



## Surveillance of cattle health in the Netherlands: Monitoring trends and developments using routinely collected cattle census data



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### ABSTRACT

Since 2002, a national cattle health surveillance system (CHSS) is in place that consists of several surveillance components. The CHSS combines enhanced passive reporting, diagnostic and post-mortem examinations, random surveys for prevalence estimation of endemic diseases and quarterly data analysis. The aim of the data-analysis component, which is called the Trend Analysis Surveillance Component (TASC), is to monitor trends and developments in cattle health using routine census data. The challenges that were faced during the development of TASC and the merits of this surveillance component are discussed, which might be of help to those who want to develop a monitoring and surveillance system that includes data analysis. When TASC was developed, there were process-oriented challenges and analytical related issues that had to be solved. Process-oriented challenges involved data availability, confidentiality, quality, uniformity and economic value of the data. Analytical issues involved data validation, aggregation and modeling. Eventually, the results had to provide information on cattle health that was intuitive to the stakeholders and that could support decision making. Within TASC, both quarterly analysis on census data and, on demand, additional in-depth analysis are performed. The key monitoring indicators that are analyzed as part of TASC all relate to cattle health and involve parameters such as mortality, fertility, udder health and antimicrobial usage. Population-Averaged Generalized Estimating Equations, with the appropriate distribution (i.e. Gaussian, Poisson, Negative Binomial or Binomial) and link function (independent, log or logit), are used for analysis. Both trends in time and associations between cattle health indicators and potential confounders are monitored, discussed and reported to the stakeholders on a quarterly level. The flexibility of the in-depth analyses provides the possibility to conduct additional analyses when anomalies in trends of cattle health occur or when developments in the cattle industry need further investigation. In addition, part of the budget for the in-depth analysis can also be used to improve the models or add new data sources. The TASC provides insight in cattle health parameters, it visualizes trends in time, can be used to support or nuance signals that are detected in one of the other surveillance components and can provide warnings or initiate changes in policy when unfavorable trends occur.

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### 1. Introduction

Monitoring and surveillance systems in livestock are of importance to ensure high standards of veterinary health, food safety and public health (OIE, 2014). At European Union (EU) level, legislation exists in which general elements of monitoring and surveillance of animal health are integrated (Commission Regulation, 1964, 2000, 2004, 2009). In addition, for many diseases, minimal mon-

itoring and surveillance requirements are established by the EU (Commission Regulation, 2014).

There are no specific requirements for national monitoring and surveillance programs of cattle health in general. Therefore, within the European countries, a large variety in monitoring and surveillance activities exist depending on, amongst others, the structure of the industry, animal density, the disease situation and financial means (Geraghty et al., 2014; Häsler et al., 2015). Surveillance components of such programs can either be passive, i.e. a farmer or veterinarian notifies clinical signs to the authorities, or active. The active components often involve collecting samples or data to determine the health status of a population. Traditionally, sam-

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ples were collected from the population of interest and tested for disease. Currently, quality of routinely collected data is improving, providing new possibilities for monitoring and surveillance such as for example syndromic surveillance (Dupuy et al., 2013; Madouasse et al., 2014; Marceau et al., 2014; Pannwitz, 2015; Bronner et al., 2015; Torres et al., 2015; Vial and Reist 2015; Veldhuis et al., 2016). Nevertheless, in these studies, data only covered a part of the country and could up to now not be used for nationwide monitoring and surveillance.

Since 2002, a national surveillance system, the Dutch Cattle Health Surveillance System (CHSS) is in place in the Netherlands that is managed by a private organization, GD Animal Health (GD), and is financed by both public and private stakeholders. In the Netherlands, cattle census data is routinely collected, providing an unique opportunity to implement a routine trend analysis surveillance component (TASC) for monitoring cattle health as part of the national CHSS.

The aim of the quarterly TASC, is to monitor trends and developments in cattle health in the Netherlands to support or nuance signals of changes in cattle health. The results of TASC provide insight in cattle health parameters, the so-called key monitoring indicators (KMIs). This information allows for visualization of trends in time, can be used to support or nuance signals that are detected in one of the other surveillance components, and can provide warnings when unfavorable trends occur. Since the start of the CHSS, stakeholders are informed about the findings including those from TASC in every quarter of the year. When unfavorable trends in cattle health occur, additional actions are taken. In this paper, we describe the monitoring and surveillance system in cattle in the Netherlands, with specific emphasis on TASC. The challenges and merits of this component within the CHSS are discussed and might be of help to others that want to develop a monitoring and surveillance system that incorporates a data-analysis component.

## 2. Monitoring and surveillance in cattle in the Netherlands

In the Netherlands, the cattle industry is vulnerable for introduction and transmission of diseases because of the high cattle density (>4 million cattle on 41,526 km<sup>2</sup>: 96 cows/km<sup>2</sup>, Eurostat, 2014) and the large number of imported and exported livestock each year. Therefore, a large scale monitoring and surveillance system was developed to monitor trends and developments in animal health and to be able to early detect exotic diseases or new disorders (Kock and Deterink, 2011). The first surveillance component of the CHSS consisted of an enhanced passive reporting system, which comprises a consultancy phone desk 'Veekijker' operated by veterinary specialists that receive approximately 4000 calls each year (Van Wuijckhuise et al., 2011). The primary aim of the helpdesk is to provide free veterinary and diagnostic advice. In turn, the helpdesk gains information on health problems that may be related to (re)emerging diseases or disorders that are valuable for early detection of animal health problems. The 'Veekijker' phone desk has successfully detected several emerging cattle health problems such as Bluetongue serotype 8 (BTV-8) in 2006 (Van Wuijckhuise et al., 2006), Schmallenberg virus in 2011 (Muskens et al., 2012), and Bovine Viral Diarrhea virus (BVDV) type 2 in 2013. The second surveillance component for early detection of (re)emerging or (exotic) diseases involves post-mortem investigations and diagnostic testing on samples submitted for toxicologic, immunologic, chemic, virologic or bacteriologic testing at GD. In the third surveillance component, random surveys are performed every other year to determine the prevalence of endemic diseases for both dairy and non-dairy herds in the Netherlands. The results of these surveys provide insight in developments in prevalence of endemic infections. The fourth component, which is the topic of this paper,

consists of trend analysis on routinely collected cattle data that is conducted on a quarterly basis by GD.

## 3. Monitoring trends and developments in cattle health using routinely collected cattle census data

When developing TASC, there were process-oriented challenges and analytical issues that had to be solved.

### 3.1. Process-oriented challenges

#### 3.1.1. Data availability

Five nationally operating data collecting organizations (the Dutch enterprise agency (RVO), GD, Dutch rendering facility (Rendac), milk quality laboratory (Qlip), milk processing companies (ZuivelNL)) provide information on mortality, slaughter, animal trade, herd health status, antimicrobial usage and bulk tank milk somatic cell count (BTM SCC) in every quarter of the year (Fig. 1). Together, these organizations collect complete data of all cattle and all cattle herds in the Netherlands and the results of TASC, therefore, reflect the true health status. In addition, two DHIA organizations (Royal Dutch Cattle Syndicate (CRV) and Milk Control Society Nijland (MCS Nijland)) that together cover about 80% of the dairy herds, provide routinely collected cattle data about udder health, fertility and metabolic parameters on a quarterly level (Fig. 1).

#### 3.1.2. Confidentiality

Because of the European privacy regulation, each farmer has to give consent for usage of his herd data. At the start of the CHSS in 2002, all farmers received a letter that informed them about the quarterly TASC that was implemented for monitoring purposes. Farmers were able to reject access to their data by returning a written refusal and less than 100 farmers did (< 1% of all cattle holdings). From then on, all farmers that requested a new farm identification number were asked for permission to use their routinely collected herd data for monitoring purposes. The farmers are assured that all data are anonymized before providing them to GD and that results of TASC are not traceable to individual farms or animals. In addition, within TASC, results are not reported when based on groups of less than 200 herds, as the objective is not to evaluate individual herds but to monitor trends and developments of cattle health in the whole population. Data from herds of which the farmers did not give their consent are excluded from the analysis. Providing the guarantees, resulted in less than 2% of the farmers refusing to cooperate in the TASC up to this moment (October 2016). Since no data of these farms are available for analysis, it is not possible to compare the characteristics of these farms to the remaining 98% of the population.

#### 3.1.3. Agreements

For TASC, contracts that covered the moment of data delivery, format of the data, information included and criteria that had to be met in order to be allowed to use the data, were signed by all collaborating parties.

Data are anonymized and encrypted with a different code in every quarter of the year and can therefore, not be combined over quarters. Because of this, in each quarterly round, the organizations need to provide data for the complete period of five years, to enable monitoring of trends in time. A notification email is send to each of the data collecting organizations in the last week of the quarter to assure timely data delivery. Because the data are not complete till a few days in the new quarter and it takes time to unlock data from software systems, a time period of up to four weeks is necessary for data delivery.

For confidentiality reasons, all data collecting organizations provide their raw data through a secured FTP server directly to

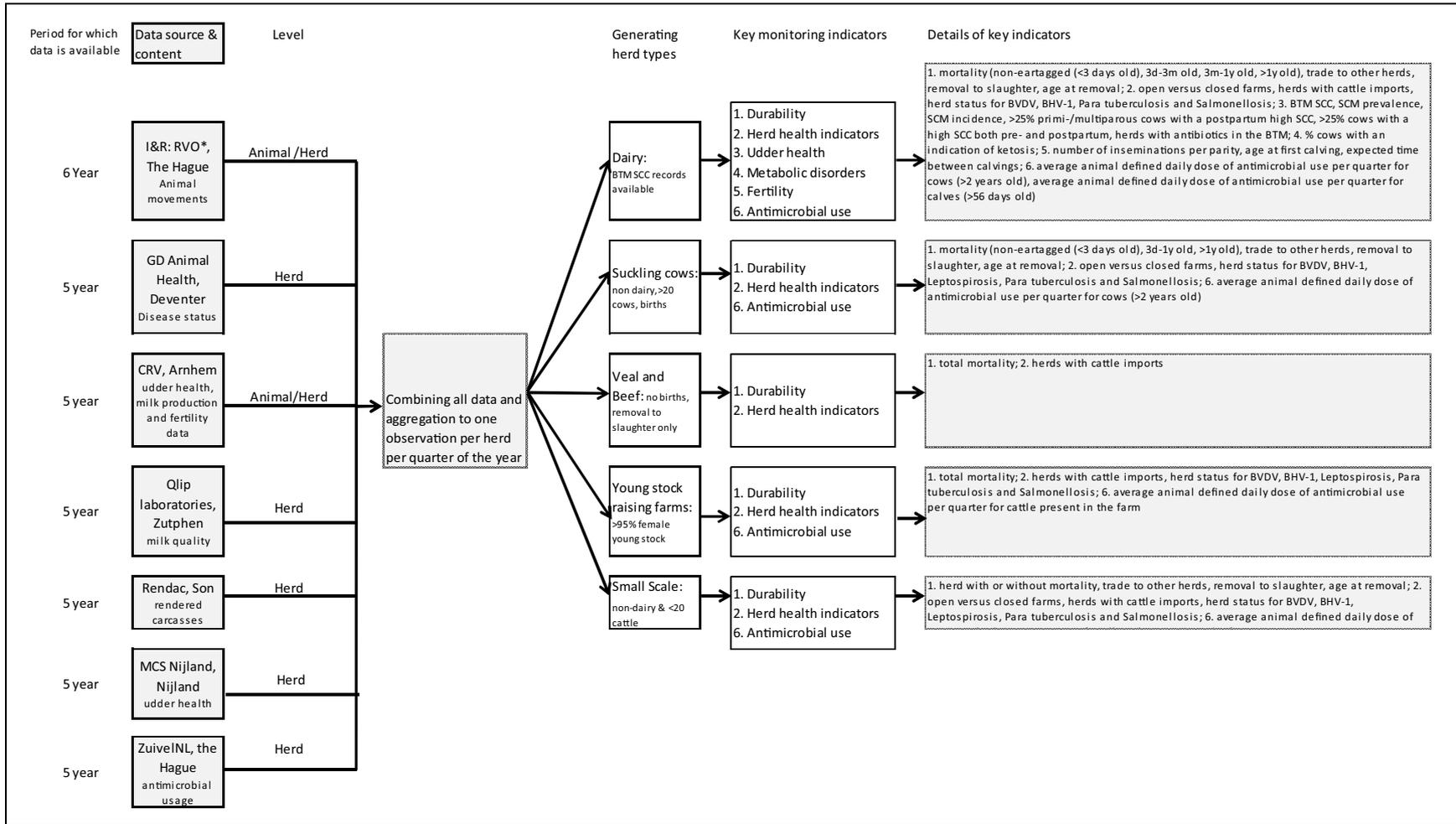


Fig. 1. Schematic overview of the trend analysis surveillance component (TASC) on cattle census data, conducted on a quarterly basis as part of the national cattle surveillance system in the Netherlands.

\*The RVO delivers complete census data of the cattle identification and registration system (I&R) in the Netherlands. In this system, all on-farm and off-farm cattle movements are registered

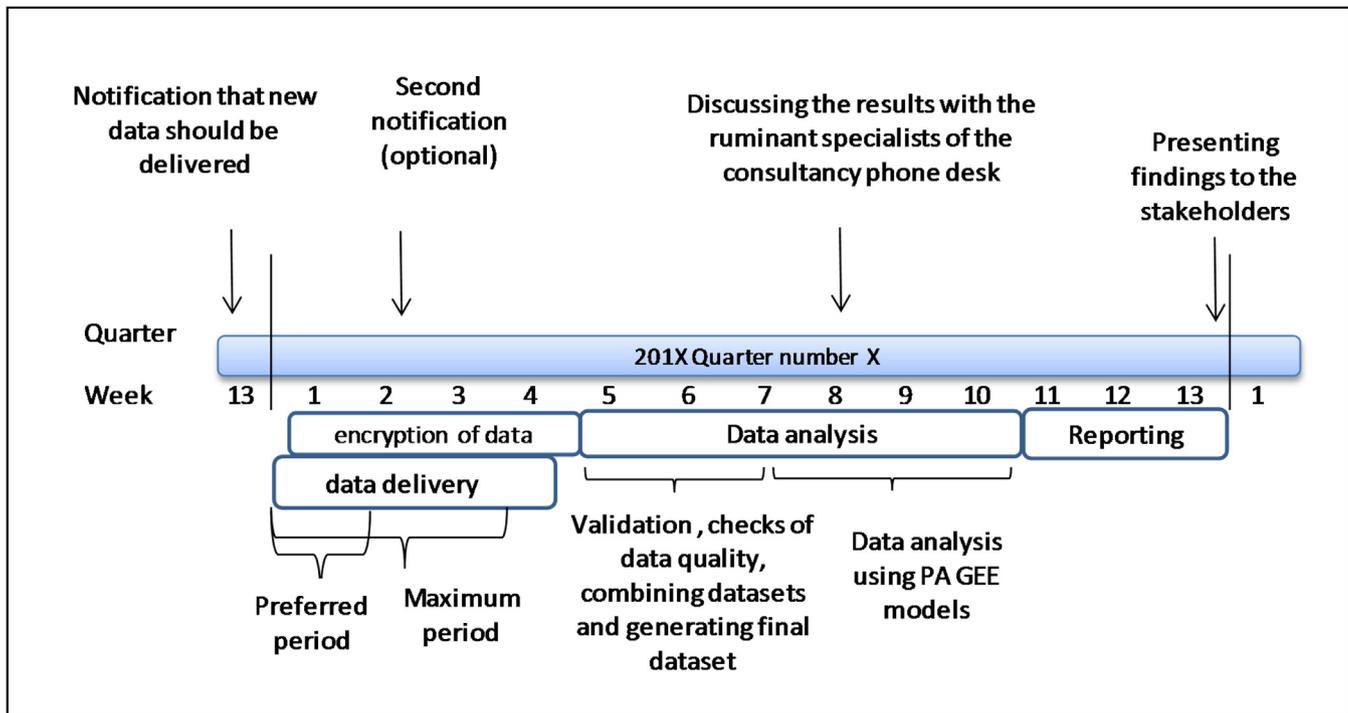


Fig. 2. Schematic overview of the process of the quarterly trend analysis surveillance component (TASC), performed on cattle census data.

an external firm (IntoFocus Data Transformation Services (IDTS), Deventer). For each organization, a separate FTP portal with IDTS is in place. IDTS encrypts all variables in the data that might link the data back to the original source, such as the Unique Herd Identification number (UHI) of the farm and the unique identification code of individual animals (Animal ID). Each quarter of the year, the same encryption code is used for all datasets to ensure that data of the different organizations can be combined for analysis. Subsequently, all encrypted datasets are provided to GD through a secured FTP server and a notification that the data is encrypted and available for analysis, is generated and sent to the researchers by email. The complete process of data delivery and encryption may take up to five weeks (Fig. 2).

#### 3.1.4. Data quality and uniformity

For TASC, standard software scripts in SAS 9.3® (SAS Institute, 2010) were developed to automate the validation process and to combine the datasets. Each delivered dataset had to contain either the UHI (Unique Herd Identifier) or the Animal ID as mutual unique identifier to ascertain that datasets from the different organizations could be combined. The animal movement data of the identification and registration system contains both variables, providing the opportunity to merge all available datasets to this source dataset.

Standard quality checks are executed on the number of observations, duplicates in the data and extreme values. When there are indications that the data are supplied incorrectly, first IDTS is contacted and requested to check whether an error occurred during the encryption process. When this is not the case, the data collecting organization is contacted, the problem that was detected is described in detail and is visualized with figures. In these cases, effort is taken by all parties involved to solve the problem as soon as possible to prevent delay. Delivery of incorrect data only occurs sporadically and the delay caused by errors in the source data is at most five working days per quarter.

#### 3.2. Analyzing routinely collected census data

##### 3.2.1. Validation

Monitoring trends and developments in cattle health based on five year of cattle census data results in an enormous amount of records. In total, the data collecting organizations provide eleven datasets of which the number of observations vary between a minimum of 143,000 and a maximum of almost 92 million records each quarter (Appendix A). The different datasets, are delivered in a txt, csv or prn format and are either directly imported in SAS® or transferred to a SAS® format using the program Stat transfer® (Stat transfer, 2010). The software program SAS® was chosen for validating and combining the data because of its ability to deal with big data. Nevertheless, the stability of the program, the completion time and the memory of the computers remained a challenge. By incorporating SAS® MACROS in the software scripts, conducting all validation steps per month (there are in total 60 months covering five years of data) and with developments leading to faster computers, these challenges were tackled.

During the whole data preparation process, routine checks and preliminary descriptive statistics are conducted to assure that errors that evolve during the validation process are detected as soon as possible. All software scripts are standardized and optimized and the same scripts are used every quarter of the year. Almost every year, the data provided by one of the data collecting organizations change, e.g. modifications in variable names, alterations in the format of the data, or inclusion of new variables and the software scripts are adapted accordingly. When the quality of the delivered dataset is approved, it is aggregated on herd and quarterly level for the analyzed period of five years. After all eleven datasets are aggregated on herd and quarterly level, the datasets are combined into the final dataset for analysis.

After validating and aggregating the data to herd and quarter level in SAS®, the data is transferred to Stata® (Stata Corporation, 2014) for further analysis.

### 3.2.2. Transforming the data into cattle health indicators

Cattle health parameters were either selected or created. Five different cattle herd types were distinguished based on the provided data:

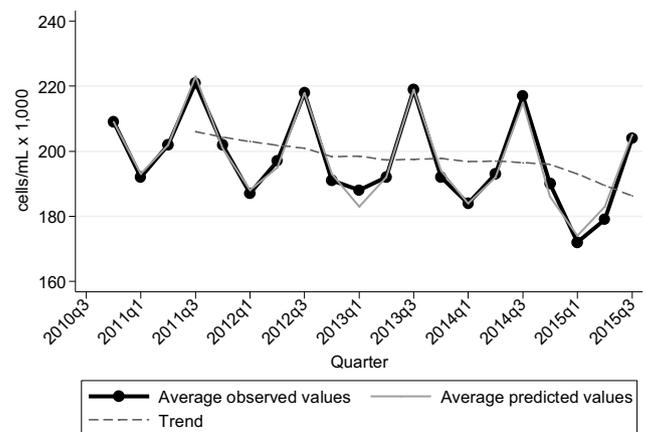
- 1 Dairy herds: milk sold for processing (Qlip data)
- 2 Suckler herds: do not sell milk, more than 80% of cows are female and give birth to a calf on an annual basis (I&R data).
- 3 Young stock rearing farms: more than 95% of the cattle is female and younger than two years of age, the cattle enter the farm at a young age (<3 months) and leave the farm before first calving (I&R data).
- 4 Beef herds: keep calves (veal) or older cattle (beef) that, in general, are exclusively moved off-farm to go to slaughter. More than 80% of the cattle are male, in general no calves are born in these herds and no milk is delivered (I&R data).
- 5 Small scale holders: herds that do not deliver milk and have less than 20 cattle (I&R data).

For each of the herd types, the trends and developments in cattle health are described using a large number of key indicators, which are described in Fig. 1. For each of the key indicators, a value per herd per quarter of the year for a period of five years was calculated. Depending on the nature of the key indicator, this could be the average of all measurements (somatic cell count parameters), the status at a specific date, i.e. the last day of each quarter (participation in herd health programs), or the total amount (mortality, antimicrobial use) within a quarter. Based on the biological background of the data, these key indicators were grouped within six KMIs: durability, herd health, udder health, fertility, metabolic disorders and antimicrobial usage (Fig. 1). For example, key indicators that were based on somatic cell count data were assigned to the KMI 'udder health'. For dairy herds, key indicators are analyzed for all six KMIs. For suckler herds, young stock rearing farms and small scale holders, key indicators were only available for the KMIs 'durability', 'herd health' and 'antimicrobial use'. For beef herds, only information on 'durability' and limited information of the KMI 'herd health' was available (Fig. 1).

### 3.2.3. Analysis

Multivariable Population-Averaged Generalized Estimating Equations (PA-GEE) models, with the appropriate distribution such as Gaussian, Poisson, Negative Binomial or Binomial, using generalized estimated equations in Stata® version 14 were used. Conditional to the distribution of the dependent variable, an identity, log or logit link function was included with an independent correlation structure. When appropriate, the number of cattle at risk were included as an exposure variable. Model fit was evaluated using the quasi-likelihood under the independent model criterion (QIC) (Pan, 2001; Cui, 2007). In each of the models, a number of potential confounders were included such as herd size, growth in herd size, replacement rate, location represented by province, milk production level (dairy only), season, milk price (dairy only), beef price, purchase of cattle, status for endemic diseases (Salmonellosis, Leptospirosis, BVDV, BHV-1, Para tuberculosis), milking parlor (regular vs. automated, dairy only), antimicrobial usage and a variable representing the trend in time. The exploratory continuous variables were categorized into four categories (10% smallest, 40% smaller, 40% larger and 10% largest). For the exploratory categorical variables, the mean of the whole population was included as the reference category, which is thus dynamic. Each quarter of the year, the change of the reference was monitored and if deemed relevant, presented as well.

Effects of the independent variables are presented by either odds ratios (OR), incidence rate ratios (IRR) or estimates depending on the distribution of the dependent variable (binary, poisson, neg-



GD Cattle Health and Surveillance System 2015

**Fig. 3.** Results of the multivariable GEE population averaged linear regression model showing the observed and expected bulk tank milk SCC (BTM SCC), and the trend in time for 17,818 Dutch dairy herds in the period from 1st of October 2010 until 30th of September 2015.

ative binomial, or linear). Dependent variables are presented as observed values, predicted values and the trend in time for the key indicators that are displayed. Every quarter, the epidemiologists that conduct TASC, discuss the results with the cattle health specialists that are involved in the CHSS. The short term trend of the last six months (favorable, stable or unfavorable), the long-term trend during the whole analyzed period of five years (increasing, stable or decreasing) and whether the direction of the trend in time is favorable or unfavorable is discussed. Interpretation of the model results is combined with the information from the other surveillance components. Possible causes for deviating trends are reported, and if necessary, additional research is proposed to the stakeholders to study the observed phenomenon in more detail (part of the in-depth analysis of TASC).

A subset of the data that are used to conduct the quarterly TASC is available upon request by the first author of this paper.

## 4. An example: bulk tank milk somatic cell count (BTMSCC)

In the Netherlands, the quarterly BTM SCC is normally distributed and therefore a PA GEE analysis with a Gaussian distribution, identity link function and independent correlation structure was used for analysis. Other correlation structures such as a first-order autoregressive correlation structure were explored but did not improve the model fit. In the presented model, data from the period between 1st of October 2010 until 30th of September 2015 were analyzed. In total, 308,021 quarterly observations based on the average of all BTM SCC measurements in the specific quarter on herd level from 17,818 dairy herds were included. The results showed that the BTM SCC is decreasing over time and that there was a seasonal trend visible with the highest BTM SCC values in summer months and the lowest values in winter (Fig. 3).

Because census data is modeled, statistics such as the *P*-value are less valuable and it was decided to exclusively present associations that are both statistically significant and biologically relevant. In general, in agreement with stakeholders, a result is considered relevant when the OR or IRR is 1.5 times higher or lower compared to the reference category. For normally distributed parameters such as BTM SCC, a threshold value for biological relevance was defined by udder health specialists. For BTM SCC this value was set at  $\pm 10,000$  cells/mL compared to the reference value (bold numbers in Table 1). The 10% dairy herds with the lowest milk production had a higher ( $+51 \times 10^3$  cells/mL) BTM SCC compared to the aver-

**Table 1**  
Results of the multivariable Population-Averaged Generalized Estimating Equation (PA GEE) linear regression model for the mean bulk tank milk somatic cell count (SCC) in 17,818 Dutch dairy herds on quarter level in the period from 1st of October 2010 until 30th of September 2015.<sup>a</sup>

Parameter	Category	Estimate x 10 <sup>3</sup> cells/mL (95% Confidence Interval)	P-value
Herd size	Population mean	Reference	
	10% smallest herds	2.7 (2.0–3.4)	<0.0001
	40% smaller herds	−4.6 (−5.0 to −4.2)	<0.0001
	40% larger herds	−3.8 (−4.2 to −3.4)	<0.0001
	10% largest herds	5.7 (5.0–6.3)	<0.0001
No. of cattle purchased per year	>2 cattle/year	Reference	
	1–2 cattle/year	−2.8 (−3.5 to −2.0)	<0.0001
	closed herd	−9.2 (−9.7 to −8.6)	<0.0001
Milk production level	Population mean	Reference	
	10% herds with the lowest milk production	<b>50.7 (50.1–51.3)</b>	<b>&lt;0.0001<sup>b</sup></b>
	40% herds with a lower milk production	7.5 (7.1–7.9)	<0.0001
	40% herds with a higher milk production	<b>−20.2 (−20.6 to −19.8)</b>	<b>&lt;0.0001<sup>b</sup></b>
	10% herds with the highest milk production	<b>−38.0 (−38.6 to −37.4)</b>	<b>&lt;0.0001<sup>b</sup></b>
Season	Population mean	Reference	
	Jan–Mar (winter)	<b>−13.5 (−13.9 to −13.1)</b>	<b>&lt;0.0001<sup>b</sup></b>
	Apr–Jun (spring)	−2.4 (−2.9 to −2.0)	<0.0001
	Jul–Sep (summer)	<b>19.8 (19.4–20.3)</b>	<b>&lt;0.0001<sup>b</sup></b>
	Oct–Dec (Autumn)	−3.9 (−4.4 to −3.5)	<0.0001
Disease status	Paratuberculosis status unknown	Reference	
	Paratuberculosis status unsuspected	−9.1 (−9.7 to −8.4)	<0.0001
	BVDV status unknown	Reference	
	BVDV status free	−9.3 (−9.9 to −8.8)	<0.0001
Milking parlor	Conventional	Reference	
	Automated	<b>23.7 (23.0–24.3)</b>	<b>&lt;0.0001<sup>b</sup></b>
Quarter	continuous	−1.1 (−1.1 to −1.0)	<0.0001

<sup>a</sup> The parameters replacement rate, location represented by province, milk price, meat price, BHV-1 status, and Salmonellosis status were also included and significant but with no relevant effect (i.e. >10,000 cells/mL difference) on the BTM SCC (results not presented).

<sup>b</sup> Figures in bold represent variables with a relevant (+/− 10,000 cells/mL difference compared to the reference category) association with the key indicator BTM SCC compared to the reference category.

age Dutch dairy herd. Herds with a conventional milking parlor had a lower BTM SCC than herds with an automated milking parlor ( $-24 \times 10^3$  cells/mL) (Table 1). Herds with the highest average milk production had a lower BTM SCC ( $-38 \times 10^3$  cells/mL) compared to the average Dutch dairy herd. As the average BTM SCC in the third quarter of 2015, was lower compared to the value of this parameter in the same quarter of previous years (Fig. 3), the short-term trend was determined to be favorable. In addition, the long-term trend during the five year period showed a decrease in BTM SCC in time, which was also favorable.

#### 4.1. Communication of the results

For presentation purposes, the results of the key indicators are summarized and presented per KMI group (See the example of the KMI 'udder health' in Table 2). Changing trends, are visualized in more detail using figures such as Fig. 3. Possible causes associated with the changing trends are discussed in the text and relevant associations with the independent variables are described. Every quarter, stakeholders are informed about the findings of TASC, through a meeting with the surveillance steering committee in which each of the stakeholder organizations are represented. In these regular meetings, the stakeholders are informed about the current cattle health status in the Netherlands. When adverse cattle health effects arise, possible intervention strategies are discussed as well as the need for more in-depth analysis.

### 5. Possibilities for in-depth analysis

Within TASC, three types of in-depth analyses can be performed, 1) aberrations in trends for which further data-analyses are necessary to clarify observed phenomena, 2) developments in the cattle industry that may have an effect on cattle health, and 3) innovations to improve the quality of TASC.

#### 5.1. In-depth analysis based on aberrations in the cattle industry

Examples of in-depth data analyses that were previously conducted within TASC include impact studies of the BTV-8 and Schmallenberg virus epidemic (Santman-Berends et al., 2011; Veldhuis et al., 2014), a large scale study evaluating the increasing calf mortality in Dutch dairy herds (Santman-Berends et al., 2014), in-depth analysis in the contact structure of the cattle industry (Brouwer et al., 2012) and a quantitative risk assessment of the risk of introduction of *Echinococcus granulosus* in the Netherlands (Berends et al., 2009). With an example we will illustrate an in-depth analysis that was performed to evaluate the association between cattle mortality and the BTV-8 epidemic in the Netherlands.

In 2006 and 2007, BTV-8 emerged in the Netherlands causing morbidity and mortality in cattle (Van Wuijckhuise et al., 2006; Elbers et al., 2009). On 21 December 2007, the agricultural Press in the Netherlands published an article in which they stated that there was an increase in mortality of 12,000 cattle in 2007 compared to 2006. This increase was, according to the Press, completely attributable to the BTV-8 epidemic (Article is no longer available online).

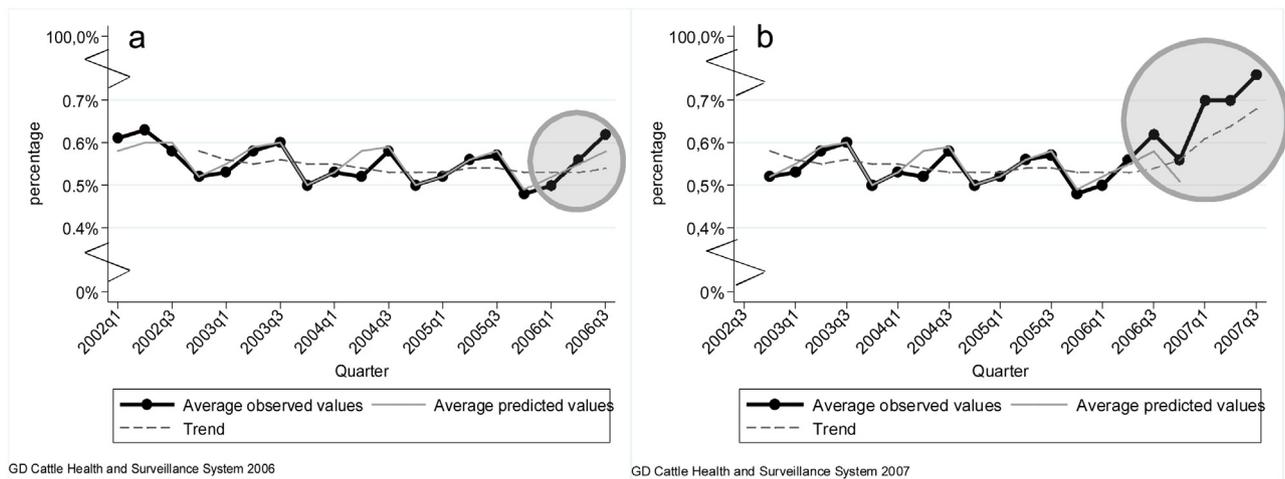
In the quarterly TASC, an increase in mortality in cattle (> 1 year of age) was also observed in 2006 (Fig. 4a), and to a larger extent in 2007 (Fig. 4b). Remarkably, the increased mortality was also visible in the first and second quarter of 2007. In the Netherlands, BTV-8 was assumed not to have spread in those months (Santman-Berends et al., 2010) because the temperature was too low for the vectors to be active. In the same period in which BTV-8 emerged, the regulations regarding emergency slaughter (from January 2006 on) and welfare of animals during transport (from January 2007 on) were tightened (regulation EG 853 and 854/2004 and EG 1/2005). Both changes could, hypothetically, have resulted in higher on-farm mortality rates. The TASC provided the possibility to substantiate whether additional mortality occurred as a result of either or both of these factors. The regulations that were implemented in 2006

**Table 2**

Summary of the key indicators within the key monitoring indicator (KMI) “udder health”, with the trend in the last six months (second and third quarter of 2015), the previous six months (fourth quarter of 2014 and first quarter of 2015), and the trend of the analyzed period of five years from 1st of October 2010 until 30th of September 2015.

	Last six months	Previous six months	5 year trend
<i>Dairy herds</i>			
Bulk tank milk somatic cell count	○	●	↓
% high somatic cell count cows	○	○	↓
% new high somatic cell count cows	○	○	↓
% with antimicrobial residues in the bulk tank milk	●	●	→
% herds with more than 25% of multiparous cows with new high SCC after calving	●	●	→
% herds with more than 25% of the multiparous cows with persisting high SCC after calving	●	○	↓
% herds with more than 25% of the uniparous cows with new high somatic cell count after calving	○	○	↓

○ positive, favorable trend   ● stable trend   ● negative, unfavorable trend   ↓ positive, decreasing 5-year trend   → stable 5-year trend   ↑ negative, increasing 5-year trend.



**Fig. 4.** Percentage of cattle mortality (>1 year of age) per quarter of the year in the period January 2002 until September 2006. Figure a, visualizes the cattle mortality after the first change in regulation (from January 2006 on) and including the first episode of the BTV-8 epidemic (from August 2006 on, represented by the grey circle). Figure b visualizes the period from October 2002 until October 2007, in which the cattle mortality is presented after the second change in regulation (from January 2007 on) and including the second episode of the BTV-8 epidemic (from July 2007 on, represented by the grey circle).

and 2007, and the period in which additional mortality due to the BTV-8 epidemic could be expected, were included in TASC models for cattle mortality (>1 year of age). The OR for the changes in the regulations of 2006 and 2007 were 1.07 (95% CI: 1.05-1.09) and 1.33 (95% CI: 1.29-1.36), respectively. The change in regulation explained more variation in mortality than the BTV-8 epidemic (OR: 1.07; 95% CI: 1.05-1.09). Based on these results, the conclusions that were drawn in the Press were attenuated. There was additional mortality in cattle (>1 year of age) associated with the BTV-8 epidemic. However, the BTV-8 epidemic was associated with a lower increase in mortality than previously suggested.

**5.2. In-depth analyses to study the impact of developments in the cattle industry on cattle health**

An example of recent assessments that were conducted include the impact of selective dry cow therapy on udder health. The Dutch policy makers decided to implement guidelines to ban all prophylactic applications of antimicrobials that were applied for dry cow therapy (KNMvD, 2013). The general opinion of farmers was that these guidelines caused a deterioration in udder health. The only udder health parameter that slightly deteriorated after implement-

ing the guidelines, was the percentage of dairy herds with more than 25% multiparous cows with a high SCC ( $> 250 \times 10^3$  cells/mL) after calving while these cows had a low SCC ( $\leq 250 \times 10^3$  cells/mL) before drying off. Performing additional in-depth analyses as part of TASC also showed that most of the udder health parameters had not worsened after implementation of the guidelines (Table 2).

**5.3. In-depth analysis to improve the quality of TASC**

Proposed in-depth analysis to improve the quality of TASC include either new modeling methods or adding new KMIs. When TASC was developed, initially only the KMIs durability, herd health and udder health were included. Thereafter, the KMIs fertility and metabolic disorders were developed and implemented in the quarterly TASC. In 2015, the in-depth analysis was used to develop a new KMI ‘antimicrobial usage’, which was implemented in the routine TASC in the beginning of 2016. In the future, the potential of inclusion of other useful KMIs such as for example slaughterhouse findings as suggested by Dupuy et al. (2013 and 2014) and Garcia-Saenz et al. (2015), will be evaluated.

## 6. Discussion

In this paper, we presented the trend analysis surveillance component, which is one of the essential parts of the Dutch Cattle Health Surveillance System. There are large differences in surveillance systems between countries depending on, amongst others, the structure of the country, animal density and financial means. Hoinville et al. (2013) described agreed-upon definitions of surveillance terms and listed options that could contribute to surveillance such as early warning surveillance, passive surveillance, participatory surveillance, monitoring, risk-based surveillance and syndromic surveillance. The Dutch CHSS with multiple components, covers most of these options with the consultancy phone desk 'Veekijker' that covers early warning surveillance, passive surveillance and participatory surveillance. The laboratory component focusses on early warning and passive surveillance, but also covers risk-based surveillance. The TASC focusses on monitoring cattle health based on census data, and at this moment options are explored to include syndromic surveillance for early detection of (emerging) diseases in the system as well. By combining all these different components to monitor developments in general cattle health, we are able to provide a unique, complete and on-going overview of cattle health in the Netherlands.

Recently, more countries evaluate the possibility to use routinely collected data for surveillance purposes. Multiple European member states, currently evaluate the possibility to use routinely collected data for syndromic surveillance (Perrin et al., 2012; Dupuy et al., 2013; Madouasse et al., 2014; Bronner et al., 2015; Struchen et al., 2015; Torres et al., 2015). In addition, from a study of Pannwitz (2015) it was concluded that analysis of routine collected data is useful and enables a standardized active monitoring and surveillance that is inexpensive and easy to implement. Nevertheless, a system as TASC, which requires regular access to census data, may not be feasible for many countries due to their demographic features (scale, density, etc.) and the costs involved with routinely collection of census data. In those cases, it might be possible to have access to regional data or to use a sample of herds on which analysis can be performed. A drawback of these alternatives is that bias might be induced when extrapolating the findings to the whole cattle population in a country because the study population might not be representative. For example, when using a sample of herds to conduct trend analysis, herds with an interest in participation in (health) schemes and/or with good registration of cattle health aspects might be more likely to be included than herds that do not participate in schemes and/or have a poor registration. This will lead to selection bias (Dohoo et al., 2009) and findings in these herds therefore might not be representative for all herds in the country. Methods such as multiple imputation to fill in missing values (Sterne et al., 2009), capture recapture techniques to eliminate underestimation of the number of eligible cases (Brenner, 1994) or bootstrapping to assess the confidence of the model parameters based on the empirical distribution of the observed data (Efron, 1979), can help to improve the model outcomes when it is not possible to include census data. Another solution is to start small with just one dataset that is available on national level such as for example the identification and registration data, which is regulated by the European parliament and is mandatory for all European countries (EC 1760/2000 and EC 911/2004). Thereafter, the system can be expanded by including other data sources step by step. If there is no option to use routinely collected data, it might still be feasible to monitor trends and developments by conducting several cross sectional studies over time.

The CHSS is regularly evaluated and adapted to the newest modeling methods available, cattle health data and additional needs indicated by either the stakeholders or other components of the CHSS, to improve efficacy and efficiency. For TASC, this meant that

new techniques for analysis were implemented and that additional KMLs were added. When developing a monitoring system such as TASC, it has to be ascertained that datasets from the different sources can be combined on a mutual unique identifier such as UHI or the cattle identification number. For a TASC, analyses are preferably conducted on herd or even animal level. The data can subsequently be aggregated to a higher level such as regional or national level. When detailed data are not available, it is recommended to combine different datasets at the lowest mutual level. In these cases, trends can probably not be monitored on animal or herd level, but can be monitored on regional level, which may also provide enough information.

Flexibility of the CHSS and TASC is important because of the continuous changes in both the beef and dairy industry that may impact cattle health. Barkema et al. (2015) stated that adoption of new technologies that provide a lot of routine herd data, such as the use of cow activity monitors and automated milking systems, is accelerating. However, at this moment on-farm utilization of data generated in herd management systems is still largely unrealized. The TASC, does not aim to provide information for individual herds given that the system aims at monitoring trends and developments in the complete Dutch cattle industry. Nevertheless, the availability of routine census animal and herd data and the experience of working with such large datasets, provide the possibility to generate routine cattle health information for individual herds as well. Building on the experience of TASC, and with approval of the stakeholders, individual farmers and data collecting organizations, a monitoring system for individual dairy herds on routinely collected data was developed (Brouwer et al., 2015). This system was based on evaluation of the results of a number of key indicators that were routinely monitored within TASC on herd level and compared to a benchmark of all dairy herds. The availability of routinely collected census data also facilitated the possibility to explore whether census data on cattle health could serve as proxy for key indicators which are usually collected in large scale field studies. For all dairy herds, routinely collected data appeared to provide an accurate estimation of clinical mastitis incidence (CMI) (Santman-Berends et al., 2015) and welfare parameters (De Vries et al., 2014).

The CHSS aims at early detection of (re) emerging exotic diseases, detection of new phenomena and monitoring trends and developments in Dutch cattle health. The TASC adds to this system by supporting or nuancing signals that are derived from the other components. Nevertheless, a drawback from TASC is that it cannot be used for early warning. As expressed in Appendix A, the census datasets are very large and the process of unlocking, encrypting, validating and analyzing the data takes time. The CHSS is a system that is not static; in all surveillance components, including TASC, on-going efforts are taken to adapt the system to altering circumstances in the cattle industry and to retain high quality standards. The information that is provided by the Dutch CHSS is used by both public and private stakeholders as they want to be informed timely and accurately about the changes in cattle health. The sustainability of the system is guaranteed by the combination of i) contractual agreements with the stakeholders for general monitoring and surveillance to early detect disease introductions and evaluation of trends and developments in cattle health, ii) the legal basis for mandatory reporting of listed diseases and iii) providing valuable information in a cost-efficient way as the TASC can be largely automated for both the data delivery as the data validation and analyses process.

As presented, the development and implementation of TASC within the CHSS was challenging and difficulties had to be solved before evolving to the quality level the system has today. Although the system was developed for the cattle population in the Netherlands, similar challenges can arise when such a TASC was

developed for other species and/or production systems in other countries. The information in this paper that described both the challenges, but also the solutions that were found and the merit of the complete system, might be valuable for those who want to develop a data analysis system for monitoring and surveillance purposes.

## 7. Conclusions

The CHSS as conducted by GD Animal Health in the Netherlands, performs according to expectations of stakeholders. The use of automatically collected and routinely available census data to monitor trends in time and to conduct in-depth analysis for a wide range of cattle health indicators is able to offer insight in general cattle health in the Netherlands. In addition, TASC provides infor-

mation to support or nuance signals of changes in cattle health. This paper provided insight in the challenges and difficulties for developing a TASC and might be of help to those that want to develop a monitoring system based on routinely collected data.

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## Appendix A. Available data in the Dutch surveillance system that is based on quarterly trend analysis of cattle census data

Dataset	Variables	Number of records in 2015 quarter 3	Level of aggregation	Source
I&R: herd data	UHI, herd type (farmer/slaughterhouse/start date of the farm, end date of the farm)	143,470	Herd	Dutch enterprise agency (RVO), The Hague
I&R: Animal data	Idcode, gender, birth date, removal date from the system + reason (death/slaughter or export), country of origin, colour of the fur	38,239,369	Animal	Dutch enterprise agency (RVO), The Hague
I&R: movement data	UHI, idcode, entry date in the herd, reason of entry (birth/purchase), removal date from the herd + reason	91,923,850	Movement within animal	Dutch enterprise agency (RVO), The Hague
Location data	UHI, quarter, postal code (2-digit level), province	969,559	Quarter within herd	GD Animal Health, Deventer
Status for endemic diseases	UHI, quarter, status for BVDV, BHV-1, Paratbc, Leptospirosis, Salmonellosis	1,397,100	Quarter within herd	GD Animal Health, Deventer
Production data*	UHI, Standardized milk production, test date, type of milking system (regular/AMS), net return corrected for 305d milk production,	802,122	Test date within herd	Dutch Royal Cattle Syndicate (CVR), Arnhem
Udder health*	UHI, test date, percentage high SCC cows, percentage new high SCC cows	784,508	Test date within herd	Dutch Royal Cattle Syndicate (CVR), Arnhem and MCS Nijland, Nijland
Antimicrobial usage**	UHI, date of antimicrobial delivery, the amount of delivered product, the age category of the animal to which the antimicrobial was supplied, the name of the product, the way of administrating the product	3,746,015	Supply date within herd	ZuivelNL, the Hague
Bulk Tank Milk (BTM) data	UHI, BTM SCC, presence of antimicrobial residues in the BTM, status for Salmonellosis	385,360	Quarter within herd	Qlip laboratories, Zutphen
Mortality data	UHI, collection date, type of collected cow (non ear tagged calf (<3 days old), ear tagged calf (3 days – 1 year old) or cattle (>1 year old)	1,622,390	Collection date within herd	National rendering plant, Son
Test day milk recording	UHI, idcode, test date, %fat (both observed and expected), %protein (both observed and expected), kg milk production (both observed and expected), SCC, start date lactation, lactose, ureum	59,735,281	Test date within cows	Dutch Royal Cattle Syndicate (CVR), Arnhem
Insemination data	UHI, idcode, calving date, insemination date, insemination number, parity, birth date, type of insemination (natural or AI)	16,703,143	Insemination date within cows	Dutch Royal Cattle Syndicate (CVR), Arnhem

\*For dairy herds only and from approximately 78% to 80% of the total dairy population, \*\*for all cattle herds excluding the veal sector.

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