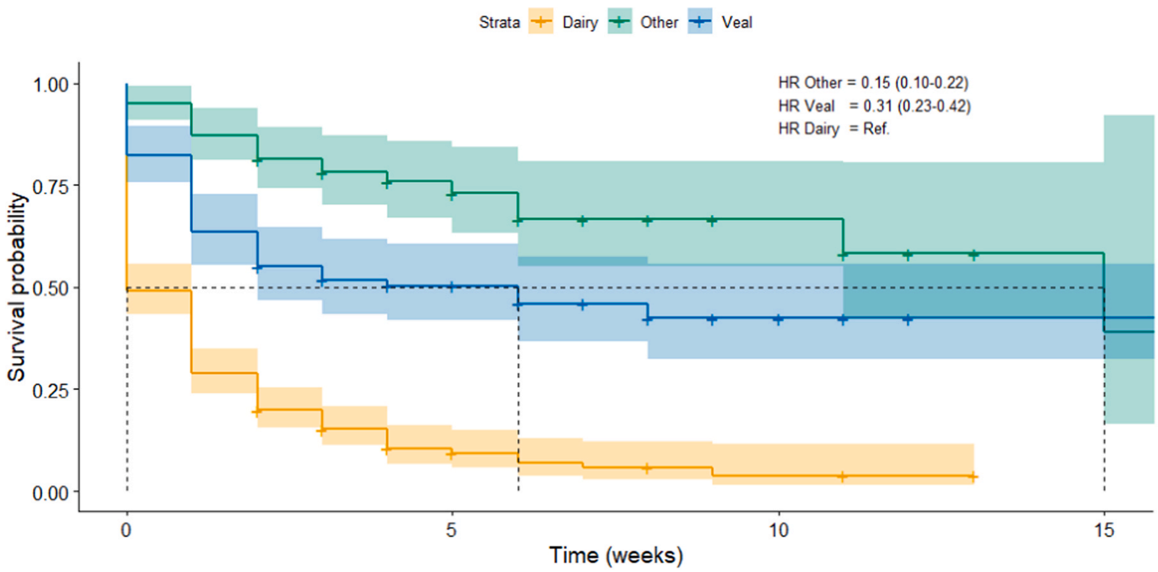

Fig. 3. Survival function of the time in weeks to the first signal (contact or postmortem) in a period of excess calf mortality for dairy farms, other beef cattle operations and veal calf operations. The vertical dotted lines indicate the median survival time. Periods without any signal were censored.

weeks and periods with excess mortality for calves in dairy herds were around two times more than for cows. However, the percentage of no signal was still low (9 % cows, 13 % calf) and the median survival time was also zero. Other beef cattle operations had the highest proportion of "no signal", 53 % for cow and 62 % for calf. The mean time of 3.90 weeks for a first signal for calf and median survival time of 1.5 weeks was also higher than for the other farm types. Veal calf operations had a high percentage of 92 % of no contact, but more often submitted calves for postmortem. Overall in 48 % of the periods there was no signal at all. The mean time until first contact was around 1.70 weeks, the median between one and two weeks and a median survival time of six weeks. Comparing the farm type other beef cattle operations and veal calf operations, they both had a lower HR of 0.15 (0.10–0.22) and 0.31 (0.23 – 0.42) of having a signal relative to dairy farms for calves. For cattle, other beef cattle operations had also a lower HR of 0.10 (0.06–0.17) relative to dairy farms.

4. Discussion

In this study we aimed to evaluate the timeliness and sensitivity of the voluntary passive surveillance component in the Netherlands, consisting of a veterinary helpdesk and postmortem examinations for early detection of emerging diseases, by using excess mortality in cattle as a proxy. Modelling of cow and calf mortality on regional level, followed by the cusum of the residuals, resulted in the identification of periods of excess mortality. The analysis was performed separately for dairy farms, veal calf operations and other beef cattle operations. The number of contacts and postmortem examinations in weeks of excess mortality were compared to weeks without excess mortality in regions. Finally we assessed the time from the start of the periods until the first signal (contact or postmortem) and the differences between the three farm types.

The absolute mortality per farm differed between the three farm types, but the yearly trends were similar. On regional level, between 83 (cows, other beef cattle operations) and 256 (calf, dairy farm) periods of excess mortality were identified. Dairy farms (OR 1.72;2.02) and veal calf operations (OR 2.19;2.24) had significantly more contact and postmortem examinations in periods of excess mortality. Other beef cattle operations showed a significant increase in postmortem submission for calves (OR= 3.71). The exclusion of contacts about mastitis or contacts classified as miscellaneous did not change directions of associations. The duration of the periods of excess mortality differed between farm types. Other beef cattle operations had the lowest average duration of a period of excess mortality in cows of 4.8 weeks. Dairy

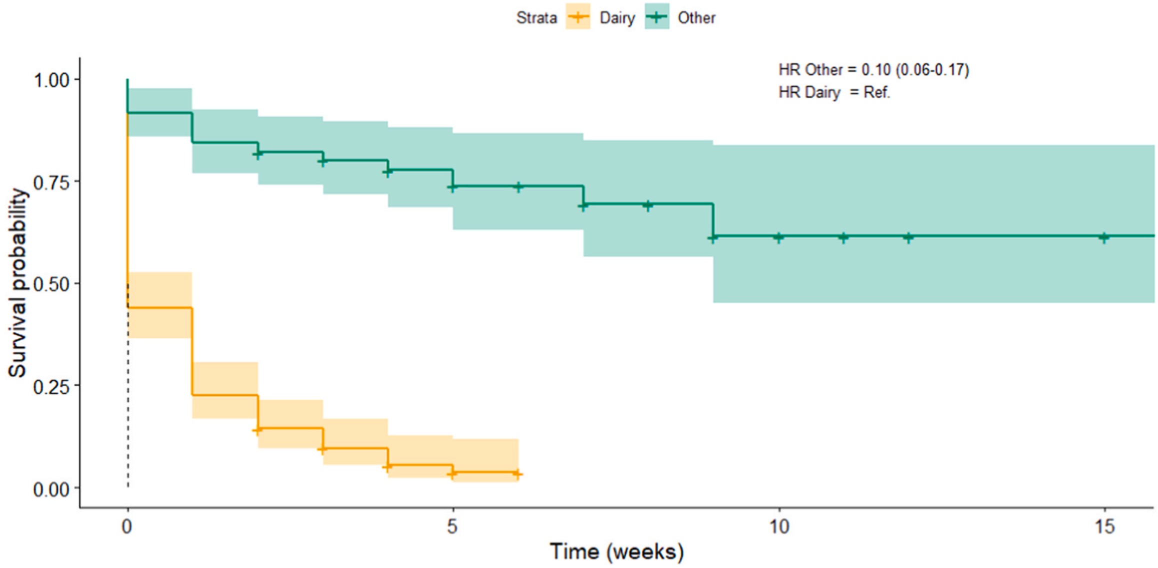

Fig. 4. Survival function of the time in weeks to the first signal (contact or postmortem) in a period of excess cow mortality for dairy farms and other beef cattle operations. The vertical dotted line shows the median survival time for dairy farms. Other beef cattle operations did not cross the 0.50 survival probability. Periods without any signal were censored.

farms had the longest duration of a period of excess mortality of 8.8 weeks for calves. Dairy farms had the lowest percentages of no signal and the shortest period until the first signal compared to veal calf operations (HR=0.31) and other beef cattle operations (HR=0.15) for excess mortality in calves. The same comparison for dairy farms and other beef cattle operations for excess mortality in cows resulted in a HR of 0.10. So, in case of excess mortality the awareness and therefore the chance of getting a timely response from dairy farms is highest, compared to the other herd types.

The results show a positive association between helpdesk contact and postmortem examination with excess mortality. So, the passive surveillance component is used more often in periods of excess mortality. Although the direction is positive the exact estimates have to be used with caution. The used method to determine the periods of excess mortality contains two arbitrary elements. First, the threshold of the minimum number of reported dead cows and calves in at least one week for a region to be included in the cusum analysis. After consultations with field veterinarians and farmers, we considered more than 3 cows and more than 4 calves valid for the Netherlands. These numbers were chosen based on the current Dutch situation, but may have to be reconsidered when used in other countries or situations. Especially average farm size will influence the choice for the used threshold. The second arbitrary element is the threshold of the CUSUM upper bound (UB). This threshold influences the number of periods and weeks marked as excess mortality and can therefore potentially influence the final results. The default in the model was 5 times the SE. A sensitivity analysis using 4 and 6 times the SE as threshold, influenced the magnitude of the effects, but not the directions of the associations (Table S2 and S3). In general, using a lower threshold the OR's moved towards one. Increasing the threshold moved the OR away from one. So choosing another threshold can influence the results, but in our study the direction of the associations and therefore the conclusion did not change.

We firstly tried to perform the analysis on farm level, but changed to regional level due to power issues and not converging models. Although the analysis on region level provides insight on usage of the passive surveillance component in periods of excess mortality, analysis on farm level would have given more detailed results. The results show periods of excess mortality of more than 10 weeks. Analysis on farm level would have made it possible to determine if this was caused by one farm in that region having increased mortality over a longer period of time or that there are multiple farms in a region with consecutive shorter periods of excess mortality. Additionally, contacts and postmortem submission can only be assigned to the region and not to the farm. In this study it is unknown if the contacts and postmortem submissions in periods of excess mortality did originate from farms having the excess mortality. In countries with larger herd sizes with higher absolute mortality the analysis may be possible on farm level. Another solution might be the use of more complex models or machine learning techniques, but this was beyond the scope of our study.

Even on regional level (PC2), mortality was not such that models converged, which made aggregation of regions necessary. For dairy farms and veal calf operations at least 20 farms per region were needed for models to converge, while for other beef cattle operations at least 100 farms per region were needed. This was due to lower average herd size and therefore lower absolute mortality in the other beef operations category. With at least 100 farms per region for other beef cattle operations and at least 20 for veal calf and dairy, even though the chance per farm may be lower, the regional chance of contact may be higher for other beef cattle operations. Therefore, the HR for other beef cattle operations may be slightly overestimated compared to the other two categories. This only underlines the importance of obtaining sufficient contacts and post-mortems from the veal calf and dairy herds.

The calves in this study were all ear-tagged, which in the Netherlands is obligatory within three days after birth (Santman-Berends et al., 2019). The causes of perinatal calves mortality is versatile (stillbirth, abortion, weakness at birth). We did not take this group into account because not all data was available and the mortality of this group was beyond the scope of our study. Other countries may have different ages at which calves need to be ear-tagged and with that different mortality rates. Additionally, the Dutch veal calf industry gives monetary value to surplus dairy calves. In other countries, the low or even negative economic value of calves may result in euthanasia of unwanted animals, thus increasing mortality. This has to be taken into account performing a comparable study for other countries. However, excess mortality is a relative measure and should not be influenced too much by the absolute mortality rate.

We analyzed the contacts with the veterinary helpdesk with and without the contact categories mastitis and miscellaneous. Previous research showed that these were the two largest categories and we considered them less relevant for early detection of infectious disease

(Vredenberg et al., 2022). Although the topics covered in miscellaneous are unknown, they are assumed to be at least not about other, more specific and further specified clinical categories. Contacts classified as miscellaneous are assumed to be mostly about animal health programs and lab results. The helpdesk employee can select multiple categories for one contact. Therefore there will be some overlap in the excluded contacts. Although we could not correct for this, excluding mastitis and miscellaneous did not result in directional change of the association nor in the conclusions.

This study shows that the voluntary passive surveillance component is used more often in periods of excess mortality. The performance of the Dutch surveillance system relative to systems in other countries is difficult to assess because no such analyses could be found in scientific literature. Studies on evaluation of surveillance mostly focused on proving freedom from disease and used methods such as scenario tree modelling and STOCfree or compare different types of passive and active surveillance (Cameron et al., 2020; Hernandez-Jover et al., 2011; Meletis et al., 2024; Veldhuis et al., 2017; Welby et al., 2013). In our study, routinely collected data was used to evaluate only the passive surveillance component for which farmers and veterinarians provided the information. When other countries would analyze their passive surveillance in a comparable way, the results can be compared to get better insight in the actual performance of passive surveillance systems in different countries. This could provide information for improving passive surveillance in general. Although, this study focusses on the Dutch situation, it can serve as an example to evaluate passive surveillance with quantitative data in other countries. We chose mortality as health outcome due to its clear definition and uniform registration in the Netherlands. Similar data should also be available in other EU countries. Other health outcomes might be used as long as they are clearly defined and comparably well registered. Emerging diseases with subtle or non-specific clinical signs or diseases which stay subclinical for a long time are more difficult to detect by farmers and their veterinarians. Therefore, to determine the effectiveness of the passive surveillance for these diseases may not be feasible. Thresholds may be adapted to better fit the country's sector characteristics. For example, if the average herd size is larger than in the Netherlands, the threshold for number of cow and calve deaths should be increased to a level considered more feasible to the local situation.

In conclusion, in periods of excess mortality the voluntary passive surveillance component is used more often by the cattle sector. The awareness and therefore the chance of getting a timely response in case of emerging diseases is highest for dairy farms, compared to veal calf operations and other beef cattle operations. For veal calf operations the change of receiving a timely response is highest for postmortem submissions, as this sector less often contacts the helpdesk. The method of our study can be used by other countries to evaluate their passive disease surveillance system. This would also make comparison of the performance of passive surveillance in different countries possible.

CRediT authorship contribution statement

Imke Vredenberg: Writing – original draft, Visualization, Methodology, Formal analysis. **Gerdien van Schaik:** Writing – review & editing, Conceptualization. **Wim H.M. van der Poel:** Writing – review & editing, Conceptualization. **Arjan Stegeman:** Writing – review & editing, Supervision, Project administration, Funding acquisition, Conceptualization.

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Data statement

Data is only available on request at G.S.

Declaration of Competing Interest

G.S. is parttime employed at Royal GD; the other authors declare no conflict of interest. The funders had no role in the design of the study; in the collection, analyses, or interpretation of data; in the writing of the manuscript; or in the decision to publish the results.

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Appendix A. Supporting information

Supplementary data associated with this article can be found in the online version at doi:10.1016/j.prevetmed.2024.106334.

References

Akaike, H. (1973). Information theory and an extension of the maximum likelihood principle.

Cameron, A. (2011). Surveillance needs, tools and options: experiences between developed and developing worlds, 91-94, In: FAO. (2011). Challenges of animal health information systems and surveillance for animal diseases and zoonoses. Retrieved from ⟨https://www.fao.org/4/i2415e/i2415e00.pdf⟩.

Cameron, A.R., Meyer, A., Faverjon, C., Mackenzie, C., 2020. Quantification of the sensitivity of early detection surveillance. Transbound. Emerg. Dis. *67* (6), 2532–2543. https://doi.org/10.1111/tbed.13598.

Elbers, A.R., Gorgievski-Duijvesteijn, M.J., Zarafshani, K., Koch, G., 2010. To report or not to report: a psychosocial investigation aimed at improving early detection of avian influenza outbreaks. Rev. Sci. Tech. 29 (3), 435–449. https://doi.org/10.20506/rst.29.3.1988.

Faverjon, C., Meyer, A., Howden, K., Long, K., Peters, L., Cameron, A., 2021. Risk-based early detection system of African Swine Fever using mortality thresholds. Transbound. Emerg. Dis. 68 (3), 1151–1161. https://doi.org/10.1111/tbed.13765.

Fernandez-Fontelo, A., Puig, P., Caceres, G., Romero, L., Revie, C., Sanchez, J., Alba-Casals, A., 2020. Enhancing the monitoring of fallen stock at different hierarchical administrative levels: an illustration on dairy cattle from regions with distinct husbandry, demographical and climate traits. BMC Vet. Res. *16* (1), 110. https://doi.org/10.1186/s12917-020-02312-8.

Hernandez-Jover, M., Cogger, N., Martin, P.A., Schembri, N., Holyoake, P.K., Toribio, J. A., 2011. Evaluation of post-farm-gate passive surveillance in swine for the detection of foot and mouth disease in Australia. Prev. Vet. Med. 100 (3-4), 171–186. https://doi.org/10.1016/j.prevetmed.2011.03.011.

Hoinville, L.J., Alban, L., Drewe, J.A., Gibbens, J.C., Gustafson, L., Hasler, B., Stark, K.D., 2013. Proposed terms and concepts for describing and evaluating animal-health surveillance systems. Prev. Vet. Med. *112* (1-2), 1–12. https://doi.org/10.1016/j.prevetmed.2013.06.006.

Meletis, E., Conrady, B., Hopp, P., Lurier, T., Frossling, J., Rosendal, T., Madouasse, A., 2024. Review state-of-the-art of output-based methodological approaches for substantiating freedom from infection. Front. Vet. Sci. 11, 1337661 https://doi.org/10.3389/fvets.2024.1337661.

Novoa, N.M., Varela, G., 2020. Monitoring surgical quality: the cumulative sum (CUSUM) approach. Mediastinum *4*, 4. https://doi.org/10.21037/med.2019.10.01.

Holwerda, M., Santman-Berends, I.M.G.A., Harders, F., Engelsma, M., Vloet, R.P.M., Dijkstra, E., van Gennip, R.G.P., Mars, M.H., Spierenburg, M., Roos, L., Van den Brom, R., Van Rijn, P.A., (2023). Emergence of bluetongue virus serotype 3 in the Netherlands in September 2023. *bioRxiv*. doi:⟨https://doi.org/10.1101/2023.09.29.560138⟩.

NVWA. (2024). Melden dierziekte. Retrieved from ⟨https://www.nvwa.nl/onderwerpen/dierziekten/melden-dierziekte#/⟩.

OIE. (2024). The Global Burden of Animal Diseases, OIE-timeline. Retrieved from ⟨https://gbads.woah.org/⟩.

Regulation (EC) No 1760/2000 of the European Parliament and of the Council of 17 July 2000 establishing a system for the identification and registration of bovine animals and regarding the labelling of beef and beef products and repealing Council Regulation (EC) No 820/97, (2000).

RISKSUR. (2013). Glossary. Retrieved from ⟨https://www.fp7-risksur.eu/terminology/glossary⟩.

Santman-Berends, I., Schukken, Y.H., van Schaik, G., 2019. Quantifying calf mortality on dairy farms: challenges and solutions. J. Dairy Sci. *102* (7), 6404–6417. https://doi.org/10.3168/jds.2019-16381.

Santman-Berends, I., Dijkstra, E., van den Brom, R., (2023). Eerste impactanalyses BTV-3 uitbraak in Nederland: Sterfte op schapen- en geitenbedrijven. Retrieved from ⟨https://www.gddiergezondheid.nl/blauwtong⟩.

Scrucca, L. (2004). qcc: An R package for quality control charting and statistical process control. R Journal. Retrieved from ⟨https://journal.r-project.org/articles/RN-2004-003/RN-2004-003.pdf⟩.

Struchen, R., Reist, M., Zinsstag, J., Vial, F., 2015. Investigating the potential of reported cattle mortality data in Switzerland for syndromic surveillance. Prev. Vet. Med. *121* (1-2), 1–7. https://doi.org/10.1016/j.prevetmed.2015.04.012.

Torres, G., Ciaravino, V., Ascaso, S., Flores, V., Romero, L., Simon, F., 2015. Syndromic surveillance system based on near real-time cattle mortality monitoring. Prev. Vet. Med *119* (3-4), 216–221. https://doi.org/10.1016/j.prevetmed.2015.03.003.

Veldhuis, A., Santman-Berends, I., Schauer, B., Mars, J., Waldeck, F., Staubach, C., van Schaik, G., 2017. Epidemiological performance and subsequent costs of different surveillance strategies to control bovine herpesvirus type 1 in dairy farms. Prev. Vet. Med. 139 (Pt B)), 105–114. https://doi.org/10.1016/j.prevetmed.2016.12.003.

Vredenberg, I., van Schaik, G., van der Poel, W.H.M., Stegeman, A., 2022. Coverage and representativeness of passive surveillance components for cattle and swine in The Netherlands. Animals (Basel) *12* (23). https://doi.org/10.3390/ani12233344.

Welby, S., Meroc, E., Faes, C., De Clercq, K., Hooyberghs, J., Mintiens, K., Van der Stede, Y., 2013. Bluetongue surveillance system in Belgium: a stochastic evaluation of its risk-based approach effectiveness. Prev. Vet. Med. 112 (1-2), 48–57. https://doi.org/10.1016/j.prevetmed.2013.07.005.

Yu, X., Cheng, Y., 2022. A comprehensive review and comparison of CUSUM and change-point-analysis methods to detect test speededness. Multivar. Behav. Res *57* (1), 112–133. https://doi.org/10.1080/00273171.2020.1809981.