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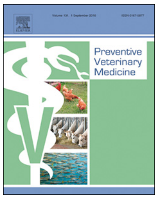

Changing surveillance objectives during the different phases of an emerging vector-borne disease outbreak: The Schmallenberg virus example

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ABSTRACT

In the late summer of 2011, a sudden rise in incidence of fever, drop in milk production and diarrhoea was observed in dairy cows in the eastern region of the Netherlands and in north-western Germany. In the autumn of 2011, a novel orthobunyavirus was identified by metagenomic analyses in samples from acutely diseased cows on a farm near the German city of Schmallenberg, and was thereafter named Schmallenberg virus (SBV). Due to the novelty of the virus, there was an immediate need for knowledge regarding the epidemiological characteristics of SBV-infections to inform surveillance and control strategies. A rapid assessment of the spread and impact of an emerging disease supports decision-makers on allocation of resources. This paper reviews the disease mitigation activities during and after the SBV epidemic in the Netherlands, to illustrate the phases in surveillance when a new (vector-borne) pathogen emerges in a country or region. Immediate and short-term disease mitigation activities that were initiated after SBV was identified are discussed in detail, as well as ways to enhance future surveillance (e.g. by syndromic surveillance) and preparedness for similar disease outbreaks. By doing so, lessons learnt from the SBV epidemic will also improve surveillance for other emerging diseases in cattle.

1. Introduction

Animal disease surveillance systems targeted at emerging diseases often comprise a combination of active and passive components. Finding the optimal surveillance strategy remains challenging as it is a dynamic process with objectives changing depending on the epidemiological phase of the infection (European Food Safety Authority (EFSA), 2011). For example, in the first phase – when the target population is still free – surveillance is targeted at early detection of outbreaks. In the second phase, when the prevalence of infection is rising, the objective changes to estimating the extent of infection in the population and identifying potentially useful control strategies. When the emerging disease is the result of an unknown or novel pathogen, resources need to be allocated to the identification of the pathogen, its transmission mechanisms and its zoonotic potential. Also, its impact in terms of clinical disease in affected animals and their offspring and impact in terms of loss of productivity needs to be estimated. The latter provides insight in the effort justified for surveillance and control of the disease, for example through the development of a vaccine. In addition, risk factors for infection need to be identified to facilitate preventive measures, and potentially, contribute to a risk-based surveillance strategy. After the prevalence of infection reaches its peak it will most likely drop to an endemic equilibrium or to zero. At this stage, the objective of surveillance shifts to monitoring changes in prevalence of infection, monitoring the impact of control measures, or eventually, demonstrating freedom from infection.

In the last decade, the cattle industry in north-western Europe has been confronted with two emerging vector-borne viruses that caused economically damaging outbreaks: bluetongue virus (BTV-8) in 2006 and 2007 (Velthuis et al., 2009) and Schmallenberg virus (SBV) in 2011 (Conraths et al., 2013). BTV-8 and SBV are both transmitted by Culicoides biting midges. Contrary to the well-known BTV-8, when SBV was identified, very little was known about the impact of the virus. Most assumptions were deduced from scientific information available on other viruses of the Simbu serogroup. The Netherlands was part of the primary outbreak area that was affected by SBV in the late summer of 2011. Due to the novelty of the virus, there was an immediate need for knowledge regarding the epidemiological characteristics of SBV-infections to inform surveillance and control strategies. This paper aims at reviewing the disease mitigation activities during and after the SBV epidemic in the Netherlands, to illustrate the phases in surveillance when a new (vector-borne) pathogen emerges in a country or region.

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2. Detection of the emerging disease outbreak

When a country is free from an important pathogen, but at risk for its introduction, surveillance is aimed at early detection of outbreaks. Early detection surveillance is defined as the surveillance of health indicators and diseases in defined populations to increase the likelihood of timely detection of undefined (new) or unexpected (exotic or re-emerging) threats (Hoinville et al., 2013) and allows control measures (if needed) to be implemented rapidly when the incidence of cases is still low. Veterinary practitioners and professionals in the second-line health care often work together closely in early detection surveillance activities, such as clinical surveillance. For a maintainable balance between costs and benefits of early detection surveillance, a surveillance system operational in the second line of health care should be tailored as such that it is not detecting diseases that are generally covered by veterinary practitioners (such as infections that occur locally with a low impact in the affected farms). Passive surveillance is often used in early detection surveillance strategies, e.g. notification of legislative diseases. The main limitation of passive surveillance is that it requires the particular infection to induce clinical signs in the host. Subclinical infections and preclinical stages of disease will not be recognized and infections that result in non-specific clinical signs will only be recognized in case of a suddenly rising incidence. In addition, for a high sensitivity of passive surveillance, motivation to report of animal owners and veterinarians is crucial, which requires trust in the organization they report to and, potentially, proper incentives (for example in the form of valuable veterinary feedback or follow-up investigations). Moreover, the more time elapses before the first suspicion is reported, the higher the probability that the pathogen spreads to other herds.

In the Netherlands, a passive surveillance component for early detection of (re-)emerging cattle diseases is embedded in the national animal health surveillance system that is carried out by GD Animal Health (Santman-Berends et al., 2016). The passive surveillance component consist of, amongst others, a telephone helpline service which is open to cattle owners and veterinarians to consult experts at GD Animal Health regarding (atypical) health problems. Calls are handled by a group of cattle health specialists and when deemed necessary for surveillance purposes, a farm is visited – free of charge - by these specialists to collect essential information for diagnosis or further research. In the late summer of 2011, there was a sudden increase in phone calls regarding diarrhoea, fever and loss in milk production in dairy cattle (Fig. 1). Although these symptoms are non-specific and may be associated with several (endemic) diseases or disorders in cattle, the frequency of calls regarding these symptoms was much higher than expected based on the call pattern from previous years. Extensive bacteriological, virological and parasitological testing of the faeces of clinically affected cows did not reveal a causative agent for the problems (Muskens et al., 2012). In early September, cattle in Germany reportedly showed similar clinical signs as observed in the Netherlands, diarrhoea excluded. Analyses of samples from acutely diseased cows excluded several known endemic and emerging viruses as causative agent (Hoffmann et al., 2012). On November 18th 2011 a novel orthobunyavirus, provisionally named Schmallenberg virus (SBV), was identified by metagenomic analyses. From early December 2011 onward, SBV-induced congenital malformations, designated as arthrogryposis-hydranencephaly syndrome, were observed in newborn lambs and calves in the Netherlands. To date, the origin and pathway of introduction of SBV is unknown.

A second type of surveillance that is commonly used for early detection purposes is sentinel surveillance. Sentinel surveillance can be described as the regular testing of animals whose geographical location and immune status is known, to either measure the incidence of a known disease (or changes therein) or as an early detection tool (Racloz et al., 2006). For early detection, the sentinel network is set up to detect the first incursion of a pathogen (or its vector) into free regions, by either measuring presence of the known pathogen or seroconversion in the sentinel units. The sentinel units act as proxies for the entire population (Hoinville et al., 2013) although sentinel surveillance is characterised by targeting herds or areas with higher probabilities of disease (McCluskey, 2003). For this reason, monitoring of transmission of vector-borne diseases specifically is most appropriate during the months of vector activity. In Australia, sentinel herds have been employed since the 1970’s to monitor arbovirus activity, which is currently tailored to more frequent sampling in areas which are known for virus transmission (Geoghegan et al., 2014). The data derived from the Australian sentinel network are used to monitor the geographic extent of infection and to provide confidence towards exporting livestock from arbovirus free areas. As sentinel surveillance may involve high costs – depending on how animals or herds are monitored – it is usually applied in situations where there is a substantial threat of incursion of the pathogen of interest.

Another approach to specifically detect incursions of vector-borne pathogens (before clinical cases are apparent) is surveillance of vectors. Entomological surveys are used to determine occurrence of infection in vectors, but also to determine vector species composition, abundance, temporal and spatial variation in vector populations, vector competence and host preference. Surveillance targeted at the vector is particularly informative when dealing with new epidemics in which the precise roles of various vector species are unclear (Vale and Torr, 2015). Due to previous incursions of BTV-8, Culicoides biting midges are trapped frequently on three locations in the Netherlands since 2007

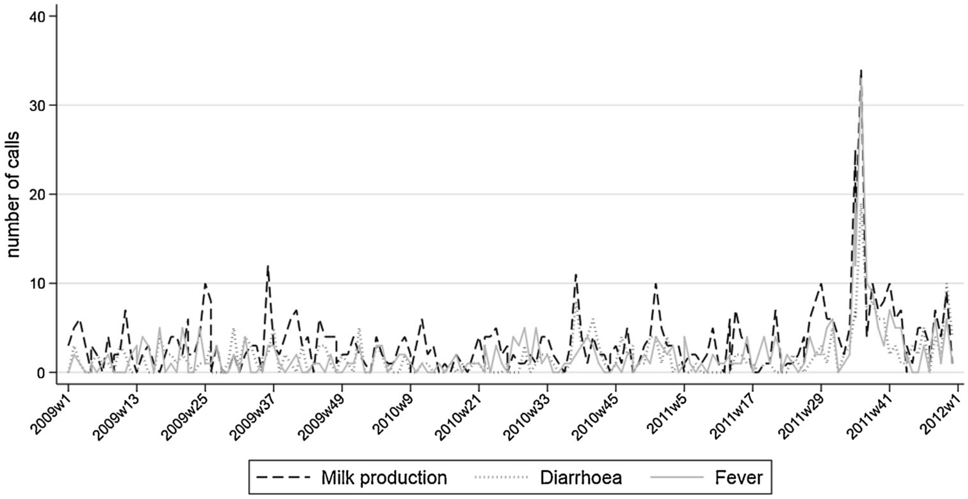

Fig. 1. Number of phone calls to the veterinary helpline service at GD Animal Health by week from January 1, 2009 to January 1, 2012, stratified by calls regarding milk production (black dashed line), diarrhoea (grey dotted line) and fever (light-grey solid line) in dairy cattle. Source: GD Animal Health, courtesy of H. Brouwer-Middelesch.

to determine their morphology and species. The midges collected during autumn 2011 were assayed by RT-PCR for presence of SBV RNA, 0.56% of the midges of the *C. obsoletus* complex and 0.14% of the *C. chiopterus* midges appeared to be infected with SBV (Elbers et al., 2013). Elbers et al. (2013) suggested that as these proportions are 5–10 times higher than reported for BTV, it might explain SBV's rapid spread throughout Europe. In Japan, where bovine arboviruses such as Akabane virus and Aino virus are endemic, monitoring of pathogens in vectors is considered important for rapid detection of arboviral activity (Kato et al., 2015). In Australia, serological data from sentinel cattle herds regarding BTV, Akabane virus and bovine ephemeral fever virus is supplemented with data on vector collections from sites across the same geographic range (Geoghegan et al., 2014). According to Geoghegan et al. (2014), these combined data sources provide a more complete understanding of arbovirus seasonality that enables better risk predictions. However, monitoring vector populations over time and virus isolation from vectors and sentinel animals is time-consuming and laborious (Kato et al., 2015). This frequently leads to ad hoc activities instead of continuous longitudinal studies, and consequently, identification of the pathogen in vectors is usually after the first outbreak in animals rather than before (Qiu et al., 2007). In addition, the ability of arthropod vectors to transmit pathogens is a non-constant process under influence of changes in climate (Tabachnick, 2010). Incursion of known pathogens may occur in new areas as a result of extension of transmission beyond traditional acknowledged vector species, as seen with the BTV-8 outbreaks in North-western Europe in 2006 (Purse et al., 2005).

3. Immediate mitigation activities

3.1. Estimation of societal impact

The likelihood and impact of an emerging disease outbreak determine the effort that is justified for control measures (e.g. movement bans or the development of a vaccine). When a disease emerges of which the impact is unclear, for example when the disease is caused by a previously unknown pathogen such as SBV, resources need to be allocated in the short term to quantify the impact of disease. The impact of an emerging disease can broadly be divided into the societal impact (animal welfare, public health risk) and economic losses following the disease outbreak (i.e. clinical disease in affected animals, production losses, trade restrictions, price effects, preventive and control measures). For the estimation of economic losses, information regarding the spread of the disease is needed which is not immediately available after a disease outbreak is detected. It is therefore discussed below in section 3 (Short-term mitigation activities).

A rapid assessment of the societal impact of an emerging disease requires close collaboration between veterinary and public health specialists and decision-makers. SBV belongs to the family Bunyaviridae (Hoffmann et al., 2012). The genus Orthobunyaviridae within the Bunyaviridae family contains several relevant zoonotic viruses, such as Oropouche virus and La Crosse virus. Therefore, the emergence of SBV triggered a joint veterinary and public health response in the Netherlands to address the possible consequences to public health. The Netherlands has an integrated structure for human–animal risk analysis and response to zoonoses, established after a massive Q fever outbreak in 2007–2010 (Reusken et al., 2012). First, based on a risk assessment algorithm, it was concluded that zoonotic transmission of the virus could not be excluded. Therefore, a public health risk assessment of the emergence of SBV in ruminants was initiated by a consortium of experts from public and veterinary health institutes. The study comprised the monitoring of self-reported health problems in humans and a serological survey among persons living and/or working on SBV-affected farms (Reusken et al., 2012). It was concluded that the public health risk for SBV was absent or extremely low, given the lack of evidence for zoonotic transmission from either the syndromic monitoring or the serological survey in humans. If zoonotic transmission was believed to be likely, so far in the absence of human cases, a chain of action would have been set in motion, including activation of preparedness plans and public health messaging activities to increase awareness and prevention, as well stringent interventions in the animal population that reduce the spread of the disease (Babo Martins et al., 2016).

3.2. Estimation of the spread of the disease in the population

After detection of the emerging disease, when incursion of the pathogen results in transmission in the population and prevalence of infection is rising, the objective of surveillance changes to estimating the extent of infection in the population and identifying potentially useful control strategies. For the first, cross-sectional surveys are often carried out, provided that diagnostic tools are available. Cross-sectional surveys aim to provide data (often prevalence of infection) on the entire population under study, by sampling a random or stratified selection of individuals at a single moment in time. In order to get a first impression of the spread of SBV and its impact, it was decided in the Netherlands on December 20th 2011 to inforce notification of SBV infection. From that moment, malformations in new-born ruminants had to be reported to the authorities. After notification, malformed new-borns were necropsied and brain tissue was sampled for reverse transcription-polymerase chain reaction (RT-PCR). At the same time, a large-scale cross-sectional serosurvey was set up to estimate regional seroprevalences and to identify the moment of first seroconversions, using serum samples collected for routine diagnostic purposes in the months prior to the outbreak. The results of the survey provided evidence that the introduction of SBV in the Netherlands had rapidly affected a large proportion of the cattle, sheep and goat holdings. SBV-specific antibodies were detected in 95.5% (95% CI: 92.3–97.7) of the dairy cattle herds, 99.3% (95% CI: 97.4–99.9) of the non-dairy cattle herds, 97.1% (95% CI: 94.7–98.6) of the sheep flocks and 81.1% (95% CI: 74.7–86.5) of the goat herds (Veldhuis et al., 2013). This finding had two important implications. First, due to the small proportion of (remaining) naïve animals after one vector-active season, it was likely that the incidence of new cases following potential overwintering of SBV was going to be low. A low seroprevalence might have been a justification for a vaccination campaign or other protective measures. Secondly, apparently this novel virus was transmitted throughout the (small) ruminant population very efficiently, affecting a large proportion of the population in the Netherlands within a limited period of time. No gradient spatial pattern in final seroprevalence could be detected and therefore no suggestions about the site of introduction and spread of SBV in the Netherlands in 2011 could be made. To identify the spatiotemporal introduction of SBV in the Netherlands, 11,493 archived sheep serum samples from April to November 2011 were tested for presence of SBV-specific antibodies (Veldhuis et al., 2013) using an in-house indirect whole virus ELISA (Van der Heijden et al., 2013). In samples from July, June and April 2011, approximately 2% of the samples tested positive. In 4.5% of the samples from August 2011 antibodies were found. To confirm a positive serostatus, positive samples from June, July and August were retested with a more specific virus neutralization test (VNT) as described by Loeffen et al. (2012). This resulted in a negative outcome for all samples from June and July. Seropositive samples from mid-August 2011 onwards were confirmed positive by VNT testing, indicating first seroconversions following SBV introduction in the Netherlands.

4. Short-term mitigation activities

4.1. Estimation of economic losses

Fortunately, the direct impact of the SBV epidemic in 2011/2012, in terms of the number of affected herds with malformed new-borns in

Europe, appeared to be limited - although greater among sheep than among cattle – with a maximum proportion of 6.6% and 4% confirmed virus positive sheep and cattle herds per NUTS2 region, respectively (European Food Safety Authority (EFSA), 2012). Nevertheless, little was known with regard to the overall within-herd impact of SBV infection (European Food Safety Authority (EFSA), 2012). In particular, impact on key performance indicators such as milk production, reproductive performance and mortality rates was unknown. Therefore, the impact of the 2011 SBV epidemic on the productivity of dairy cattle in the Netherlands was estimated using routinely collected milk production, fertility and mortality records. It was concluded that there was a negative association between SBV infection and milk production and a number of fertility parameters, yet productivity of dairy cattle was not dramatically affected during the epidemic. Between August 15th and September 19th 2011, the average loss in milk production per cow was -0.26 kg (95% CI: -0.30 ; -0.22) per day in dairy herds, compared to the reference period ($p < 0.001$) (Veldhuis et al., 2014a). In addition, SBV had no or limited impact on mortality rates, which was as expected given the lack of mortality in SBV-infected adult cows and the low incidence of notified malformations in new-born calves (Veldhuis et al., 2014a). This is similar to the impact of SBV in sheep flocks in the Netherlands, in which the effect of SBV on mortality rates and reproductive performance was estimated to be limited as well (Luttikholt et al., 2014). These results contributed to the optimization of the surveillance and control strategy of SBV in the Netherlands; the absence of a public health risk and the moderate direct impact of the disease provided confidence that control measures such as the application of a vaccine were deemed unnecessary.

In other affected countries in Europe, the direct impact of SBV is also considered to be limited or moderate. In France, SBV associated morbidity between January 2012 and August 2013 was generally moderate and the impact of SBV in infected ruminant herds was primarily due to the birth of stillborn or deformed foetuses and neonates (Dominquez et al., 2014). Raboisson et al., (2014) estimated the net SBV economic costs for various beef suckler production systems under French and British conditions and found that the major SBV cost was associated with the losses due to steers and heifers not produced because of the disease. An online survey among 494 sheep farmers in Great-Britain in the summer of 2012 indicated limited animal losses from the disease, although some farmers reported greatly elevated mortality and overall, the impact of the disease as perceived by the farmers was high (Harris et al., 2014). The fear of ruminant new-borns being malformed by SBV infections also caused serious concerns amongst farmers in the Netherlands. It should be noted however that the overall impact of the epidemic on the ruminant industry differed between affected countries due to differences in production systems, varying from intensively managed, indoor housed, year round reproduction, dairy herds to extensively grazed, low stocking density, block mated in autumn, sheep flocks (Stavrou et al., 2017).

According to the WTO Agreement on the Application of Sanitary and Phytosanitary Measures (‘SPS Agreement’), any SBV-related preventive measure with regard to trade should be taken in compliance with the basic principles of scientific justification, proportionality and non-discrimination. More specifically, SBV is, like other viruses of the Simbu serogroup such as Akabane virus, not an OIE listed disease nor notifiable in the EU or subject to specific OIE standards or restrictions. Therefore, with regard to international trade, the virus should not be treated different than other Simbu serogroup viruses which are endemic in several parts of the world (Anonymous, Communication by the European Union, 2012). Nevertheless, by October 2012, one year after SBV was first identified in Europe, more than 25 countries outside the EU imposed SBV-related import restrictions to EU products (ProMED-mail, 2012). It is expected that the economic burden of the SBV epidemic on the ruminant industry as a whole is mainly attributable to these international trade restrictions (live animals and genetic products from affected countries) (Conraths et al., 2013). For this reason, SBV surveillance remained opportune in several European countries including the Netherlands for several years after the 2011 outbreak.

4.2. Identification of risk factors

Although SBV rapidly infected a large fraction of the ruminant population in the Netherlands, morbidity at herd level was diverse and varied from subclinical infection to acute clinical disease in cattle and malformations in new-born calves. As little was known about the factors that determine the severity of clinical manifestation at herd level, a matched case-control study was performed to investigate potential risk factors for clinical disease in either adult cattle or new-born calves in dairy herds (Veldhuis et al., 2014b). Case herds were selected based on (i) reported presence of clinical signs in adult cattle that were likely due to SBV infection in the late summer of 2011, or (ii) the notification of malformations in new-born calves between December 2011 and March 2012. Control herds were selected based on a request to the veterinary practitioner of case farms to select a control herd located in the same geographical area as the case herd. The results of the study showed that malformations in new-born calves were less likely to occur in herds where no clinical signs were observed in combination with a reduced seroprevalence (OR 0.10 (95% CI: 0.01-0.87)) compared to herds in which clinical signs were observed in combination with a high seroprevalence. Also, grazing was identified as risk factor for high seroprevalence (OR 9.89 (95% CI: 2.37–41.2)) as well as for the occurrence of malformations in new-born calves (OR 2.64 (95% CI: 0.99–7.06)) (Veldhuis et al., 2014b).

4.3. Monitoring seroprevalence

After the primary phase of an emerging disease outbreak, the objective of surveillance changes to monitoring changes in prevalence of infection, monitoring the impact of control measures or eventually, demonstrating freedom from infection. The latter is of particular importance if trade restrictions are involved as long as disease freedom is not substantiated. As a consequence of the efficient spread of SBV in the Netherlands in 2011, the herd immunity after one vector-active season was high. As a result, although SBV was still circulating in the Netherlands and in other primary affected regions (Conraths et al., 2013; Elbers et al., 2013; Méroc et al., 2013), it was at a low level in the subsequent vector active season (2012). When herd immunity declines in Europe, reintroduction or re-emergence of SBV in Europe (or parts thereof) might result in a new epizootic. The question was when herd immunity would drop to a critical level where the risk of a new epidemic is substantial. Presence of SBV-specific antibodies in naive cattle (youngstock) was therefore investigated in the Netherlands in three cross-sectional surveys in fall/winter 2013–2014, 2015–2016 and 2017–2018, aiming to determine if SBV was still circulating, and if so, to what extent. In each survey, a random sample of dairy and/or non-dairy herds was selected and a blood sample of 5 randomly selected animals (8–12 months of age) was collected in each herd to be examined for presence of SBV-specific antibodies. It was assumed that animals with maternal antibodies were excluded by these sampling restrictions.

In the 2013–2014 survey, 394 dairy farms were sampled between October and December 2013. Antibodies were detected in 21 out of 1923 animals (1.1% (95% confidence interval (CI): 0.7–1.7)) and confirmed by VNT testing in 13 out of them (Veldhuis et al., 2015). Thus, the survey revealed a low level of SBV-seroconversions in the sampled youngstock, although the results were somewhat surprising as all but one of the seropositive calves were single-reactors in the study herds. This suggested that these positive test results were unlikely the result of natural infection in 2013, as SBV circulation in a herd is known to result in high within-herd seroprevalences. It can however not be excluded that the level of herd immunity was sufficient to prevent large outbreaks at farm level.

In 2015, presence of SBV-specific antibodies in naive youngstock was investigated in 193 randomly selected dairy herds and 149 randomly selected beef suckler herds between October and December. A low level of circulation of SBV was found, based on SBV-specific antibodies in youngstock born in 2015 and at least 8 months old at time of sampling (GD Animal Health, unpublished data). The overall true animal-level seroprevalence in dairy herds was significantly higher in 2015 (6.5% (95% confidence interval: 5.0–8.3)) compared to 2013 (0% (95% confidence interval: 0.0-0.2)). This suggests that the virus was again circulating in the Netherlands in 2015, yet at a low level as in 72% of the dairy herds and 64% of the beef suckling herds in the study all of the sampled youngstock were seronegative.

In winter 2017, 423 randomly selected dairy farms and 148 randomly beef suckler herds were sampled for presence of SBV-specific antibodies as aforementioned. In 14.3% (95% CI: 12.3–16.6) and 29.7% (95% CI: 26.3–33.3) and of the sampled sampled youngstock from dairy herds and suckling herds respectively, antibodies were found (GD Animal Health, unpublished data). These figures indicate a significant increase in seroprevalence since the survey of 2015, yet signals of significant health problems or detrimental losses have been absent so far. Other European countries have also reported circulation of SBV in 2016 and 2017 (Animal and Plant Health Agency (APHA), 2016; Delooz et al., 2017; ProMED-mail, 2018a, 2018b).

The results of the three consecutive surveys after the 2011 epidemic suggest that the infection in the population is settling towards an endemic equilibrium, with fluctuating numbers of susceptible, infectious and immune animals until the equilibrium is stable. Moreover, it is evident that SBV has circulated since 2012, yet the level of herd immunity may have been sufficient to prevent large outbreaks.

5. Enhancing future surveillance and preparedness

5.1. The added value of syndromic surveillance

Critical factors for early detection of emerging diseases are the sensitivity and timeliness of the surveillance system, i.e. the ability to detect an outbreak soon after introduction of a pathogen. Conversely, specificity should be high in order to limit the number of false alarms. When an emerging pathogen affects productivity parameters such as milk yield and reproductive performance, there is a potential to use such data to enhance early detection surveillance in the form of syndromic surveillance. The advantages of syndromic surveillance over passive surveillance are its more objective nature, and the absence of underreporting issues and time delay involved in reporting of suspect cases. Recent examples in the field of cattle health surveillance illustrate the interest in the use of non-specific herd productivity data for veterinary syndromic surveillance (Dupuy et al., 2015; Bronner et al., 2015). SBV had a significant – though limited – effect on cattle productivity during the 2011/2012 epidemic (Veldhuis et al., 2014a, 2014b). BTV-8 also had a negative impact on cattle productivity in the Netherlands (Santman-Berends et al., 2010, 2011). Therefore, the added value of a syndromic surveillance system based on routinely collected milk production or cattle reproductive performance data for the early detection of BTV-8 and SBV was examined (Veldhuis et al., 2016). Results showed that gestation-based reproductive indicators, such as the rate of short gestations (i.e. calving a few days earlier that what is expected based on AI date that led to gestation) have the potential to add value to existing passive surveillance strategies to detect emerging diseases in cattle similar to SBV, but not BTV-8. Differences in transmission characteristics and pathogenicity between SBV and BTV-8 is a probable explanation for the different sensitivity of detection of the outbreaks of these viruses by production indicators. More specifically, although SBV had a lower impact on reproductive performance and milk production than BTV-8 (Santman-Berends et al., 2010, 2011; Veldhuis et al., 2014a), its fast spread has likely resulted in production parameters being (temporarily) deprived more than what can be explained by normal variation. Besides milk production and reproductive performance data, examples of data sources that have been explored for syndromic surveillance in livestock are meat inspection data (Dupuy et al., 2015; Vial et al., 2015), laboratory test submissions (Gibbens et al., 2008; Dórea et al., 2013) and mortality data (Perrin et al., 2012; Torres et al., 2015). The simultaneous application of aberration detection methods on multiple data sources could enhance the sensitivity and specificity of syndromic surveillance as part of early detection surveillance.

The added value of a syndromic surveillance system depends on (i) the availability and performance of conventional passive surveillance systems, (ii) the availability and demographic coverage of data suitable for syndromic surveillance, (iii) the costs of the follow-up of signals from the syndromic surveillance system, (iv) the ability to rapidly collect samples for diagnostic purposes following a signal and (v) the characteristics of the emerging disease. Regarding the latter, syndromic surveillance is probably most valuable as a complement to passive surveillance when clinical signs are moderate to mild and diffuse. More specifically, if the impact of an emerging disease is high (for example in terms of incidence of clinical disease in animals), syndromic surveillance might be of limited value as it is likely that passive surveillance components alone will pick up the outbreak. Nevertheless, in countries without a sensitive passive surveillance system, the added value of syndromic surveillance will be greater, provided that data that allow the monitoring of the population at risk are available and analysed quickly, at a small cost. It is important to emphasize that syndromic surveillance is not a replacement for traditional surveillance, as alerts generated by the system need to be interpreted by epidemiologists. A follow-up procedure to deal rapidly and effectively with the alerts must be in place, with veterinary specialists performing in-depth investigations and the availability of sensitive diagnostic tests. When the system's specificity is imperfect, it is challenging to keep the costs of such a follow-up procedure and its public support at an acceptable level.

5.2. Costs and benefits of surveillance

Economic assessment of surveillance for emerging diseases is of particular importance if the disease neither has a public health nor a large economic impact. In such situations, the expenses required for surveillance (and control) might be higher than the economic benefits as a result of the programme (Doherr and Audigé, 2001). In order to maintain a sustainable balance between costs and benefits of surveillance for emerging diseases, veterinary authorities should relate surveillance costs to the likelihood and impact of emerging disease outbreaks, including possible animal trade bans in case of suspects. The same holds true for control measures such as movement bans and vaccination programmes. The fact that direct economic consequences and societal impact of SBV were limited has indisputably influenced the effort that was allocated to surveillance and control of SBV in the Netherlands and other parts of Europe. If SBV would have had a zoonotic potential or its impact in terms of clinical disease and loss of productivity would have been large, control measures such as movement bans, the use of insecticides or the development of a vaccine would have been given high priority. Such interventions indirectly will also benefit public health. More specifically, it is likely that animal health surveillance data would then be used in addition to public health surveillance data to directly inform actions to prevent human cases (Babo Martins et al., 2016).

5.3. Preparedness

Early detection of emerging diseases, whether vector-borne by nature or directly transmitted, is crucial to allow control measures (if needed) to be implemented rapidly when the incidence of cases is still low. Surveillance efforts for emerging diseases however need to be proportionally tailored to the likelihood and impact of an outbreak.

Structured risk-assessments can help to identify the probability of introduction and establishment of a known disease and to assess – in 'peacetime' – the potential impact of an outbreak (De Vos et al., 2015) to aid decision-making on allocation of surveillance resources. For an unknown disease such as SBV however, resources need to be allocated in the short term to quantify the spread and impact of the disease. A rapid assessment of the spread and impact of an emerging disease demands health authorities and institutes to be prepared to facilitate epidemiological research such as cross-sectional serosurveys and impact assessments. This preparedness includes the presence or development of validated cost-effective diagnostic tests. In the Netherlands, the presence of large numbers of routinely collected ruminant blood serum samples enabled the rapid estimation of the magnitude of the SBV epidemic after one vector-active season. Also, the impact on cattle productivity could be quantified as being low based on analysis of bulk milk collection records that were available for a large fraction of the dairy cattle population. Preparedness is of fundamental importance for timely detection and control of emerging diseases, which is however greatly influenced by knowledge of emerging diseases in neighbouring countries (Dórea et al., 2016). Therefore, in order to react timely in case of an outbreak, it is essential to continuously share information on outbreaks between researchers and decision-makers across borders (Dórea et al., 2016). In the context of the risk of a re-emergence of SBV, a European surveillance collaboration is suggested, exchanging data on midge abundance and virus circulation in midges and ruminants. Such a programme might give livestock holders the opportunity to timely assess whether vaccination or delayed mating would be necessary for their herds and flocks (Stavrou et al., 2017).

6. Concluding remarks

SBV was not the first disease that emerged unexpectedly in Europe, and it will not be the last. With regard to vector-borne diseases, it is well-known that increasing travel and trade, including legal and illegal movement of animals and animal products, contribute to the introduction and establishment of vector-borne diseases in new geographic areas. In addition, climate change facilitates vector-borne diseases to move more regularly out of the tropics, spreading into temperate latitudes (Meiswinkel et al., 2015). The spread of viruses like SBV is not limited by territorial borders and incursion into previously-free areas is therefore difficult to prevent. The Schmallenberg virus example underlines the need for a tailored surveillance strategy, adapted to the changing objectives during the different epidemiological phases of an emerging disease outbreak.

Conflicts of interest

None.

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