Development of a Decision Support System for Aujeszky's Disease Outbreaks in the Netherlands

Minor Msc. Thesis

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Abstract

A Decision Support System was developed to model the development of piglet surpluses, due to movement restrictions, on farrowing farms in the Netherlands in case of an outbreak of Aujeszky's disease (AD). The DSS consist of a forecasting tool using real-time epidemiological input, which is extrapolated under assumed epidemiological developments. The DSS allows to evaluate *ex ante* the mitigating effect of relaxing and early lifting of subzones in an MRZ, on the development of piglet surpluses; and to evaluate the need for buffer capacity in an MRZ. Real-life data on AD outbreaks in the Netherlands under the AD free status were not available for validation of the DSS. A simulation approach was designed, using Interspread plus output for three types of areas (SPLA+, DPLA+, DPLAeq) and combing epidemiological scenarios (small, moderate, large) with mitigating strategies (Relaxation and Early Lifting) and two levels of buffer capacity (2 & 6 weeks) to evaluate the credibility of the DSS. Outbreaks in DPLAs result in larger piglet surpluses than in SPLAs. The Relaxation Strategy has potential to mitigate these piglet surpluses. The Early Lifting Strategy has additional mitigating potential in areas with a high need to export piglets. Having sufficient buffer capacity to overcome transport standstills is very important, especially in DPLAs. It was concluded that the validity of the DSS is sufficient, but further attempts for a complete validation of the DSS are recommended.

Key words: Aujeszky's disease, movement restrictions, mitigating strategies, Decision Support System, model credibility

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Summary

The Netherlands was granted the official AD free status in 2009, by the EU. Outbreaks of AD will be contained by vaccination and installing movement restrictions (MR). Culling and welfare slaughter will no longer be applied because of the high costs and the public concern about animal welfare. However the application of MR as contingency measure can provoke new welfare issues in the form of overcrowded pens on farrowing farms and overweight slaughter pigs on fattening farms. The Dutch pig sector, characterized by specialization, high export dependency and densely populated livestock areas is vulnerable for the economic and animal welfare consequences of MR. The beneficial effect of applying mitigating strategies, like relaxing or early lifting of MR in subzones of MRZs has been shown by Bosman *et al.*(2012). However the effect is dependent on epidemiological determinants and production characteristics of the area affected. The aim of this project was to develop a Decision Support System, to assist the decision maker in carefully deciding where and when to apply these mitigating strategies. The DSS uses real-life epidemiological input, and would have to model the development of piglet surpluses in MRZs under extrapolation of the current situation under assumed epidemiological scenarios. This should allow to estimate *ex ante* the mitigating effect on the development of piglet surpluses.

Data on farm locations and capacities were taken from Dutch system for company registration and management (BRBS) and put up to date using data on animal transports from the system for Identification and Registration (I&R). A tool was programmed to simulate the establishing and lifting of MRZs, under the ruling contingency plan for AD. This tool extracted the required info from the database to weekly list the farms under MR and perform calculations on piglet surpluses, placing possibilities and exceeded buffer capacities. A simulation approach was designed, using Interspread Plus (ISP) output for three types of areas. The areas were characterized by a high or low level of livestock density and a high or low discrepancy between the piglet production and placing possibilities in the area. For this three areas, three epidemiological scenarios were chosen from the ISP output, i.e. a small, moderate and a large outbreak. These scenarios were combined with three strategies , differing in lifting and relaxing MR, i.e. Strict Strategy, Relaxation and Early Lifting. This simulation approach was used to get insight in the need for and effect of mitigating strategies and the tactics of where and when to apply these strategies. Furthermore the results were used to comment on the credibility and validity of the DSS

MR cause larger problems in DPLAs than in SPLAs. From an economical point of view the need for mitigating strategies is larger in DPLAs. In DPLAs the shock in supply on the market can amount a considerable percentage of or even exceed the normal domestic piglet production. The mitigating strategies showed potential to lower the development of piglet surpluses. In areas with a high degree of surplus piglet production (see glossary) the Early Lifting showed additional mitigating potential compared to Relaxation, because of the early export possibilities, and because the lifted subzones do not add piglets to the pool of locked piglets anymore. When applying the Early Lifting Strategy in an equilibrium area it has less additional potential. When the subzone eligible for the mitigating strategies are small the mitigating effect is seriously reduced. Having two weeks of buffer capacity is not sufficient to cope with MR. In most cases six weeks of buffer capacity, in combination with a mitigating strategy can be sufficient. Still in longer outbreaks more buffer capacity is needed.

A complete validation of the DSS was not possible, because no real-life data on outbreaks in the AD free situation are available. The DSS was validated using face validation. The data validity and internal validity were considered to be good. The conceptual validity was considered to be sufficient, but a discussion on the impact of the underlying assumptions is included. Furthermore suggestions for improving the DSS have been made.

It is concluded that the DSS could be applied for other diseases and for other countries, provided that it is parameterized and fine tuned to the contingency plans in question. Lastly it is stated that the mitigating strategies are not the saving solution. Especially, when it cannot be guaranteed that the epidemiological risk are not increased by application of the mitigating strategies. In this case sufficient buffer capacity is the only valid tool to cope with MR. Alternative solutions would have to be found to mitigate the economic consequences of MR.

1 Introduction

Aujeszky's disease (AD), also known as pseudorabies, is a highly contagious disease caused by the *Suid* Herpesvirus type 1. Though other animal species can also be affected, pigs are the primary host for the virus (van Nes, 2001). The disease is not harmful to humans but it can have major socio-economic consequences when the pig production sector is struck by an outbreak of AD. The mortality rate decreases with increasing age of the animal population. In newborn piglets this can be up to 100%. Weaner piglets, grower and finisher pigs can survive an infection, but may suffer from growth retardation. Sows may abort and show reduced fertility following an infection (Animal Health Australia, 2009). The disease spreads mainly through direct and indirect animal contacts but airborne transmission of the virus is also possible. Airborne spread of AD is more likely to occur in areas with higher pig density (Stärk, 1999). For a country like the Netherlands with some very dense pig production areas, this transmission route cannot be neglected.

In the past Aujeszky's disease occured in most countries of Europe (Elbers *et al.*, 2000). It was endemic in most of the intensive pig farming regions until eradication programs were established. Nowadays in most of the European countries the domesticated pig populations are free from AD, but wild pig populations act as a reservoir for AD (FAVV, 2012). The Netherlands started its AD eradication program in 1993 with compulsory vaccination of its pig herds with marker vaccines and AD free certification of pig farms. Vaccination with non-marker vaccines had been forbidden since the 1980's. In the years following 1993 the seroprevalence decreased markedly (Elbers *et al*., 2000). The final step in the process towards an AD free status, imposing a ban on preventive vaccination was done in 2007. This resulted in 2009 into the achievement of the article 10 status, granted by the European Commission (EC, 2008). Saatkamp *et al.* (2005)studied the economic implications of this achievement. Annually the Dutch pig sector saves 16 million euros. Savings are made on the preventive vaccination (13,4 million euros), the costs of AD free certification (1,8 million euros) and the costs for farms to get exemption for the preventive vaccination (1,6 million euros). Moreover export to other AD free countries in and outside the EU got easier and the image of the Dutch pig sector improved as well. On the contrary when the virus gets reintroduced into a fully susceptible pig population the outbreak could spread easily.

The Netherlands should be cautious about a reintroduction of AD into its fully susceptible pig population. About twelve millions pigs are kept in the Netherlands. There are 937,000 sows present, which produce 25,9 million piglets each year (CBS, 2012).Furthermore the Dutch pig sector is characterized by a high degree of specialization. About 80 percent of the pigs are kept on specialized farms. This degree of specialization is higher for farrowing farms then it is for fattening farms (Swormink & Hilkens, 2010). The country is known to have some very densely pig populated areas. These areas are located in the southern provinces: Noord-Brabant and Limburg, and in the provinces Gelderland and Overijssel (CBS, 2012). Most of these areas border with neighboring countries and are imbalanced in the amount of piglet production and amount of fattening places. In general the Dutch pig sector, and especially the multiplier farms are export dependent. In 2011 6,8 million of the produced piglets were exported. Through the years the export dependency of the Netherlands for live piglets and live slaughter pigs has only increased. Moreover the dependency on Germany as the main export market is also increasing, especially for live piglets. From 2010 to 2011 the percentage exported to Germany of the total amount of exported piglets raised from 51,6 to 57,8 percent (PVE, 2012).

This export dependency makes the Dutch pig sector vulnerable. The economic consequences of a contagious disease outbreak can be devastating. An AD outbreak is a valid example of what the Dutch Pig sector could suffer. Looking at the current situation, all the neighboring countries are free from AD. It is highly likely that these countries would close their borders at least for a while to preserve their AD free status. Instantly other and more distant export destinations would have to be found, where to sell the piglets for discount prices. Additionally the domestic piglet market would get disturbed as well. Moreover falling back to the article 9 situation would again cost 16 million euros annually that are saved in the current situation. Moreover this 16 million might be an underestimation because the export numbers have only increased since 2005.

A necessary condition for achieving the article 10 status, is to have an eradication program for AD and a strategy to preserve the article 10 status. The Dutch AD contingency plan is designed by the commodity board for livestock, meat and eggs (PVE) (Summary included in Appendix A). This contingency plan differs from the strategies that were used in the past to eradicate contagious diseases. During the 1997/98 classical swine fever epidemic, stamping out and welfare slaughter were applied to contain and eradicate the disease (Pluimers *et al*., 1999). The majority of culled animals were destructed out of welfare considerations on farms under Movement Restrictions (MR). Moreover the costs of the welfare slaughter program made out the largest part of the total costs of eradicating the disease (Meuwissen *et al.,* 1999). Nowadays the taxpayer is not willing anymore to account for such high costs. Moreover the livestock sector recognized the detrimental effects of these contingency measures on its already fragile image (Van Lent, personal communication). Therefore emergency vaccination and isolation through movement restrictions are the key measures to contain future AD outbreaks. Not a single animal will be preemptively culled nor will any healthy animal be slaughtered and destructed out of welfare considerations. This way the costs of the disease eradication should be lower and the public concern about animal welfare should be comforted.

At the moment there is no experience from previous outbreaks to estimate the impact of this new approach to containing animal contagious diseases. Though Saatkamp *et al.* (2005) illustrated the possible economic consequences of applying MR. Direct costs are incurred for creating extra places to keep the surplus pigs on the farm. Extra feed has to be bought to feed these surplus pigs. Most certainly market effects will occur inside and outside the movement restriction zones (MRZ). Outside the MRZ, piglet prices might initially increase because a part of the supply is cut off from the market. Finally when MR are lifted the market will be flooded by surplus piglets. Most probably the piglet prices will drop. Considering the export dependency of the Dutch piglet producers, the consequences might be dramatic. Lastly the discounting effect on the piglet price of vaccination status and deviant weight should be considered.

Another drawback of this new approach to containing contagious disease outbreaks are animal welfare problems stemming from MR. Stegeman *et al.* (2000) urged for a solution for welfare problems under MR. Problems arise as farms get overcrowded because neither piglets can be transported to fattening farms nor slaughter pigs can be delivered at slaughterhouses. Farrowing farms are not equipped to house piglets heavier than 25 kg. On fattening farms additional problems, such as fighting, cannibalism and collapsing of the slatted floors exist as finisher pigs get overweight. The problem of overcrowded stables is of great importance for the Netherlands; especially when recalling the high amount of specialized farrowing farms and the trend towards multisite housing on farrow-to-finish farms. Enting *et al.,* (2006) showed that the premises on specialized farrowing farm are overcrowded sooner than on monosite farrow-to-finish farms and fattening farms. Still pig farmers are legally supposed to be able to buffer a standstill of 6 weeks. However, Van Lent (personal communication) stated that the current economic situation made it impossible for almost every pig farmer to reserve this buffer capacity in his stables, especially on farrowing farms. Most of them would be overcrowded from the start of the epidemic onwards and would have to seek alternative placing possibilities.

Bosman *et al.* (2012) studied the development of these piglet surpluses on farrowing farms and the effects of strategic actions to mitigate the development of piglet surpluses. They modeled the development of piglet surpluses in two types of areas, surplus and equilibrium (see glossary), under three epidemiological scenarios, small, moderate and large. The effect was studied of three strategies differing in time of relaxing and lifting MR. The included strategies were Strict, Relaxation and Early Lifting[1]. They found that applying these mitigating strategies can affect the development of piglet surpluses significantly. The effect however depends on the characteristics of the epidemics and the area affected. The duration of the epidemics and the number of infected farms and the production structure of the area affected, i.e. surplus or equilibrium, determine the outcome of the piglet surpluses. Moreover the larger the need to export piglets outside an area and the higher the degree of specialization of an area the bigger the problems will be under MR. In real-life outbreak situations it can result in large quantities of piglets, being locked on farrowing farms. The question remains if, and if so, which mitigating strategy should be chosen and at which moment during the epidemic should it be installed? For *ad hoc* answers to this question a kind of quantitative forecasting tool, estimating the development of these piglet surpluses, would be very helpful to provide guidance in this respect. Extrapolation of the actual situation under assumed epidemiological developments and economic interventions provides key information for this task. Accurate extrapolation of the actual situation will assist the decision maker in choosing the possible options that might lead to mitigation of the problems.

Aim of this study is to develop a tactical Decision Support System (DSS) to forecast possible developments of piglet surpluses in case of an outbreak of AD. Moreover this tool should allow to conduct *ex ante* evaluation of possible mitigating strategies. This should allow the development of rules of thumb of what to expect and what to undertake as a policy maker. Furthermore, the credibility of the DSS is discussed.

[1] The explanation of these strategies is included in the section Materials and Methods on page 5

2 Materials & Methods

2.1 Overview

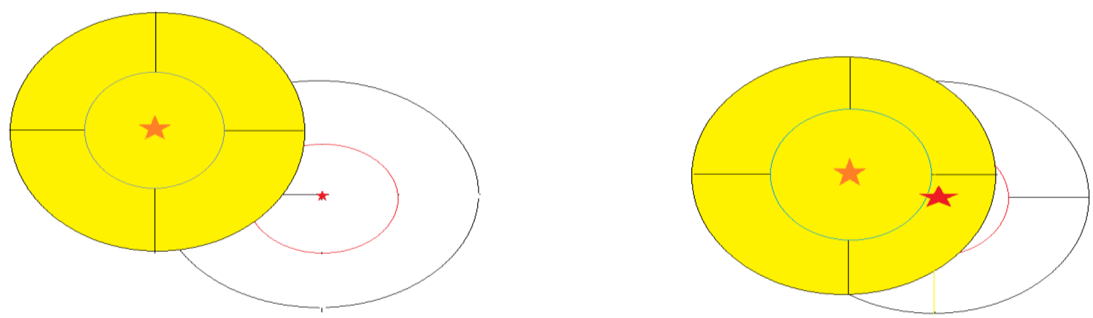
The aim is to create a useful tool for decision makers to get insight in the development of piglet surpluses in a particular area of the Netherlands, under different epidemiological scenarios. This section will describe the different elements of the DSS and how they are integrated into the DSS, i.e. the contingency plan for AD outbreaks, the possible mitigating strategies, the underlying data and model description and the protocol used to validate and verify the DSS with epidemiological input.

2.2 Contingency plan

In order to develop a DSS with high practical value for decision makers, the DSS has to consistently model the actions that would be taken in case of an AD outbreak. Therefore it was important for the development of the DSS to have a clear view on the contingency plan for AD outbreaks. The contingency plan covers all the directives and actions, taken in (pre) crisis time until the relaxing and the lifting of control measures in case of an AD outbreak. A detailed summary can be found in appendix A. Here only the major points for a clear understanding of the contingency plan and the DSS are given. Upon an outbreak of AD the following actions will be taken:

- A 72 hours national standstill to get a good impression of the spread of the virus and to trace the contacts of the detected farm.
- In 24 hours all the animals on the detected farms will be vaccinated, all the animals on farms lying in a 10 km zone around the detected farms will be vaccinated within 72 hours.
- The farms in this 10 km zone will be placed under MR for at least 4 weeks.
- The animals on the farms in the MRZ get a second vaccination, at least two weeks after the first, to assure the immunization of the animals. Neonatal piglets from sows that received two vaccinations are protected by maternal antibodies and will not be vaccinated. Piglets born from sows, having received only one vaccination, will get vaccinated at the moment the veterinarian samples blood for an endscreening of the MRZ.
- This endscreening is a serological investigation and can take place the earliest after 30 days from the first vaccination
- In case of a negative endscreening farms in the MRZ can transport piglets inside but not outside the MRZ. Slaughter pigs can again be delivered to slaughterhouses inside and outside the MRZ. . The infected detected farms will have to deliver early all its pigs, except breeding sows , to the slaughterhouse. After that these farms can start cleansing and disinfecting.
- Two weeks after the infected farms have been cleansed and disinfected, the MR can be lifted in the zone
- Subsequent detections trigger extensions of the initial MRZ if they are located further than 5 km from the initial MRZ center. In this case the procedures are initiated only for the farms in the new part of the MRZ (See figure 2.1). On the left an additional detection at more than 10 km from the initial MRZ center is shown. The yellow area includes all the farms within the 10 km radius of the MRZ center. The farms in the yellow area will be relieved from MR together with the initial MRZ center (Orange Star). Although there is an overlap with the extension of the MRZ,

the extended MRZ covers a considerable area. On the right the extension of the MRZ covers a smaller area because the detection, triggering the extension, lies closer to the initial detection.



Legenda

Orange Star: First detection and centre of initial MRZ **Red star :** Subsequent detection and centre of the extension

Blue line: 5 km area around the first detection **Yellow:** 10 km area around, all farms under the MR triggered by the first detection

Red line: 5 km area around subsequent detection **White:** 10 km area around subsequent detection , all farms under MR procedure triggered by the subsequent detection

Figure 2.1 Different scenarios for extending MRZs

2.3 Mitigating strategies programmed in the DSS

The Strict Strategy is the benchmark to which the mitigating strategies are compared. This strategy is chosen, because most likely this would lead to the largest surpluses in an MRZ. Under the strict strategy, no pig movements are allowed from the establishment of the first MRZ until the last subsequent detection is under control. Soon problems would arise on farrowing farms which are limited or not suited at all for housing piglets heavier than 25 kg. At first sight it may seem unrealistic that such measures would be installed. The contingency plan for AD allows animal movements in the MRZ under strict conditions, assuming that the vaccination effectively stops the viral spread. In case of an ineffective vaccine, the virus would continue to spread. In this case the scenario of the Strict Strategy would become very realistic. Moreover when the source of infection is not traceable or not traced yet, the Strict Strategy might be installed.

Relaxation Strategy

The Relaxation Strategy is in most cases in line with the directives in the current ruling contingency plan for AD, though with a very important deviation. The summary (Appendix A) stated that in case of the development of piglet surpluses that cannot be placed inside the subzone of the MRZ in which the MR are relaxed, they could be exported to areas with a lower AD status, i.e. article 9 or lower. The neighboring countries of the Netherlands all have the article 10 status. So other export markets have to be found. It is doubtful that instantly new export markets will be found for the total amount of surplus piglets that have to be exported. In the DSS it is assumed that when MR are relaxed in a subzone of the MRZ, the pool of locked piglets will be reduced with the cumulative availability of fattening places in that subzone of the MRZ. If this relaxed subzone of the MRZ is characterized by a surplus piglet production, the cumulative net surplus cannot be placed because transport outside the MRZ is not allowed. So this number of piglets is still locked in the subzone of the MRZ. Hence the relaxed subzone of the MRZ will still add the weekly net surplus piglet production to the total pool of locked piglets until the final lifting of the MR. This implicates that although transport is allowed in a subzone of the MRZ, the surplus of piglets in that subzone would continue to grow with the discrepancy between the weekly piglet production and weekly available fattening places in the subzone. Other important assumptions have been made for this strategy. Firstly it is assumed that there is ample slaughtering capacity to clear the fattening places in the relaxed subzone. Secondly transport capacity is not limiting to transport these slaughter pigs to the slaughterhouses and to transport the piglets from farrowing farms to fattening farms

Early Lifting Strategy

Under this strategy parts of the MRZ that are vaccinated twice and had a negative third serological inspection, would be allowed to transport piglets inside and outside the area and restock with piglets from either in or outside the MRZ. It is assumed that upon lifting of the MR first the available fattening places in the lifted subzone of the MRZ are filled. The same assumptions as for the Relaxation Strategy apply. Firstly it is assumed that there is ample slaughtering capacity. Secondly transport capacity is not limiting. Thirdly fattening farmers from outside the MRZ are willing to stock their farms with vaccinated or unvaccinated animals from inside an MRZ. Under these assumptions the piglet surpluses in the lifted subzone can be reduced to zero instantly and no more animals will be added to the total pool of surplus piglets of the entire MRZ by this subzone anymore.

Legally imposed buffer capacity

The contingency plan for classical swine fever warns pig farmers for the consequences of an outbreak. They are advised to establish buffer capacity or emergency shelter to bridge a standstill of six weeks without having to transport animals off farms (MinLNV 2007). It is interesting to find out if this buffer capacity would make a difference in the AD crisis. In the DSS the buffer capacity is incorporated with a parameter, setting the number of weeks that farms can house the locked animals without troubles. The buffer capacity of an individual farm will consist of the weekly piglet production multiplied with the number of weeks of assumed buffer capacity in the parameter. There is no assumption of whether this buffer capacity is foreseen within the existing premises or whether it concerns improvised emergency shelter.

2.4 Model description

The DSS is programmed in Microsoft Excell (Microsoft Corporation, Redmond, Washington, USA) , using the general purpose programming language Visual Basic for Excell (Microsoft Corporation, Redmond, Washington, USA) It consists of several modules, that should be initiated in a specified order. A flowchart of the different procedures in the DSS is included in appendix B. The DSS is operated from a central worksheet in the EXCELL Workbook. In this worksheet several parameters can be adjusted and the individual procedures for simulating the epidemic and the development of piglet surpluses can be executed. Parameters to be entered are:

1. MRZ radius.

2. The critical distance between the center of an MRZ and an MRZ modifying detection.
3. The sum of the two above mentioned parameters, i.e. the maximum distance between a particular farm and a Non-modifying detection, used to identify all the pig farms in the same MRZ as a Non-modifying detection.
4. The default duration of MR, being the time period in which the animals ,in the MRZ, build up immunity through vaccination and in which no animal movements are allowed. At the end of this period a screening of the MRZ is performed.
5. The extension of the time period of MR in case of a Non-modifying detection.
6. The critical time period between the detection of the MRZ centre and a Non-modifying detection, for extending the duration of MR in the current MRZ.
7. The amount of piglets, of about 25 kg, ready to be fattened, produced per average sow.
8. The turnover rate per average fattening pig.
9. Weeks per year.
10. The first week after initiating the eradication program in which MR can be relaxed or lifted.
11. Buffer capacity in weeks

Central Database

The basis of the DSS is a database containing all the 8,110 Dutch pig farms. Every physical location where pigs are kept is listed up with a unique farm number (UBN), their geographical coordinates, production type and the capacity for respectively sows, gilts, slaughter pigs and piglets. The coordinates and UBNs come from the Identification and Registration (I&R) system maintained by the commodity boards for Livestock, meat and eggs. The figures on farm capacity were taken from the Dutch system for farm registration and management (BRBS), maintained by the Dutch Animal Health Service. To update the figures, the animal places per farm have been calculated by Bosman (2012), based on the registered animal transports in I&R. From this database all information is extracted for listing up pig farms under MR and for calculations on the development of piglet surpluses.

Epidemiological Input for the DSS

The required input for the DSS consist of a list of UBNs of detected infected farms with the corresponding week index of detection. Week one is the week in which the first detection of an infected farm is made. This list should be entered chronologically in order to make the program work correctly.

Step 1: Differentiating detections into MRZ Modifying and Non-Modifying detections

The first step in the flowchart (Appendix B) is to classify this list of UBNs into MRZ centers and Non-modifying detections. Detections in week one are automatically designated as MRZ centers. The classification for a particular detection, after week one, is done by calculating the Pythagorean distance between this detection and the previous MRZ centers in the list. Only if the week of detection differs between the previous MRZ centers and the current detection the distance is calculated. Distances between newly detected farms in the same week are not calculated. If the smallest of these distances is larger than or equal to the critical distance for extending the MRZ, the detection is designated as an MRZ centre. If not, the detection is designated as a Non-modifying detection by the UBN of the closest MRZ centre. A summary is made of the number of MRZ centers per week. This summary is used to design the worksheet in which the establishment of the MRZs is simulated. The tool calculates on a weekly basis. Therefore detections are only evaluated with centers from previous weeks.

Step 2: Indicating the UBNs under MR and determining the week of relaxing or (Early) lifting of MR

The summary of the MRZ centers is used to design the worksheet in which the extensions of the MRZs under the current epidemic are simulated. All the UBNs and their figures are imported from the central database. Each MRZ centre gets its own column in the sheet. Based on the Pythagorean distances between the corresponding coordinates, each of the 8,110 UBNs gets indicated with a 1 or 0, whether it falls within the preset radius around the MRZ centre in the current column.

The next procedure in the flowchart simulates the week in which relaxing or lifting of MR can apply to a UBN under MR. It uses a modified approach of the MRZ extending simulation. In this procedure also the Non-modifying detections get a column in the sheet. A 0,1 indication is used to indicate whether a UBN belongs to an MRZ associated with the centre in the current column. A 2 is used to indicate that a UBN lies in the same MRZ as the Non-modifying detection in the current column. In this procedure a UBN, can only be designated to one MRZ, i.e. from the moment it gets its first 1 it cannot get another . This way the DSS stays close to the contingency plan of the PVE. The overlapping part of an extended MRZ, keeps on following the MR procedure triggered by the earlier MRZ centre (figure 2.1). The next step in the procedure converts the indicators 1 and 2 into an index of the week in which a tactical decision can apply to the UBN. Each UBN now has a row with indicators. The procedure runs through each of these rows. When it encounters a 1 it adds the preset default duration of MR to the week index of detection of the associated MRZ centre.

When it encounters a 2 the situation is more complex. As the contingency plan did not specify the effect of a Non-modifying detection on the duration of MR, assumptions had to be made. The rationale is that upon establishing an MRZ, it is likely that Non-modifying detections will occur in the first weeks after the establishment. The incubation period of AD can range between three and 11 days (Animal Health Australia, 2009). So it is assumed that if Non-modifying detections occur in two weeks after the establishment of the MRZ, the duration of the MR in the zone will not be prolonged. If they occur in week three or later of the MR, the duration would be prolonged to check the area around these detections for further viral spread. As these are assumptions, they were built into the procedure in a way that the critical moment for prolongation and the prolonged duration can be varied in the simulations. For the sake of generalizability the procedure can cope with multiple separate MR periods per UBN. To simulate the Strict Strategy, the parameter ten, the indicator of the first week to start a mitigating strategy, is set at the last week of MR of the epidemic. This way every farm is released from MR at the end of the MR period triggered by the last detection.

Step 3: Creating Zone Codes

The next procedure creates zone codes for every UBN, dealing with MR , based on the info from the previous procedure. As the previous procedure can produce two separate MR periods for a UBN, they receive 2 codes. The codes consist of the week index in which the UBN got under MR, the week index in which the MR of a UBN can be relaxed or early lifted, and the detection index number of the MRZ centre or the Non-modifying detection that will determine the moment of application of a tactical decision. If a UBN has only one period of MR, the second code is 0_0_0.

Step 4: Calculations on piglet surpluses, placing possibilities and export need

The zone coding is used to filter the UBNs, dealing with MR, from the central database into a result sheet. For every UBN in the sheet the weekly piglet production and weekly availability of fattening places are calculated. The difference between these two figures is defined to be the farm net surplus. These calculations are based on the info from the central database on farm capacity and average production parameters (KWIN, 2009), using the following equations.

$$\text{weekly piglet production per farm} = \frac{\text{number of sows} * \text{annual amount of piglets per average sow}}{\text{weeks per year}} \qquad (1)$$

$$\text{weekly farm stocking of fattening pigs} = \frac{\text{number of fattening places} * \text{turnover rate for average fattening pig}}{\text{weeks per year}} \qquad (2)$$

$$\text{weekly farm net surplus} = \text{weekly farm piglet production} - \text{weekly farm availability of fattening places} \qquad (3)$$

It is assumed that restocking of fattening farms proceeds at a rate equal to the delivery rate of slaughter pigs to the slaughterhouse. Furthermore, it is assumed that each produced piglet ends up as slaughter pig. The procedure goes through the list of UBNs and performs calculations for every week in the epidemic. Table 2.1 summarizes the calculated variables. For each farm the cumulative figure of piglet production, availability of fattening places and the net surplus piglet production is calculated. These farm level figures are summed to get the weekly figures for the entire MRZ. Two sets of variables are calculated. One set describes the evolution of the production in the entire MRZ, i.e. all the farms that are and were under MR. The other set of variables describes the production on those farms that are still under MR and cannot transport animals. When dealing with the Strict Strategy these two sets will not differ from each other. Dealing with the mitigating strategies, these sets allow to monitor the developments in the entire area that dealt with MR and the developments in the subzones that are still under MR. These figures are used in calculating the pool of locked piglets on farrowing farms. These figures are also used to calculate the amount of piglets that can be placed inside the relaxed or lifted subzones and the need for export when relaxing or early lifting of MR takes place.

To simulate the vaccine status of the piglets the approach of Bosman (2012) is used. On a farm under MR, the last piglets are vaccinated in week three of the MR. It takes on average 10 weeks to get the piglets to the desired weight of 25 kg. So a farm, struck by MR, will supply unvaccinated piglets from week 13 after the establishment of MR onwards.

Table 2.1 Variables calculated by the DSS

Variables describing the entire MRZ		
Variable	**Farm Level**	**MRZ level**
Weekly Piglet production	+	+
Weekly (un)vaccinated piglet production	+	+
Weekly availability of fattening places	+	+
Weekly net surplus piglet production	+	+

Cumulative piglet production	+	+
Cumulative (un)vaccinated piglet production	+	+
Cumulative availability of fattening places	+	+
Cumulative farm net surplus	+	+
Number of locked piglets on MRZ farms	-	+
Variables describing the subzone of the MRZ, that is still under MR		
Variable	**Farm Level**	**MRZ level**
Weekly Piglet production	+	+
Weekly Availability of fattening places	+	+
Weekly net surplus piglet production	+	+
Cumulative piglet production	+	+
Cumulative availability of fattening places	+	+
Cumulative net surplus piglet production	+	+

At this point in the flowchart the effect of the mitigating strategies comes in. Two procedures have been developed. One to perform calculations under the Early Lifting and Strict Strategy and one for the Relaxation Strategy.

Calculations for the Strict Strategy

Under the Strict Strategy, no transports take place during the total duration of MR in an area. The piglet surplus for the MRZ is then equivalent to the on-farm cumulative piglet production, summed for all the farms in the MRZ. The part of the surplus to be exported equals the cumulative discrepancy between the weekly piglet production in the MRZ and the weekly availability of fattening places in the MRZ, i.e. the cumulative net surplus of the MRZ. The number of piglets that can be placed inside the MRZ upon lifting MR equals the difference between the locked piglets and the export need. Also the exceeded buffer capacity is calculated. The buffer capacity is a parameter expressed in weeks. The following equations are used:

$$\text{Number of locked piglets} = \sum_{i=1}^{n}\sum_{j=1}^{w} \text{piglet production (i, j)} \qquad (4)$$

Where:

- I= farm index
- j= the week index
- n= the amount of farms in the MRZ in week w.

$$\text{Export need w} = \sum_{i=1}^{n}\sum_{j=1}^{w} \text{net farm surplus (i, j)} \qquad (5)$$

Where:

- I= farm index
- j= the week index
- n= the amount of farms in the MRZ in week w.

$$\text{Exceeded buffer capacity (i, j)} = \text{cumulative piglet production (i, j)} - \text{buffer capacity} * \text{weekly production i} \quad (6)$$

Where:

- I= farm index
- j= the week index
- buffer capacity expressed in weeks

Calculations for the Early Lifting Strategy

Under the Early Lifting Strategy, the piglet surplus consists of the cumulative weekly piglet production of the farms which cannot transport animals. The procedure for calculations under the Early Lifting Strategy, has a special variable, presenting the number of releasable piglets in week w, in the pool of locked piglets. The amount to be exported in week w from this releasable piglets is calculated in a similar way. The calculation on the exceeded buffer capacity is done is the same way as for the Strict Strategy. The following equations are used:

$$\text{Number of locked piglets w} = \sum_{i=1}^{n}\sum_{j=1}^{w}(\text{piglet production}|\text{Start MR i} \leq \text{w} < \textit{End MR i})(\text{i, j}) \quad (7)$$

Where:

- I= farm index
- j= the week index
- n= the amount of farms in the MRZ in week w.

$$\text{Releasable piglets w} = (\text{End MR i} - \text{Start MR i})\sum_{i=1}^{n}(\text{weekly piglet production i }|\text{w} = \text{End MR i}) \quad (8)$$

Where:

- I= farm index
- n= the amount of farms in the MRZ in week w.

$$\text{Export need w} = (\text{End MR i} - \text{Start MR i})\sum_{i=1}^{n}(\text{weekly farm net surplus i }|\text{w} = \text{End MR i}) \quad (9)$$

Where:

- I= farm index
- n= the amount of farms in the MRZ in week w.
-

$$\text{Exceeded buffer capacity (i, j)} = \text{cumulative piglet production (i, j)} - \text{buffer capacity} * \text{weekly production i} \quad (10)$$

Where:

- I= farm index
- j= the week index
- buffer capacity expressed in weeks

Calculations for the Relaxation Strategy

Calculating the same figures under the Relaxation Strategy proceeds somewhat different. It is assumed that upon relaxing a subzone of the MR, only the available fattening places in the MRZ are filled. No export to article 9 or lower would occur. So the cumulated weekly net surplus piglet production remains on farms in the MRZ. Upon lifting of MR, the part of the total surplus that has to be exported outside the MRZ is calculated for the Relaxation Strategy in the same way as for the Strict Strategy. It is important to notice that these numbers of export need, are not exported during the MR. These animals are exported at the end of the MR The following equations are used:

$$\text{Number of locked piglets w} = (\textstyle\sum_{i=1}^{n}(\text{ cumulative piglet production w} \mid \text{Start MR i} \leq w < End\ MR\text{i}) + (\textstyle\sum_{i=1}^{n}(\text{ cumulative net farm surplus (i, w)}) - \textstyle\sum_{i=1}^{n}(\text{ cumulative net farm surplus (i, w)} \mid \text{Start MRi} \leq w < End\ MR\text{i})) \quad (11)$$

Where:

- I= farm index
- w= the week index

$$\text{Export need w} = \sum_{j=1}^{w}\sum_{i=1}^{n} \text{net farm surplus (i, w)} \quad (12)$$

Where:

- I= farm index
- j= the week index
- n= the amount of farms in the MRZ in week w.

The calculation on the exceeded buffer capacity under the Relaxation Strategy is also more complex because the amount of surplus piglet production of the relaxed part of the MRZ has to be taken into account. These piglets should be but cannot be exported. As these piglets cannot leave the MRZ, they keep on being locked in the relaxed part of the MRZ until the MR are lifted at the end. A distribution of these piglets among farms with a positive net farm surplus has to be assumed. For each farm with a positive net farm surplus the procedure calculates the fraction of the total positive net surplus of the relaxed part that is contributed by the farm in question. This farm will receive the same fraction of the total net surplus of the relaxed part to be subtracted from its buffer capacity.

$$\text{percentage} + \text{surplus i} = \frac{(\text{farm net surplus} |>0)\text{i}}{(\text{total}+\text{net surplus of relaxed part})} \quad (13)$$

where:

- i= farm index of the farms in the relaxed part of the MRZ.

$$\text{Exceeded buffer capacity (i, j)} = \text{percentage} + \text{surplus i} * \text{cumulative net surplus of Relaxed part of MRZ j} \quad (14)$$

Where:

- i = farm index of the farms in the relaxed part of the MRZ
- j= week index.

2.5 Simulation approach

The simulation of AD outbreaks was done based on Interspread Plus (ISP) output produced by Bosman (2012). Table 2.2 shows some characteristics of the index farms and the area in which they are located. The index farms are located in three different areas. Index farms 1 and 3 are located in a densely populated livestock area (DPLA). Index farm 1 is located in an area with large discrepancy between the weekly piglet production and the availability for fattening places. This will be further designated as a DPLA with surplus piglet production (DPLA+). The goal was to model also a DPLA in which the weekly piglet production would match the weekly availability of fattening places. Such an area does not exist in the Netherlands so an area with a minimal surplus piglet production was chosen. This is further designated as a DPLA with equilibrium piglet production (DPLAeq).

Farm number 2 is located in a sparsely populated livestock area (SPLA). Again it was decided to model an area with a higher piglet production than the availability for fattening places. This area will be designated as a SPLA+. At first also farms of a higher biosecurity status (Type A), were selected as index farms. According to the Dutch regulation for pig deliveries (VVL), these farms have more possibilities for delivering piglets to other farms. It turned out that there was no indication for an effect of A status on the epidemiological development of an outbreak. Therefore it was decided to take only B farms as index farms, as they are far more numerous than A farms in the Netherlands.

Table 2.2 Characteristics of the index farms and their surrounding area for ISP input

Index farm specific								Area specific				
Nr.	XCO	YCO	Type	Sows	Gilts	Slaughter pigs	Piglets	Farms	Piglet production	Slaughter pig stocking	Surplus	Ratio
				(places)	(places)	(places)	(places)		(per week)	(per week)	(per week)	
1	176,6	406,6	B	1001	0	1	5726	406	37838	22839	14999	1.66
2	218,9	566,9	B	822	82	63	4662	33	1921	1297	623	1.48
3	244,7	470,9	B	326	75	2053	580	244	10664	9545	1119	1.12

From the ISP output specific iterations were chosen to serve as input for the DSS. The timeframe of this study did not allow to run all the iterations in the DSS. So it was impossible to sort the iterations on objectively measurable criteria, like duration or amount of detected farms, and to consequently mark the 5%, 50% and 95% percentiles. For each area iterations representing a small, moderate and large outbreak were selected. A small outbreak was defined to be a detection of the index farm and no more. The MR would last for only the preset duration of MR, being five weeks. A moderate outbreak would be one in which more than one farm would get detected in week one. Consequently a larger area would get struck by MR. Moreover an additional detection would take place in week three or four, so that the MR would be prolonged in a part of the MRZ. Lastly a large outbreak would be characterized by several detections in week one followed by additional detections in the following weeks. In this case extensions of the initial MRZ would be modeled next to prolonged MR in subzones of the MRZ. The applied epidemiological scenarios are presented in table 2.3. The first column describes the area in which the outbreak takes place. The second column designates the size of the outbreak. The third column gives the week index. In the fourth column the number of detections in the corresponding week is given. Column five shows the largest distance between the index farm and one of the detections in the corresponding week. Lastly columns seven and eight describe whether the detections in a particular week trigger an extension of the MRZ or a prolonged duration of MR in a subzone of the MR.

Table 2.3 Epidemiological scenarios for evaluating the credibility of the DSS

Area	Outbreak	Week	Number of Detections per week	Maximal distance from Index (km)	Cumulative number of detections	Extension of MRZ	Prolongation of MR in subzone
SPLA+	Small	1	1	0,0	1	-	-
	Moderate	1	3	7,5	3	-	-
	Large	1	1	0,0	1	-	-
		4	2	10,6	3	X	-
DPLA+	Small	1	1	0,0	1	-	-
	Moderate	1	5	7,3	5	-	-
		3	1	6,9	6	-	X
	Large	1	7	2,8	7	-	-
		3	4	2,7	11	-	-
		4	2	15,6	13	X	-
		6	1	13,3	14	-	X
DPLAeq	Small	1	1	0,0	1	-	-
	Moderate	1	4	6,5	4	-	-
		3	1	6,3	5	-	X
	Large	1	11	4,4	11	-	-
		3	2	1,6	13	-	X
		4	4	21,7	17	X	-
		5	1	21,7	18	-	X
		6	1	21,2	19	-	X

For the three index farms iterations representing small, moderate and large outbreaks were selected and simulated with the DSS. These outbreak were then simulated under the three different mitigating strategies and for two values of buffer capacity (2 & 6 weeks). The simulation approach is summarized in figure 2.2.

Epidemic

-Density * Epidemic	• **DPLA+** • **DPLA-/0** • **SPLA+**	• **Small outbreak** • **Moderate outbreak** • **Large Outbreak**

Economic Measures

-Default **-Alternatives**	• **Strict** • **Relaxation** • **Early lifting**
-Buffer capacity	• **2 weeks** • **6 weeks**

Figure 2.2 Simulation Protocol

3 Results

3.1 Results for a SPLA+

The results of the simulated outbreaks in the SPLA+ are easy to understand and are suited for explaining the format by which all the results are presented in this report.

Results small outbreak SPLA+

Table 3.1 represents the results for a small outbreak in a SPLA+. The second column represents the piglet production in the MRZ for the corresponding week, mentioned in the first column. A cumulative figure of this weekly production is given in column three. The same is done for the net surplus in the MRZ, given in columns four and five. This table deals with an outbreak in which only one farm gets detected and the MR last for five weeks (Table 2.3). No extensions of the MRZ or prolonged duration of MR for a part of the MRZ occur. This can be deducted from column two, the production in the MRZ remains constant through the epidemic. Column six shows the size of the pool of piglets of 25 kg and heavier which are locked on farrowing farms due to MR. This figure increases through the weeks of MR and drops to zero in the week of lifting of MR. In this situation this figure is exactly the same as the cumulative production in the MRZ. When mitigating strategies are modeled this will no longer be true. Columns seven and eight differentiate the number of piglets that get released from farms that were previously under MR into a number of piglets that can be placed inside the MRZ and into a number that has to be exported to fattening farms outside the MRZ. In week six 9,600 piglets will come onto the market *in addition to* the normal weekly domestic supply of piglets. Of these 9,600 piglets 6,300 can be placed on a fattening farm inside the former MRZ, 3,300 piglets will have to be placed on fattening farms outside the MRZ or in article 9 or lower. Columns nine and ten show the numbers of piglets which exceed the buffer capacity. These amount are a part of the number of locked piglets (column six) and represent the amount of animals that are present on top of the assumed buffer capacity in the farms. In essence in column nine farmers are only prepared to overcome a standstill of two weeks, from week three onwards farmers will have to seek alternative housing possibilities for these piglets. The most important figures are represented in bold. A visual representation of the number of locked piglets (red bar), the placing possibilities inside the MRZ (green bar), the export need (purple bar) and the exceeded buffer capacities (resp. black mark two weeks, yellow mark six weeks) is given in figure 3.1. A map of the MRZ is shown in Appendix D. The farms under MR are designated with green dots and the detected farm is designated with a red star (figure D.1).

Table 3.1 Small outbreak in a SPLA + under default measures (numbers are in thousands)

Week	Production	Cumulative production	Net surplus	**Cumulative net surplus**	**Locked piglets**	**Released piglets**		Exceeded buffer capacity	
						Place inside MRZ	**Export Need**	2 weeks	6 weeks
1	1.9	1.9	0.7	**0.7**	**1.9**	**0.0**	**0.0**	0.0	0.0
2	1.9	3.8	0.7	**1.3**	**3.8**	**0.0**	**0.0**	0.0	0.0
3	1.9	5.8	0.7	**2.0**	**5.8**	**0.0**	**0.0**	1.9	0.0
4	1.9	7.7	0.7	**2.6**	**7.7**	**0.0**	**0.0**	3.8	0.0
5	1.9	9.6	0.7	**3.3**	**9.6**	**0.0**	**0.0**	5.8	0.0
6	-	-	-	**-**	**0.0**	**6.3**	**3.3**	-	-

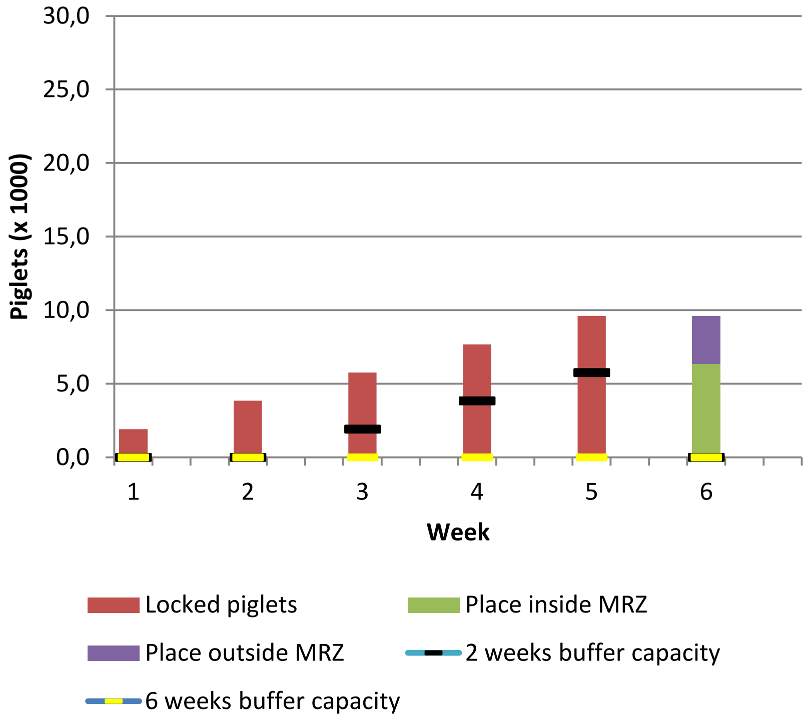


Figure 3.1 Small outbreak in SPLA+ under default measures

Table C.1 in appendix C shows the results of a moderate outbreak in the SPLA+. The understanding is the same as for table 3.1. The numbers are larger because the MRZ considered covers a larger area due to several detections in week one (Table 2.3).

Results Large outbreak SPLA+

In the large outbreak two farms get detected in week four in addition to the index farm in week one. From table 2.3 it can be read that these additional detections trigger an extension of the MRZ in week four. Figure D.2 presents a map of the outbreak, showing the farms struck by MR and the detected farms. The farms have different colored dots designating the start and end of MR. Now the different mitigating strategies will show their impact. Table 3.2 represents what happens under the Strict Strategy. In week one an MRZ is established with a weekly production of 1,900 piglets. In week four this zone is extended to become a zone with a total weekly production of 2,700 piglets. The farms from the initial MRZ keep on being locked together with those in the extension of the MRZ until this extension triggers the lifting of the MR in week 9.

Table 3.2 Large outbreak in a SPLA+ under the Strict Strategy (numbers are in thousands)

Week	Production	Cumulative production	Net surplus	**Cumulative net surplus**	**Locked piglets**	**Released piglets**		Exceeded buffer capacity	
						Place inside MRZ	**Export Need**	2 weeks	6 weeks
1	1.9	1.9	0.7	**0.7**	**1.9**	**0.0**	**0.0**	0.0	0.0
2	1.9	3.8	0.7	**1.3**	**3.8**	**0.0**	**0.0**	0.0	0.0
3	1.9	5.8	0.7	**2.0**	**5.8**	**0.0**	**0.0**	1.9	0.0
4	2.7	8.4	1.1	**3.1**	**8.4**	**0.0**	**0.0**	3.8	0.0
5	2.7	11.1	1.1	**4.2**	**11.1**	**0.0**	**0.0**	5.8	0.0
6	2.7	13.8	1.1	**5.4**	**13.8**	**0.0**	**0.0**	8.4	0.0
7	2.7	16.5	1.1	**6.5**	**16.5**	**0.0**	**0.0**	11.1	1.9
8	2.7	19.1	1.1	**7.7**	**19.1**	**0.0**	**0.0**	13.8	3.8
9	-	-	-	-	**0.0**	**11.5**	**7.7**	-	-

The extension increases the net surplus of the MRZ up to 11 100 piglets per week. At the end of the MRZ the pool of locked piglets amounts 19 100 piglets of which 11 500 have to be placed in the MRZ and 7700 have to be exported. The legally mandatory buffer capacity of six weeks is no longer sufficient to provide housing for all the piglets.

Looking at the results for the same outbreak but under the Relaxation Strategy some striking differences come forward. First the extension of the MRZ in week four is visible (Table 2.3; Table 3.3). In week six the relaxing of MR in a subzone of the MRZ takes place, the production on farms under MR decreases to 800 piglets per week (Table 3.3). From week six onwards the figure of locked piglets is no longer equal to the cumulative production of farms under MR. This difference stems from the surplus production on the farms in the relaxed subzone that cannot be placed outside the MRZ. The effect of relaxing a subzone of the MRZ is shown in week six, the amount of locked piglets drops from 11,100 to 6,200 piglets. In week six this pool is lowered with 6,300 piglets that can be placed on fattening farms in the MRZ. But 800 piglets, produced in week six on farms in the MRZ, are added next to 700 surplus produced piglets in the relaxed subzone. This results in a pool of about 6,200 piglets in week six. At the end only 9,000 piglets are added to the market of which 1,300 find a place in the MRZ. From week nine piglets can again be transported outside the area, resulting in the same amount of piglets that have to be exported as in the Strict Strategy. Troubles arise when buffer capacity for only two weeks is foreseen. No large problems arise when the farms are capable of providing six weeks buffer capacity.

Table 3.3 Large outbreak in a SPLA+ under the Relaxation Strategy (numbers are in thousands)

Week	Production	Cumulative production	**Net surplus	Cumulative net surplus	**Locked piglets**	**Released piglets**		Exceeded buffer capacity	
						Place inside MRZ	***Export Need**	2 weeks	6 weeks
1	1.9	1.9	0.7	0.7	**1.9**	**0.0**	**0.0**	0.0	0.0
2	1.9	3.8	0.7	1.3	**3.8**	**0.0**	**0.0**	0.0	0.0
3	1.9	5.8	0.7	2.0	**5.8**	**0.0**	**0.0**	1.9	0.0
4	2.7	8.4	1.1	3.1	**8.4**	**0.0**	**0.0**	4.0	0.0
5	2.7	11.1	1.1	4.2	**11.1**	**0.0**	**0.0**	5.9	0.0
6	0.8	2.3	1.1	5.4	**6.2**	**6.3**	**3.3**	1.6	0.1
7	0.8	3.0	1.1	6.5	**7.6**	**0.0**	**0.0**	2.9	0.1
8	0.8	3.8	1.1	7.7	**9.0**	**0.0**	**0.0**	4.2	0.1
9	-	-	-	-	**0.0**	**1.3**	**7.7**	-	-

*Part of the MRZ is allowed to transport animals again, this figures represents the part of the transportable animals, that theoretically should be exported.
Under the Relaxation Strategy this can only take place at the end of the MR.
** The net surplus is shown for the total area that was struck by MR, i.e. the net surplus of the relaxed part of the MRZ is still included in the figure

The Early Lifting Strategy has a more profound effect than the Relaxation Strategy (Table 3.4). The same pattern of expansion and reduction of the MRZ is visible in the production figure. Again the figure of locked piglets equals the amount of cumulative production of the farms that are still under MR. This figures rises to the same maximum of 11,100 piglets as under the Relaxation Strategy. But thereafter it drops to a lower level because piglets can also be exported outside the MRZ. So the pool is lowered with 9,600 piglets in week six. Thereafter it does not increase that much anymore in comparison to the developments under the Relaxation Strategy. The reason again is that piglets can be exported outside the MRZ, so the surplus production in the early lifted subzone has no effect on the pool of locked piglets anymore after the early lifting of MR. The growth of the pool of locked piglets, after early lifting of a subzone, is lower compared to the situation under Relaxation, due to the early export possibilities. This aspect of Early Lifting is the main advantage over Relaxation. At the end of the MR less piglets have to be instantly exported outside the MRZ.

Table 3.4 Large outbreak in a SPLA+ under the Early Lifting Strategy (numbers are in thousands)

Week	Production	Cumulative production	**Net surplus	Cumulative net surplus	**Locked piglets**	**Released piglets**		Exceeded buffer capacity	
						Place inside MRZ	***Export Need**	2 weeks	6 weeks
1	1.9	1.9	0.7	0.7	**1.9**	**0.0**	**0.0**	0.0	0.0
2	1.9	3.8	0.7	1.3	**3.8**	**0.0**	**0.0**	0.0	0.0
3	1.9	5.8	0.7	2.0	**5.8**	**0.0**	**0.0**	1.9	0.0
4	2.7	8.4	1.1	3.1	**8.4**	**0.0**	**0.0**	3.8	0.0
5	2.7	11.1	1.1	4.2	**11.1**	**0.0**	**0.0**	5.8	0.0
6	0.8	2.3	0.5	1.5	**2.3**	**6.3**	**3.3**	0.8	0.0
7	0.8	3.0	0.5	2.0	**3.0**	**0.0**	**0.0**	1.5	0.0
8	0.8	3.8	0.5	2.4	**3.8**	**0.0**	**0.0**	2.3	0.0
9	-	-	-	-	**0**	**1.4**	**2.4**	-	-

* Piglets can be transported outside the MRZ from the farms that were struck by MR in week 1

** Only the net surplus of the farms under MR are shown, i.e. the surplus of the farms of the early lifted part is no longer included from week 6

It shows that the Relaxation Strategy holds the middle between the Early Lifting and the Strict strategy. At the end, under relaxation the same amount of piglets has to be exported as under the Strict Strategy and the same amount of piglets has to be placed inside the MRZ as under the Early Lifting.

Figure 3.2 suits well for a visual comparison of the three simulated strategies. In the first graph it is clear that under the Strict Strategy the pool of locked piglets grows steadily until week 9 (red bars). Under Relaxation a drop of this figure is visible in week six, thereafter it increases again. A larger drop is also visible under Early Lifting, but the increase after week six is far smaller than under Relaxation. In week nine the difference in the export need for Early Lifting and Relaxation is clearly visible. The results of the other areas will mainly be presented and discussed, based on these graphs. From top to bottom the Strict Strategy, Relaxation and Early lifting is presented. The information shown, contains the figure of the amount of locked piglets on farms under MR (red bar), in green the amount of animals that can be placed inside the MRZ upon relaxing or (Early) lifting of MR and in purple the need for export from the MRZ. In addition the amounts of piglets in excess of the buffer capacity are shown. The black line marks the excess of the two weeks buffer capacity and the yellow one marks the excess of the six weeks buffer capacity.

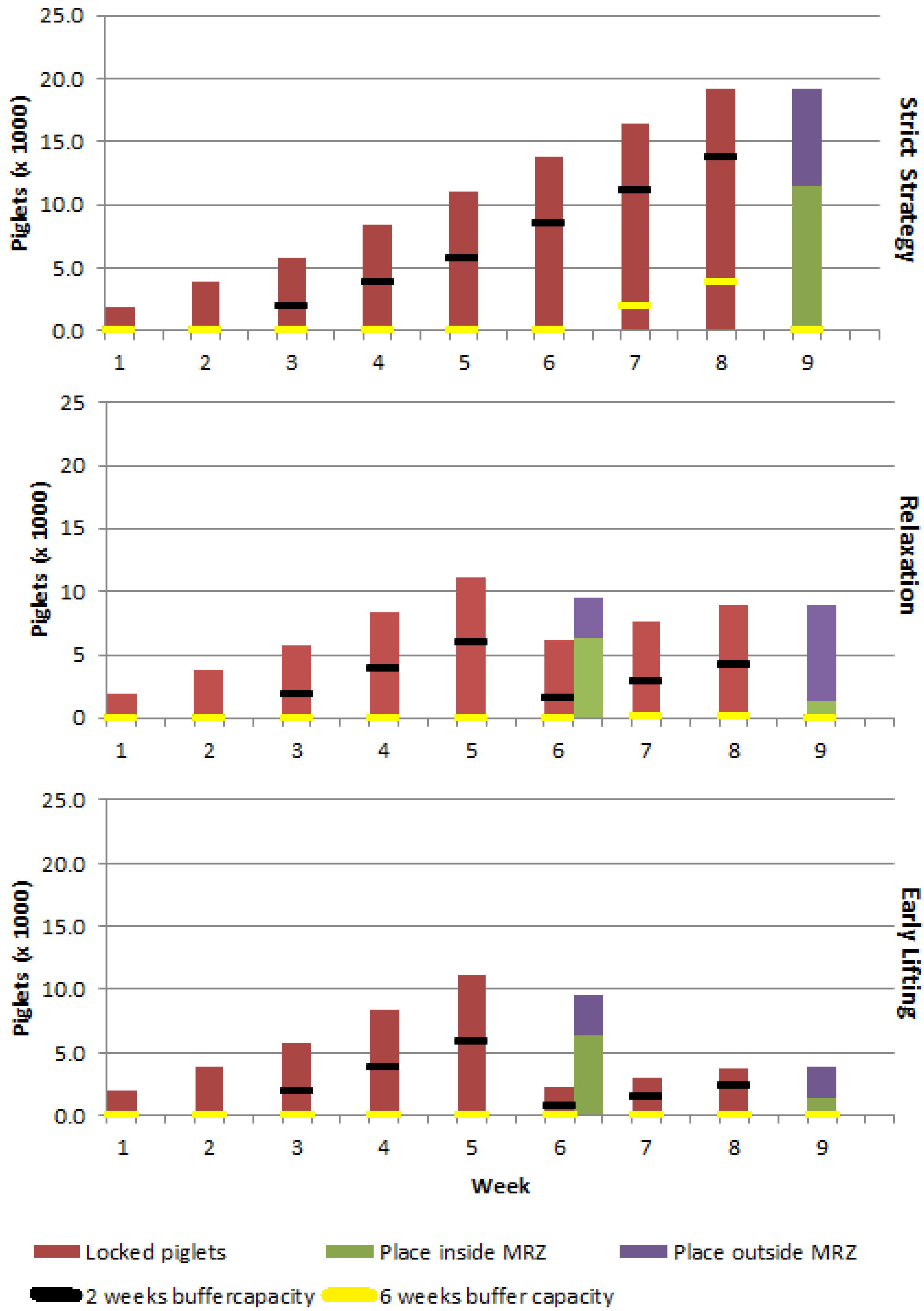


Figure 3.2 Outcome of a large outbreak in a SPLA+ under three strategies

3.2 Results for the DPLA+

Results small outbreak DPLA+

In table 3.5 the results for a small outbreak in a DPLA+ are presented. Only the index farm gets detected. No extensions and or prolongation of MR in subzones occur (Table 2.3). Figure D.3 presents a map of this outbreak. It is clear that the numbers are far higher than for the SPLA+. Moreover the high surplus piglet production of the area creates a high need for export at the end of MR. Large problems will arise if only two weeks of buffer capacity is available in the MRZ.

Table 3.5 Small outbreak in a DPLA+ under default measures (numbers are in thousands)

Week	Production	Cumulative production	Net surplus	Cumulative net surplus	**Locked piglets**	**Released piglets**		Exceeded buffer capacity	
						Place inside MRZ	**Export Need**	2 weeks	6 weeks
1	37.8	37.8	15.5	15.5	**37.8**	**0.0**	**0.0**	0.0	0.0
2	37.8	75.7	15.5	31.0	**75.7**	**0.0**	**0.0**	0.0	0.0
3	37.8	113.5	15.5	46.5	**113.5**	**0.0**	**0.0**	37.8	0.0
4	37.8	151.4	15.5	62.0	**151.4**	**0.0**	**0.0**	75.7	0.0
5	37.8	189.2	15.5	77.5	**189.2**	**0.0**	**0.0**	113.5	0.0
6	0.0	0.0	0.0	0.0	**0.0**	**111.7**	**77.5**	0.0	0.0

Results moderate outbreak DPLA+

Table 3.6 shows the results of the moderate outbreak in the DPLA+. The details of the outbreak can be found in Table 2.3. A large MRZ is established with a maximal production of 52,800 piglets per week. The detected farms lie at a considerable distance from the index farm, therefore the MRZ is considerably larger than in the small outbreak. From Tables C.2 and C.3 in appendix C and Figure D.4 it is clear that only a small number of farms can be Relaxed or Early Lifted in week six. The impact of relaxing or lifting the MR on these farms is very small on the total figures of the outbreak. That is the reason why the mitigating strategies, Relaxation and Early Lifting, are of little use in this case. The large impact of the course of the epidemics on the effect of the mitigating strategies is clearly visible in Figure 3.3. The graphs on the left, displaying the moderate outbreak, are almost identical for each strategy.

Table 3.6 Moderate outbreak in a DPLA+ under the Strict Strategy (numbers are in thousands)

Week	Production	Cumulative production	Net surplus	Cumulative net surplus	Locked piglets	Released piglets		Exceeded buffer capacity	
						Place inside MRZ	Export Need	2 weeks	6 weeks
1	52.8	52.8	21.7	21.7	52.8	0.0	0.0	0.0	0.0
2	52.8	105.7	21.7	43.4	105.7	0.0	0.0	0.0	0.0
3	52.8	158.5	21.7	65.1	158.5	0.0	0.0	52.8	0.0
4	52.8	211.3	21.7	86.8	211.3	0.0	0.0	105.7	0.0
5	52.8	264.1	21.7	108.5	264.1	0.0	0.0	158.5	0.0
6	52.8	317.0	21.7	130.2	317.0	0.0	0.0	211.3	0.0

7	52.8	369.8	21.7	151.9	369.8	0.0	0.0	264.1	52.8
8	0.0	0.0	0.0	0.0	0.0	217.9	151.9	0.0	0.0

Results large outbreak DPLA+

Table 3.7 presents the results for the large outbreak in a DPLA+. In the large outbreak additional detections extend the MRZ in weeks four and six to an area covering a weekly production of ultimately 76,700 piglets. The details of the outbreak are given in Table 3.2. Tables C.4 and C.5. in appendix C also show the extension and the reduction of the MRZ under Relaxation and Early Lifting. Under the Strict Strategy 647,100 piglets reach the market in addition to the weekly domestic piglet production. 269,600 piglets have to be exported outside the MRZ. Applying the mitigating strategies in this outbreak certainly can lower the amount of locked piglets (see graphs on the right in Figure 3.3). Due to the mitigating strategies the locked piglets are released and supplied to the market in a more gradual way. When applying Relaxation the number of locked piglets reaches its highest value of 263,600 in week five. In week six it drops to 190,600 due to relaxing of the first subzone. From week six it grows again to 294,100 until it drops to 254,100 when relaxing the second subzone in week nine. Finally in week 11, 290,500 piglets have to be placed of which 269,600 have to be exported outside the MRZ. Again, Early lifting has a larger mitigating effect, due to the early export of piglets. The number of locked piglets drops to 79,400 in week six and to 40,500 in week nine as subzones are early lifted. Moreover these subzones do not add piglets to the number of locked piglets anymore after the early lifting. At the end of the MR the least animals have to be placed under Early Lifting. Compared to Relaxation, only a little amount has to be exported. Under the two mitigating strategies the six week buffer capacity suffices to prevent serious problems with housing the animals during this epidemic. Capacity for two weeks is not enough. Again under Early Lifting the problems are less than under Relaxation.

Table 3.7 Large outbreak in a DPLA+ under the Strict Strategy (numbers are in thousands)

Strict									
Week	Production	Cumulative production	Net surplus	Cumulative net surplus	**Locked piglets**	**Released piglets**		Exceeded buffer capacity	
						Place inside MRZ	**Export Need**	2 weeks	6 weeks
1	43.5	43.5	18.5	18.5	**43.5**	**0.0**	**0.0**	0.0	0.0
2	43.5	87.0	18.5	37.1	**87.0**	**0.0**	**0.0**	0.0	0.0
3	43.5	130.5	18.5	55.6	**130.5**	**0.0**	**0.0**	43.5	0.0
4	66.6	197.0	26.3	81.9	**197.0**	**0.0**	**0.0**	87.0	0.0
5	66.6	263.6	26.3	108.3	**263.6**	**0.0**	**0.0**	130.5	0.0
6	76.7	340.3	32.3	140.5	**340.3**	**0.0**	**0.0**	197.0	0.0
7	76.7	417.0	32.3	172.8	**417.0**	**0.0**	**0.0**	263.6	43.5
8	76.7	493.7	32.3	205.1	**493.7**	**0.0**	**0.0**	340.3	87.0
9	76.7	570.4	32.3	237.3	**570.4**	**0.0**	**0.0**	417.0	130.5
10	76.7	647.1	32.3	269.6	**647.1**	**0.0**	**0.0**	493.7	197.0
11	-	-	-	-	**0.0**	**377.5**	**269.6**	-	-

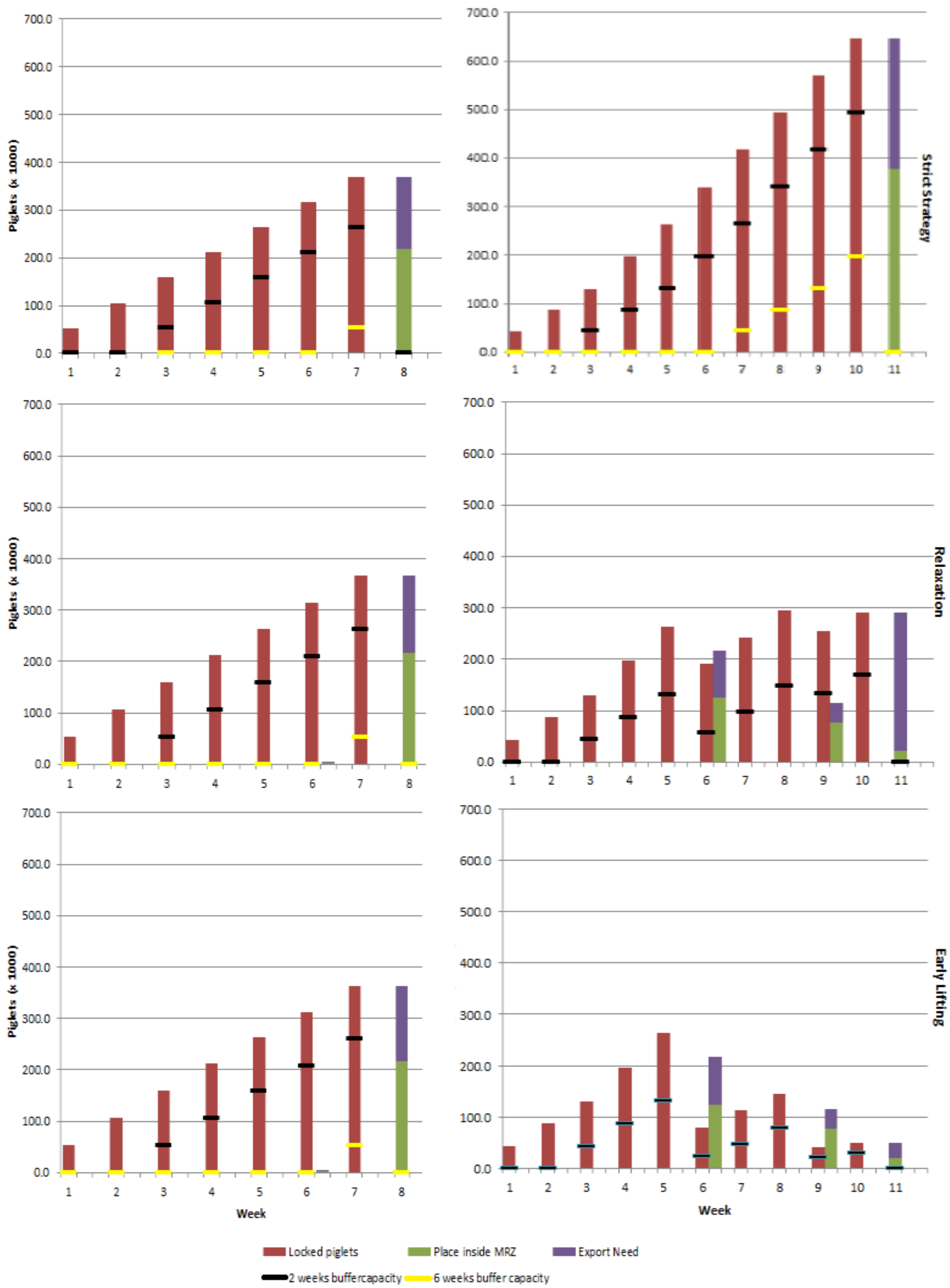


Figure 3.3 Moderate (left) and large outbreak (right) in a DPLA+ under three strategies

3.3 Results for a DPLAeq

Results small outbreak in DPLAeq

The results for a small outbreak for the DPLAeq are shown in Table 3.8. The DPLAeq is characterized by a smaller surplus piglet production. The small outbreak in de DPLAeq covers an area with a weekly piglet production of 10,700. The MRZ is shown on the map in figure D.6. One MRZ is established, and is lifted in week six. The effect of the production structure of the area, i.e. the lower degree of surplus piglet production comes forward in table 3.8. The export need in week six, as a fraction of the amount of locked piglets in week five is lower than compared to the same situation in the DPLA+.

Table 3.8 Small outbreak in a DPLAeq under default measures (numbers are in thousands)

Week	Production	Cumulative production	Net surplus	Cumulative net surplus	**Locked piglets**	**Released piglets**		Exceeded buffer capacity	
						Place inside MRZ	**Export Need**	2 weeks	6 weeks
1	10.7	10.7	1.3	1.3	**10.7**	**0.0**	**0.0**	0.0	0.0
2	10.7	21.3	1.3	2.7	**21.3**	**0.0**	**0.0**	0.0	0.0
3	10.7	32.0	1.3	4.0	**32.0**	**0.0**	**0.0**	**10.7**	0.0
4	10.7	42.7	1.3	5.3	**42.7**	**0.0**	**0.0**	**21.3**	0.0
5	10.7	53.3	1.3	6.6	**53.3**	**0.0**	**0.0**	**32.0**	0.0
6	-	-	-	-	**0.0**	**46.7**	**6.6**	-	-

Results moderate outbreak in DPLAeq

The same aspect is visible in the moderate outbreak (Table 3.9). During this outbreak no extension of the MRZ takes place (Table 2.3). Only a part of the MRZ suffers from prolonged MR, caused by a Non-Modifying detection in week 3. The detected farms lie between 6 and 6.5 km from the index farm. The area is therefore a bit larger than in the small outbreak (Figure D.7). The export need is less than half of the total amount of piglets that have to be placed. Furthermore, the same remark, regarding the mitigating strategies, applies. The subzone with prolonged MR is very small (Tables C.6 and C.7). The mitigating strategies are of little use in this situation. Hardly any effect is visible on the charts comparing the different strategies (figure 3.4).

Table 3.9 Moderate outbreak in a DPLAeq under the Strict Strategy (numbers are in thousands)

Week	Production	Cumulative production	Net surplus	Cumulative net surplus	**Locked piglets**	**Released piglets**		Exceeded buffer capacity	
						Place inside MRZ	**Export Need**	2 weeks	6 weeks
1	14.9	14.9	3.7	3.7	**14.9**	**0.0**	**0.0**	0.0	0.0
2	14.9	29.9	3.7	7.4	**29.9**	**0.0**	**0.0**	0.0	0.0
3	14.9	44.8	3.7	11.1	**44.8**	**0.0**	**0.0**	14.9	0.0
4	14.9	59.7	3.7	14.7	**59.7**	**0.0**	**0.0**	29.9	0.0
5	14.9	74.7	3.7	18.4	**74.7**	**0.0**	**0.0**	44.8	0.0

6	14.9	89.6	3.7	22.1	**89.6**	**0.0**	**0.0**	59.7	0.0
7	14.9	104.5	3.7	25.8	**104.5**	**0.0**	**0.0**	74.7	14.9
8	-	-	-	-	**0.0**	**78.7**	**25.8**	-	-

Results large outbreak in DPLAeq

Table 3.10 presents the results of the large outbreak in the DPLAeq. Under the large outbreak, an extension of the MRZ takes place in week four. Additional detections in week three, five and six cause prolonged duration of MR in subzones of the MRZ (Table 2.3). At its largest, the zone will cover a piglet production of 29,200 per week. It seems that the outbreak spreads to an area with a larger net surplus. The net surplus increases more than a threefold in week three. The effect of the lower net surplus piglet production on the export need is lower than it was in the small and moderate outbreak. The mitigating strategies can clearly alleviate the consequences of the MR, as seen in Figure 3.4. But the difference in outcome between Early Lifting and Relaxation in this case is smaller than in the large outbreak in the DPLA+ area. This can be explained by the difference in production structure of the areas. The advantage of Early lifting is the ability to early export piglets outside the MRZ. In the DPLAeq the need for export is lower so the outcome under the two strategies is more alike. Nevertheless 21,800 piglets more have to be exported at the end of the MR under Relaxation compared to Early Lifting. Having buffer capacity ready for six weeks causes relatively little problems under the two mitigating strategies. Two weeks of buffer capacity is insufficient to cope with the MR. Early Lifting causes equal excess to the buffer capacity than Relaxation.

Table 3.10 Large Outbreak in a DPLAeq under the Strict Strategy (numbers are in thousands)

Week	Production	Cumulative production	Net surplus	Cumulative net surplus	**Locked piglets**	**Released piglets**		Exceeded buffer capacity	
						Place inside MRZ	**Export Need**	2 weeks	6 weeks
1	13.1	13.1	2.1	2.1	**13.1**	**0.0**	**0.0**	0.0	0.0
2	13.1	26.1	2.1	4.2	**26.1**	**0.0**	**0.0**	0.0	0.0
3	13.1	39.2	2.1	6.3	**39.2**	**0.0**	**0.0**	13.1	0.0
4	29.2	68.4	7.1	13.4	**68.4**	**0.0**	**0.0**	26.1	0.0
5	29.2	97.5	7.1	20.5	**97.5**	**0.0**	**0.0**	39.2	0.0
6	29.2	126.7	7.1	27.7	**126.7**	**0.0**	**0.0**	68.4	0.0
7	29.2	155.9	7.1	34.8	**155.9**	**0.0**	**0.0**	97.5	13.1
8	29.2	185.1	7.1	42.0	**185.1**	**0.0**	**0.0**	126.7	26.1
9	29.2	214.3	7.1	49.1	**214.3**	**0.0**	**0.0**	155.9	39.2
10	29.2	243.5	7.1	56.2	**243.5**	**0.0**	**0.0**	185.1	68.4
11	-	-	-	-	**0.0**	**187.2**	**56.2**	-	-

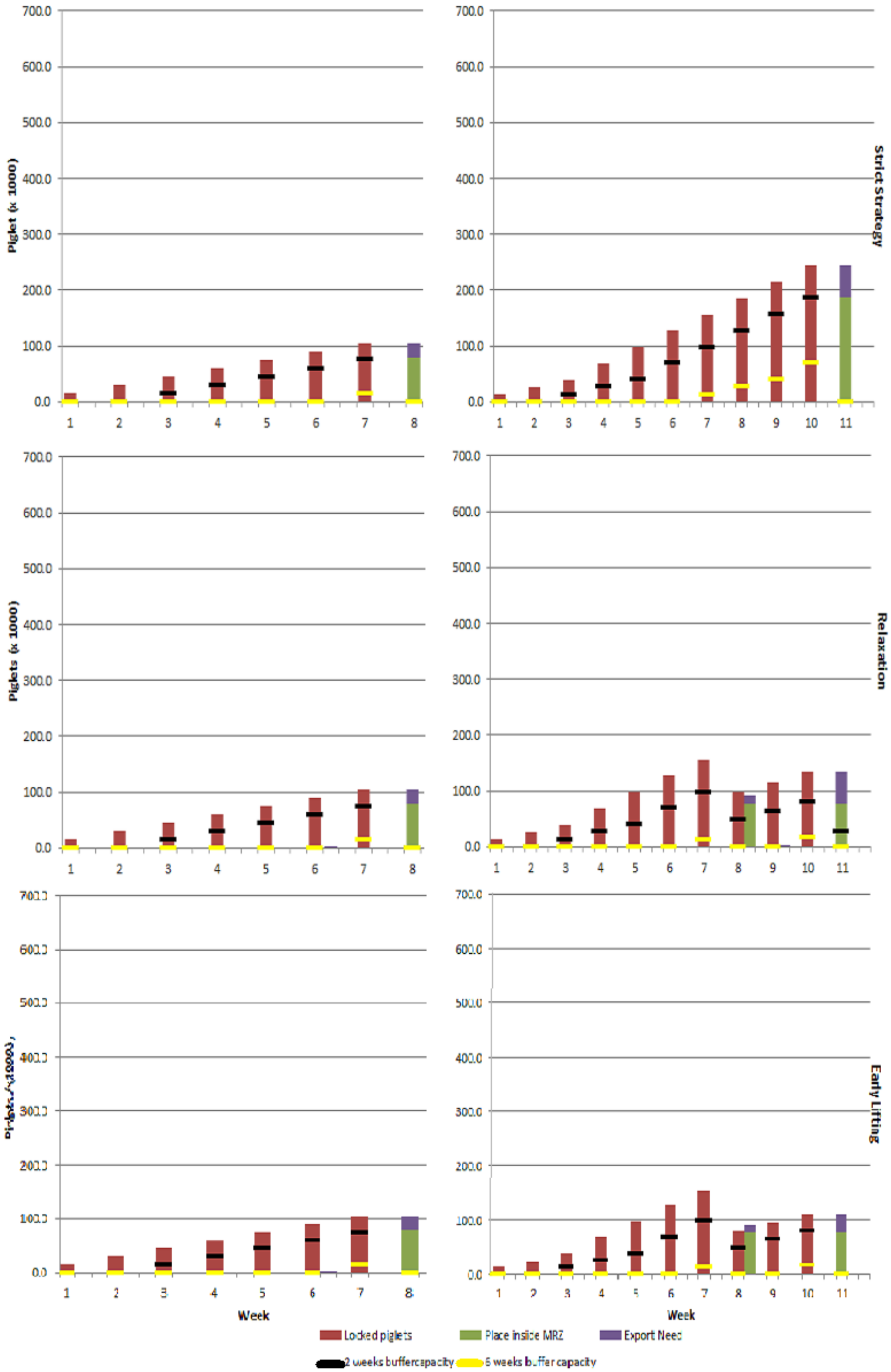


Figure 3.4 Moderate (left) and large outbreak (right) respectively in a DPLAeq under three strategies

4 Discussion

The aim of this study was to develop a DSS to estimate the impact of MR, established after an AD outbreak, on the development of piglet surpluses on farrowing farms. This DSS has to model the pool of locked piglets on farrowing farms, starting from real life epidemiological data and subsequently extrapolation of this real life situation under assumed epidemiological developments; i.e. small, moderate, large outbreaks. In addition it should be able to analyze the effect of mitigating strategies, i.e. Relaxation and Early Lifting. The crucial assumption underlying this DSS is that the mitigating strategies do not increase the veterinary risks. The DSS has to provide insight into the factors that determine the outcome of MR. This study was set up to develop the DSS, to partly validate and investigate its credibility and to detract from its results, rules of thumb of what to expect in case of an AD outbreak.

4.1 Basic results

The outcome of an outbreak of AD is determined by a combination of the characteristics of the epidemics and the characteristics of the control measures taken. Moreover there are important interactions between these different determinants. These important determinants are:

1. Livestock density of an area.
2. The duration of the epidemics.
3. Size of the epidemics in terms of geographical spread of the virus.

Furthermore the moment of subsequential outbreaks and the detection of this spread can importantly affect the duration of the MR. Moreover livestock density is correlated with size and duration of the epidemics. The economic impact of MR is affected by:

4. The production structure of the area.
5. The type of mitigating strategy.

Moreover there is an important interaction between the production structure and the applied mitigating strategy. From an animal welfare point of view the presence of buffer capacity (determinant 6) is an important determinant for the problems that will be caused by MR.

1. Livestock density

The importance of livestock density as a determinant for the outcome shows from the results. The problems in a DPLA develop faster and run out of hand faster compared to the SPLA. Under the strict strategy, after an outbreak lasting nine weeks in a SPLA+, the one-time shock of piglets that are released onto the market amount 2.3 percent of the regular weekly domestic piglet production. The weekly market supply would have a sudden one-time increase with 2.3 percent. In a DPLA+ after an outbreak of 11 weeks under the strict strategy, the one-time shock in supply of piglets to the market will be about 130 percent of the normal weekly market supply. Though this might seem an extreme case it points out the need for mitigating strategies.

2. Duration of the epidemics

The longer the MR last, the larger the pool of locked piglets will grow. The larger the need will be for mitigating strategies. The duration has important implications for the welfare and economic consequences of the outbreak. The longer piglets will be locked on farrowing farms, the heavier and larger they will get. On farrowing farms the piglets will outgrow the pens and on fattening farms cannibalism, fighting, joint and leg problems occur and slatted floors might collapse. From an economical point of view, the longer the MR will last, the larger the shock in supply will be at the lifting of MR. Moreover the larger the variation will be in terms of weight and vaccination status of the piglets that come on the market.

3. Geographical spread of the epidemic

The geographical spread of the disease is important because it determines whether an MRZ gets extended or not. Logically the longer it takes stop the viral spread and the further away the spread the larger the area that will be dealing with MR. The results show the expansion of an MRZ upon further spread. When comparing the outcome of the moderate and large outbreak in the DPLA the effect of further spread is clear. The moment of detection of this further spread is important too. Detection of several farms in week one can result in an epidemic covering a large area but without further spread it would only last for the default duration of MR of five weeks. When these farms get detected over a time span of several weeks the period of MR gets prolonged. In this case only, the mitigating strategies can come into practice and make a difference. The consequences of a short but large outbreak can be larger than those of a longer lasting less progressive outbreak.

4. Production structure of the area affected

The important aspects of the production structure are the degree of specialization and hence the degree of surplus piglet production in the area. An area with a large discrepancy between the weekly availability of fattening places and weekly piglet production, i.e. a surplus area has to export more animals outside the area at the end of the MR. On the other hand an area can have a matching piglet production and demand but when there is a large degree of specialization in the area still welfare problems can occur due to MR. Furthermore running the simulations made clear that the geographical spread can importantly affect the production structure of the whole area under MR. When an epidemic spreads into an area with an equilibrium in its piglet production and stocking of fattening piglets, the production structure of the entire MRZ is not affected. In case of spread into an area with a larger demand for piglets than the piglet production, the need for export from the total MRZ at the end of the MR can be lowered. On the other hand spread into an area with a surplus piglet production will increase the need for export.

5. Mitigating Strategies

The mitigating strategies can have an important impact on the consequences of MR. Relaxation of MR in parts of the MRZ has an important mitigating effect on the outcome of the MR in an area. In the large outbreak of 11 weeks in the DPLA+ it reduced the amount of piglets to be placed from 647,100 to

290,500 piglets. The export need still amounted 269,600 piglets. Early Lifting further decreased the problems in the DPLA+, because it allows early export from the MRZ. The drops in the number of locked piglets is larger compared to Relaxation and the early lifted subzones do not add piglets to the pool of locked piglets anymore. By this the need for export at the end is dramatically lower than under the Strict Strategy or Relaxation. Early Lifting has an important additional value compared to Relaxation in DPLA+s. The effect of production structure can importantly affect the impact of the mitigating strategies. It can enforce or weaken the effect of these strategies. In general, equilibrium areas need the mitigating strategies mainly to tackle welfare problems caused by MR. Surplus areas on the other hand also need the mitigating strategies to mitigate the economic impact of the MR. Therefore these areas have a higher need for Early Lifting than equilibrium areas. The results of the DPLAeq show that the more the area affected has a balanced piglets production and demand for fattening piglets the less difference in the outcomes of the different mitigating strategies exist. It is of no use, in terms of piglet placement possibilities to apply Early Lifting to an area in equilibrium.

The developments in the epidemic are of major importance for the effect of the mitigating strategies. When only very small subzones of the MRZ are eligible for being relaxed or early lifted there will be no large differences with the Strict Strategy and it can be questioned if it is worth the effort to install these mitigating strategy. As already stated, when an outbreak takes of furiously large economic and welfare problems can already exist before mitigating strategies can be applied.

6. Buffer capacity

The buffer capacity is important to prevent welfare problems but it cannot affect the economic impact of MR. Though at the end of MR it might be wise to not empty the buffer capacity all at once but organize the clearing of the buffer capacity in a way that the surplus piglets can be supplied to the market in a more gradual way rather than flooding the market at once. Having enough buffer capacity to house locked piglets is very important. It is clear that two weeks of buffer capacity is insufficient according to the model. Especially in DPLAs, where the piglet surpluses can be as large as 25 percent of the weekly domestic piglet production before the mitigating strategies can be implemented, the need for buffer capacity is very large. Even six weeks of buffering capacity was not sufficient in some cases.

These results are not surprisingly in line with the findings of Bosman *et al.* (2012). They also found that duration and size largely affect the pool of locked piglets. They also stated that Early Lifting makes no difference in an area with a balanced piglet supply and demand. Their study focused also on the difference in production structure. Though they modeled areas assuming a constant ratio between piglet production and demand for piglets. They suggested that spread into areas with a variable demand-supply ratio could affect the outcome. In this study this was clearly visible.

4.2 Credibility of the DSS

A complete validation of the DSS could not be conducted for several reasons. First of all the newly designed contingency plan for AD, based on isolation and vaccination, has never been put to practice in real time outbreak situations. There are no data on a real time situation to be compared with the model outcomes. Garner & Hamilton (2011) warn that it is hard to ensure operational validity when no reference can be made to a real life situation. Though they suggest relative validation as the second best alternative. Again this was also not feasible as there are currently no other models to simulate the development of piglet surpluses in an area under MR. The only option left to check operational validity are subjective assessments of the results and internal model behavior by experts. This assessment was done with the supervisors of this project and experts of the PVE. At this point the only way to comment on the credibility of the DSS is to discuss on the data validity, conceptual validity, model verification and sensitivity of the model to parameters.

Data validity

The central database, being the core base of the DSS, was delivered by Bosman (2012). These data were extracted from the Dutch System for Identification & Registration of pig herds and the System for Company Registration and Management. These systems are legally mandatory by the EU, and practical tools for decision and policy makers. They are the best source of information about the locations, types and capacity of pig farms. Though the data about farm capacity had to be updated based on data on animal transports on and off farms (Bosman *et al.*, 2012), the data validity is considered to be good.

Internal validation

The calculations on per farm piglet production, fattening capacity and surplus were done using straightforward calculations and official average production parameters, taken from KWIN (2009). The validity of these production parameters is considered to be good. The other calculations are based on these farm level variables by simple adding and subtracting them at the right moment based on the zone codes of the farms. No calculation rules were violated in this process. It is considered that the internal validity is sufficient.

Conceptual validity and sensitivity to parameters

The conceptual validity was assessed by face validation (Garner & Hamilton 2011). The supervisors of this project and experts of the PVE were consulted to comment on the assumptions and the algorithms in the design of the model. Face validation was the only possibility for validating the DSS, because of the lack of reference data. It was concluded that the calculations and the underlying assumptions do not hamper the conceptual validity of the DSS.

4.3 Model assumptions and improvements

In the previous sections the validity of the DSS was discussed and approved. Still important assumptions were made when designing the DSS. The most important assumptions and their effect on the credibility of the DSS will be discussed in this section.

In- and output of the pool of locked piglets

The amount of calculated available fattening places is crucial in modeling the development of piglet surpluses. The model calculates the available fattening places like in a peace time situation. Options for additional fattening capacity like keeping fattening piglets on the places for gilts and piglet, or temporary higher stocking densities in times of MR were not regarded. In this way the net farm surplus might be an overestimation. Especially for calculations on the exceeded buffer capacity these options can have an important impact. In the database the pig farms are categorized according to their production type and hygiene status. A discussion with van Lent (2012) revealed that the places for fattening pigs on gilt producing farms (C farms) are reserved for substandard gilts which will be fattened on the gilt farm and later on be delivered to the slaughterhouse. Although the amount of C farms in the database is rather low (83 farms on 8110 included in the database), these might cause an underestimation as they add inexistent availability of fattening places to the model. Furthermore the algorithms assume that each produced piglet will end up as a slaughter pig. At the end of a long lasting epidemic some locked piglets might already be suited for slaughter right away and would not have to be placed on a fattening farm. Moreover a part of the piglets could be slaughtered right away as weaner piglets. A reviewed version of the DSS could take into account these other output from the pool of locked piglets. More important is the outflow from the pool of locked piglets by the early culling of detected farms. This aspect is not incorporated in the current version of the DSS but would significantly improve its accuracy.

Designation of MRZ centers and Non-modifying detections

When differentiating the detections into MRZ-Modifying detections and Non-modifying detections, every farm that gets detected in the same week can trigger an extension of the MRZ, regardless the fact that these farms can be clustered together. This way the DSS might cover a larger area than would be the case in reality. Though this approach was chosen to prevent making an underestimation of the situation. It allows for extensions into several directions in the same week.

Effect of Non-Modifying detections on prolongation of MR

A crucial assumption was made about the effect of a Non-Modifying Detections on the duration of MR in an MRZ. This issue was covered by two parameters determining at which moment a detection influences the duration of MR and for how long the MR would be prolonged. This approach has not been discussed with experts and might be different in reality. The simulations were done by assuming that MR would be prolonged with two weeks if a Non-Modifying detection would take place two weeks or later than the establishment of MR in the zone. As the incubation time for AD ranges up to 11 days, it is valid to append additional detections in the first two weeks to the established MRZ centre. After this point in time additional detections should trigger further investigation of the surrounding area. The model is sensitive to this particular parameters because of the large influence on the duration of MR. A model that is very sensitive to parameters, known with little certainty, can suffer from low accuracy (Garner and Hamilton 2011). This approach has to be reviewed for future application of the DSS and for enhancing its credibility.

Buffer capacity under Relaxation

Under the Early Lifting Strategy and the Strict Strategy these calculations, based on the cumulative piglet production, were straightforward. Under the Relaxation Strategy a distribution of the cumulated surplus in the MRZ had to be assumed. The assumption of a proportional distribution over the farms with a positive net farm surplus avoided making different scenarios for distributing the released piglets over the available fattening places under Relaxation. Designing these scenarios would have been beyond the scope of this research. Though in reality upon releasing a part of an MRZ, the situation of every piglet farmer getting rid of a proportional amount of his locked piglets will not happen. It would be a matter of first come first serve. As the calculated figure of exceeded buffer capacity is a sum of the individual exceeded buffer capacities of the farms involved, this might deviate of the true values. In general the calculations on the buffer capacity might have to be revised. They were designed in a simple way based on the weekly piglet production of the pig farms and did not take into account the possibilities of increasing pen density or housing piglets in other pens than for slaughtering pigs. A more elaborate version of the DSS might want to incorporate the model of Enting (2006), for calculating the true buffer capacity of farms.

Assumptions concerning the mitigating strategies

The assumption of ample slaughter capacity to instantly clear the fattening places on fattening farms at the end of MR, might be corrupted in real life. Enting *et al.* (2006) stated that in case of long lasting MR the fattening pigs that were to be slaughtered in the week of establishing MR, are too large and too heavy to be slaughtered in a conventional slaughterhouse at the end of the MR. These pigs would have to be processed in a slaughterhouse for culled sows. Slaughterhouses of this kind are few in the Netherlands and could have to little capacity to deal with large amount of animals. Pluimers *et al.*(1999) reported the same problems at the end of the CSF epidemic of 1997/1998. Also the availability of sufficient transport capacity can be discussed. This aspect of slaughter capacity and transport capacity can endorse the need for mitigating strategies. Under the Strict Strategy the amount of pigs that have to be transported instantly, can be very large and might exceed the transport capacity. In this case the problems would last longer than needed. Under the mitigating strategies the need for transport capacity is more gradually distributed through time and might facilitate the logistics.

The assumption that under Relaxation no export to article 9 areas or lower would take place might be too rigid. Nonetheless this approach was justifiable as it would be very hard to instantly find the right export markets for the surplus piglets in the current situation. This consideration can question the export dependency of the Dutch pig sector in general and certainly the crucial importance of Germany as main export destination.

Further improvements

When using the DSS one has to make sure that the pig farm database is up to date, to ensure the highest model accuracy. A way to automatically update this database would be handy for its practical application. The current model is suited for modeling connected areas. For modeling a virus jump, one would have to run separate simulations for the different areas. These simulations would have to be synthesized to get the insight on the entire situation. Though when modeling an epidemic in which two infected areas would merge, double calculations could be possible. An extension of the DSS, making it suitable for modeling these virus jumps would improve the generalizability of the DSS.

Unfortunately it was not possible to study the economic consequences of these piglets surpluses. The DSS could significantly gain in value when estimations of market disturbance, and estimations on the loss of value of locked piglets, due to deviant weights and vaccination status, could be incorporated. To further improve the generalizability of the DSS, a module to estimate the consequences of MR for fattening farms should be included. In this way the decision makers would get a better view on the consequences of MR.

4.4 Rules of thumb

- In case of an outbreak, the size of the effect of mitigating strategies has to be estimated. Thereafter, the costs and the benefits of applying the strategies should be evaluated, i.e. relaxing or early lifting small subzones might not be worth the effort.
- If an outbreak occurs in a SPLA, the consequences will not be as large as those for DPLAs. The welfare consequences can be tackled by sufficient buffer capacity. The need for mitigating strategies is not as large as for DPLAs. An outbreak in a SPLA should be treated carefully to prevent spread into DPLAs, the application of mitigating strategies might be postponed as long as possible.
- If a DPLA is struck by outbreaks the consequences of MR might already be huge before mitigating strategies can be applied. Buffer capacity is extremely important to mitigate the welfare consequences in these areas. Direct transports of fattening pigs to slaughterhouses results in extra buffer capacity in the MRZs. With longer lasting outbreaks, application of Relaxation is inevitable. When dealing with a DPLA+, Early Lifting has to be applied to get the highest mitigating effect.
- Foreseeing enough buffer capacity is important for all areas, but most important in DPLAs.
- When choosing between Early lifting and Relaxation, Early Lifting has to be preferred only when dealing with a surplus area. Application of Early Lifting in equilibrium areas should not be done to lower the risk of viral spread

4.5 Relevancy to other diseases and countries

Problems with piglet surpluses can occur in every country with every contagious disease outbreak for which movement restrictions are a contingency measure. The application of the DS is possible but requests tuning to the contingency measures of the country and the disease in question. The current version is designed to comply to the contingency plan for AD at rule in the Netherlands, which is unique in the European Union. First of all the DSS would have to be parameterized according to the contingency measures for the specific country. Algorithms to incorporate culling and welfare slaughter would have to be programmed, because other countries in the EU might still want to install these measures. A lower status than the article 10 status could request modifications to the DSS as well. In the Netherlands the contingency measures in the article 10 situation are very strict to preserve this precious status.

The same remarks apply when the DSS is to be used for modeling animal surpluses under outbreaks of other contagious diseases. First of all the relevant parameters have to be checked and altered to ensure accurate modeling for the particular disease. With another disease might come a different contingency plan to which the DSS has to comply. For example, in case of an outbreak of CSF the infected farms would be culled together with preemptively culling all the pig farms in a designated zone around the detected farm (MinLNV 2007). It can be decided to vaccinate a variable part of the protection area around the detected farms to lower the amount of animals that have to be culled to get control on the disease. Culling of animals would lower the amount of locked animals on farms. Also decision makers have the ability to impose a breeding ban when it is likely to be a very long epidemic of more than 4 months. Another striking difference between the contingency measures for CSF and AD is the establishment of compartments in the country. Contacts between pig farms are restricted to the compartment. These measures can also enhance the development of animal surpluses and should be programmed into the DSS. Moreover it is highly unlikely that policy makers would want to implement mitigating strategies when dealing with an extremely contagious disease like CSF. In this case the value of the DSS would be reduced to modeling the number of locked animals under the Strict Strategy.

4.6 Considerations on contingency measures and mitigating strategies

The results showed that the mitigating strategies can lower the accumulation of live piglets on farrowing farms under MR. Though in cases where only small parts of MRZs were eligible for mitigating strategies, the mitigating effect is minor. Therefore the decision to install mitigating strategies should be thought out thoroughly. This question request further research into the costs and benefits of installing these mitigating strategies. Moreover organizing the implementation of these strategies should go without increasing epidemiological risks. As already mentioned by Bosman *et al* (2012) a screening system to guarantee that the transported animals are free of AD is crucial for the feasibility and acceptance of installing mitigating strategies. The epidemiological risks of the mitigating strategies might be too large to set these through. Pluimers *et al.* (1999) reported that animal transports for the welfare slaughter program were responsible for spreading the virus during the CSF epidemic in 1997/98 and had to be minimized.

The mitigating strategies are not the saving solution to the problem, as they might not continue in case of increasing the epidemiological risks. It is therefore extremely important to have enough buffer capacity to overcome a period of MR. Moreover when looking at the results of the small outbreak in a DPLA+ there are already considerable amounts of piglets locked at the end of the default MR. In this case the described mitigating strategies could not be applied in time to prevent these huge surpluses. Buffer capacity is the only valid tool to mitigate the welfare problems in this case.

The default duration of MR might have to be deliberated as well. The present regulations implicate a safety margin (van Lent, personal communication). The second vaccination is to make sure that all animals are immunized thoroughly. Thereafter another two weeks have to pass before animals can be transported. As the duration of MR has an important effect on the piglet surpluses, the surplus problems might be mitigated by downsizing the duration of MR. The effects of a reduced MR period should be investigated thoroughly. Still in densely populated livestock areas it can be expected that this safety buffer will not be reduced, however the biggest surplus problems will occur in these areas. Therefore the possibilities of designing an early slaughter program should be considered. The possibilities to allow early transports, direct to the slaughterhouse should be investigated to make space for housing surplus piglets. Then again if this program would not be started before six weeks of the epidemics have passed, likewise the contingency plan for Foot and Mouth disease (MinLNV, 2005), welfare problems can already run out of hand. The only alternative then is to design a strategy to efficiently organize sufficient and cheap emergency shelter on pig farms.

5 Conclusion and recommendations

From this study it can be concluded that the DSS works consistently under the boundaries of this project. It allows to make calculations on the development of piglet surpluses caused by MR, the need for export from MRZs , and the sufficiency of buffer capacity in connected areas struck by MR. These calculations can provide insight in what to expect in case of a real life AD outbreak. Relaxation of the MR in parts of the MRZ can prevent large accumulations of piglets on farrowing farms. Moreover Early Lifting has large additional mitigating potential in areas with high surplus piglet production, but has little or no additional value in areas in equilibrium or with minor surplus piglet production. Furthermore it is clear that having sufficient buffer capacity ready for living through periods of MR is extremely important for a country like the Netherlands. The study indicates the usefulness of the mitigating strategies but even more it indicates the need to consider the shortcomings of the current contingency measures for AD.

Extensions and modifications to the DSS should be designed with intensive cooperation and supervision of experts to improve its conceptual validity and generalizability. The assistance of experts at improving the DSS is crucial as face validation is currently the only way to confirm the validity and credibility of the DSS. The data validity was considered to be sufficient, but for future application a recheck is recommended likewise an update of the central database. In general work has to be done to thoroughly validate and verify the DSS.

Glossary

- **Article 10 status**: Official AD free status of a member state of the EU, granted by the EC. This means that the country is officially free of AD, has a ban on preventive vaccination and the last vaccination was carried out at least 12 months before. Moreover the country has an approved contingency plan for AD outbreaks (EC, 2008; EEC,1964).
- **Article 9 status:** A member state of the EU receives the article 9 status when it has an approved eradication program for AD, including preventive vaccination with marker vaccines (EC, 2008; EEC,1964)..
- **Decision Support System**: A tool to improve the decision space of the decision maker, estimating the impact of MR in terms of numbers of piglets locked on farrowing farms, export need and exceeded buffer capacity; using real time epidemiological input and extrapolation under assumed epidemiological developments.
- **MR:** Movement restrictions: A prohibition to transport animals for at least 35 days, being the time span in which animals are getting immunized through vaccination. This immunization is checked with serological end screening after at least 30 days.
- **Mitigating strategy**: A strategy designed to prevent or mitigate the development of enormous amounts of piglets ready for fattening , locked on farrowing farms under MR.
- **MRZ:** Movement Restriction Zone, being the area around an AD infected and detected pig farm in which all animals will be vaccinated twice and in which no animal transport are allowed
- **MRZ-radius**: The radius of the area around a detected pig farm in which all animals will be vaccinated and animal transportations will be prohibited
- **MRZ-modifying detection** : A subsequent detection, lying further away from the current MRZ centre then the critical distance for extending the MRZ.
- **Non-modifying detection**: A neighboring detection in the current MRZ not exceeding the critical distance for MRZ extension
- **Piglet surplus**: The pool of locked piglets of 25 kg and heavier, ready to be delivered to fattening farms, but which cannot leave farrowing farms due to MR or due to a lack of available fattening places in the area under the Relaxation Strategy
- **Surplus area**: An area in which there exist a discrepancy between the weekly piglet production and the weekly availability of fattening places. Meaning that a part of the weekly produced piglets in the area has to be exported elsewhere.
- **Surplus piglet production**: see Surplus area
- **Equilibrium area**: An area in which there is none or just a little discrepancy between the weekly piglet production and the availability of fattening places. Theoretically all the produced piglets can be fattened in the same area where they were produced.

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Appendix A: Summary Contingency Plan for Aujeszky's Disease outbreaks

The following is a summary of the contingency plan in case of a confirmed outbreak of AD in the Netherlands, relevant for the understanding of the development and functioning of the DSS. Basic considerations of the contingency plan are the following (PVE, 2011)

- Stamping-out and welfare slaughter are not included as control measures. Instead outbreaks will be contained by vaccination and isolation.
- Since 2007 preventive vaccination against AD is not allowed anymore. An outbreak in a susceptible pig population can spread easily and can possibly have devastating consequences.
- Getting control of an outbreak of AD by vaccination goes slower than by stamping out, as the immunization of the animals takes time, during which the animals can still spread virus.
- Animals in the vaccination area are vaccinated twice, to be sure that they are immunised. Two weeks after the second vaccination, infected animals are assumed not to spread virus anymore so they can be transported without the risk of spreading the virus.

Following an outbreak of AD, a standstill of 72 hours will be established in the Netherlands to get an impression of the outbreak. In essence, the contacts of the detected pig farm will be traced, so that further spread can be minimised.

The pigs on all farms, including the detected farm, in a zone with a radius of 10 km around the detected farm will be vaccinated twice. The detected farm will be vaccinated in 24 hours and the other farms in maximum 72 hours after the detection. This will proceed from the outside to the inside of the vaccination zone. At the same time of the first vaccination, veterinarians will check for clinical symptoms on the farms in the vaccination zone. Also blood samples will be taken for serological inspection. The second vaccination will be executed 14 to 21 days after the first detection. At this time a check on clinical symptoms is done again. The second vaccination is done to make sure that the animals are immunised thoroughly. Piglets born from sows that have received two vaccinations are considered to be immunised by maternal antibodies and they are not vaccinated. Piglets born from sows between the first and second vaccination receive their second vaccination when the third inspection is done. This third inspection consist of a serological screening for wildtype antibodies. It can be conducted only after 30 days since the first vaccination have elapsed.

For all the pig farms in the vaccination area it will be forbidden to transport pigs until 2 weeks after the second vaccination. If the serological end screening in the zone is negative, pigs can be delivered to the slaughterhouse again. Detected farms are obliged to directly slaughter their pigs, and will be financially compensated. These farms have to cleans and disinfect their stables. Two weeks after the reception of a cleansing and disinfection certificate they can restock their farms. When the end screening is negative and no further detections have been made the movement restrictions will be lifted in the area.

Non-infected farms in the vaccination zone will have to wait until the screening results in the area are negative to transport pigs again. From that moment pigs can be transported to slaughterhouses in and outside the MRZ. Piglets from within the MRZ can be transported inside the MRZ. If a surplus of piglets has been produced during the MR and the conditions for transportation are met, then these animals can be exported to areas with a lower status concerning AD.

If during the outbreak a subsequent detection is made outside the current MRZ, then the whole procedure is initiated again, with exception of the initial 72 hour-standstill. When a subsequent detection is made inside the current MRZ, the actions depend on the location of the subsequent detection. When a subsequent detection is made further away than 5 km from the current MRZ centre, then the MRZ is extended. The described procedure is than initiated only for all the companies that are located in the new part of the extended MRZ. The farms that were already under MR, but also lying in 10 km from the new MRZ centre, keep on following the procedure triggered by the initial MRZ centre (figure A.1).

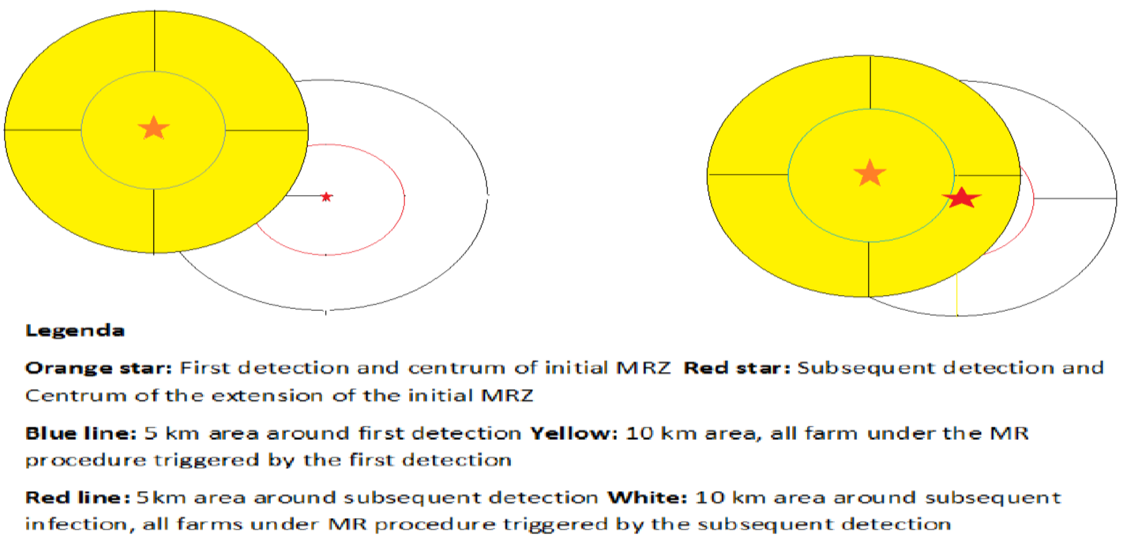
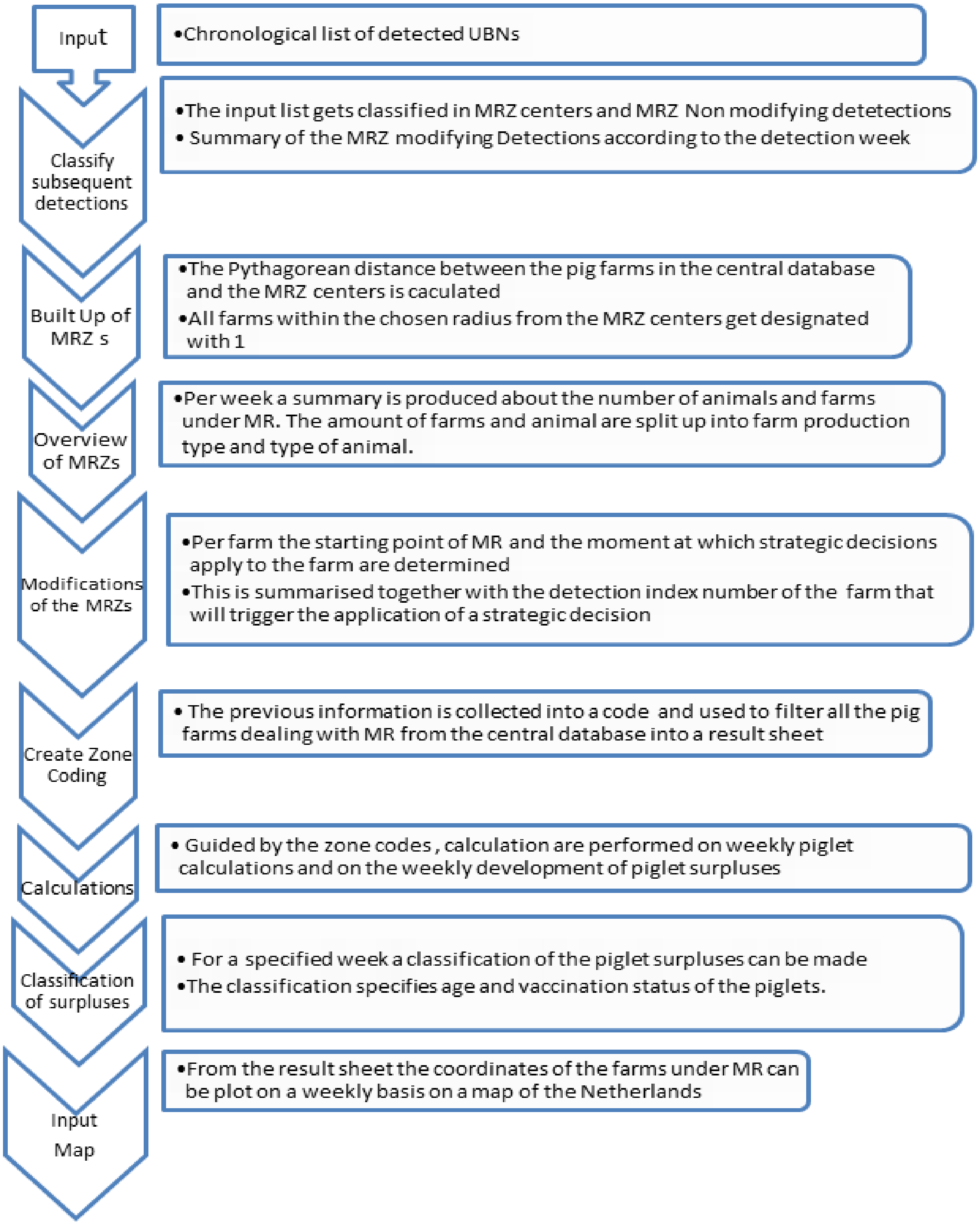


Figure A.1 Extension of an MRZ following a subsequent detection outside the 10 Km area

When a subsequent detection is made after 10 weeks and the former MRZ is still in place, then the piglets born after the second vaccination in the former MRZ, will be vaccinated. If this detection would occur 14 weeks after the establishment of the MRZ or the last extension of the MRZ, previously vaccinated animals get a new vaccination and piglets born after second vaccination get their first vaccination.

The control measures will be lifted after the last detection is under control. The MR are lifted two weeks after the last detected farms has received the certificate of cleansing and disinfection and the inspections on contact farms are negative and the third serological inspections on the farms in the MRZ are also negative.

Appendix B: Flowchart of the DSS



Appendix C: Additional Tables

Table C.1 Moderate outbreak in a SPLA+ default measures (numbers are in thousands)

Week	Production	Cumulative production	Net surplus	**Cumulative net surplus**	**Locked piglets**	**Released piglets**		Exceeded buffer capacity	
						Place inside MRZ	**Export Need**	2 weeks	6 weeks
1	2.8	2.8	1.1	**1.1**	**2.8**	**0.0**	**0.0**	0.0	0.0
2	2.8	5.5	1.1	**2.1**	**5.5**	**0.0**	**0.0**	0.0	0.0
3	2.8	8.3	1.1	**3.2**	**8.3**	**0.0**	**0.0**	2.8	0.0
4	2.8	11.1	1.1	**4.2**	**11.1**	**0.0**	**0.0**	5.5	0.0
5	2.8	13.9	1.1	**5.3**	**13.9**	**0.0**	**0.0**	8.3	0.0
6	-	-	-	-	**0.0**	**8.6**	**5.3**	-	-

Table C.2 Moderate outbreak in a DPLA+ under Relaxation (numbers are in thousands)

Week	Productio n	Cumulative production	**Net surplus	**Cumulativ e net surplus**	**Locked piglets**	**Released piglets**		Exceeded buffer capacity	
						Place inside MRZ	**Export Need***	2 weeks	6 weeks
1	52,8	52,8	21,7	**21,7**	**52,8**	**0,0**	**0,0**	0,0	0,0
2	52,8	105,7	21,7	**43,4**	**105,7**	**0,0**	**0,0**	0,0	0,0
3	52,8	158,5	21,7	**65,1**	**158,5**	**0,0**	**0,0**	52,8	0,0
4	52,8	211,3	21,7	**86,8**	**211,3**	**0,0**	**0,0**	105,7	0,0
5	52,8	264,1	21,7	**108,5**	**264,1**	**0,0**	**0,0**	158,5	0,0
6	52,0	311,7	21,7	**130,2**	**315,0**	**1,7**	**2,7**	209,4	0,0
7	52,0	363,7	21,7	**151,9**	**367,5**	**0,0**	**0,0**	261,9	52,0
8	-	-	-	-	**0.0**	**215,6**	**151,9**	-	-

*Part of the MRZ is allowed to transport animals again, this figures represents the part of the transportable animals, that theoretically should be exported. Under the Relaxation Strategy this can only take place at the end of the MR.

** The net surplus is shown for the total area that was struck by MR, i.e. the net surplus of the relaxed part of the MRZ is still included in the figure

Table C.3 Moderate outbreak in a DPLA+ under Early Lifting (numbers are in thousands)

Week	Production	Cumulative production	Net surplus	**Cumulative net surplus	**Locked piglets**	**Released piglets**		Exceeded buffer capacity	
						Place inside MRZ	**Export Need***	2 weeks	6 weeks
1	52,8	52,8	21,7	21,7	**52,8**	**0,0**	**0,0**	0,0	0,0
2	52,8	105,7	21,7	43,4	**105,7**	**0,0**	**0,0**	0,0	0,0
3	52,8	158,5	21,7	65,1	**158,5**	**0,0**	**0,0**	52,8	0,0
4	52,8	211,3	21,7	86,8	**211,3**	**0,0**	**0,0**	105,7	0,0
5	52,8	264,1	21,7	108,5	**264,1**	**0,0**	**0,0**	158,5	0,0
6	52,0	311,7	21,1	126,9	**311,7**	**1,7**	**2,7**	207,8	0,0
7	52,0	363,7	21,1	148,0	**363,7**	**0,0**	**0,0**	259,8	52,0
8	-	-	-	-	**0.0**	**215,6**	**148,0**	-	-

* Piglets can be transported outside the MRZ from the farms that have reached the end of MR
** Only the net surplus of the farms under MR are shown, i.e. the surplus of the farms of the early lifted part is no longer included from the week of lifting onwards

Table C.4 Large outbreak in a DPLA+ under Relaxation (numbers are in thousands)

Week	Production	Cumulative production	**Net surplus	Cumulative net surplus	**Locked piglets**	**Released piglets**		Exceeded buffer capacity	
						Place inside MRZ	***Export Need**	2 weeks	6 weeks
1	43,5	43,5	18,5	18,5	**43,5**	**0,0**	**0,0**	0,0	0,0
2	43,5	87,0	18,5	37,1	**87,0**	**0,0**	**0,0**	0,0	0,0
3	43,5	130,5	18,5	55,6	**130,5**	**0,0**	**0,0**	43,5	0,0
4	66,6	197,0	26,3	81,9	**197,0**	**0,0**	**0,0**	87,0	0,0
5	66,6	263,6	26,3	108,3	**263,6**	**0,0**	**0,0**	130,5	0,0
6	33,2	79,4	32,3	140,5	**190,6**	**124,7**	**92,7**	57,4	0,0
7	33,2	112,6	32,3	172,8	**242,3**	**0,0**	**0,0**	97,5	0,0
8	33,2	145,8	32,3	205,1	**294,1**	**0,0**	**0,0**	148,2	0,0
9	10,1	40,5	32,3	237,3	**254,1**	**76,4**	**39,0**	133,6	0,0
10	10,1	50,6	32,3	269,6	**290,5**	**0,0**	**0,0**	168,9	0,0
11	-	-	-	-	**0.0**	**20,9**	**269,6**	-	-

*Part of the MRZ is allowed to transport animals again, this figures represents the part of the transportable animals, that theoretically should be exported.
Under the Relaxation Strategy this can only take place at the end of the MR.
** The net surplus is shown for the total area that was struck by MR, i.e. the net surplus of the relaxed part of the MRZ is still included in the figure

Table C.5 Large Outbreak in a DPLA+ under Early Lifting (numbers are in thousands)

Week	Production	Cumulative production	**Net surplus	Cumulative net	**Locked piglets**	**Released piglets**		Exceeded buffer capacity	
						Place inside	***Export Need**	2 weeks	6 weeks
1	43,5	43,5	18,5	18,5	**43,5**	**0,0**	**0,0**	0,0	0,0
2	43,5	87,0	18,5	37,1	**87,0**	**0,0**	**0,0**	0,0	0,0
3	43,5	130,5	18,5	55,6	**130,5**	**0,0**	**0,0**	43,5	0,0
4	66,6	197,0	26,3	81,9	**197,0**	**0,0**	**0,0**	87,0	0,0
5	66,6	263,6	26,3	108,3	**263,6**	**0,0**	**0,0**	130,5	0,0
6	33,2	79,4	13,7	29,3	**79,4**	**124,7**	**92,7**	23,1	0,0
7	33,2	112,6	13,7	43,1	**112,6**	**0,0**	**0,0**	46,2	0,0
8	33,2	145,8	13,7	56,8	**145,8**	**0,0**	**0,0**	79,4	0,0
9	10,1	40,5	5,9	23,7	**40,5**	**76,4**	**39,0**	20,2	0,0
10	10,1	50,6	5,9	29,7	**50,6**	**0,0**	**0,0**	30,4	0,0
11	-	-	-	-	**0.0**	**20,9**	**29,7**	-	-

* Piglets can be transported outside the MRZ from the farms that have reached the end of MR
** Only the net surplus of the farms under MR are shown, i.e. the surplus of the farms of the early lifted part is no longer included from the week of lifting onwards

Table C.6 Moderate outbreak in a DPLAeq under Relaxation (numbers are in thousands)

Week	Production	Cumulative production	**Net surplus	Cumulative net surplus	**Locked piglets**	**Released piglets**		Exceeded buffer capacity	
						Place inside MRZ	***Export Need**	2 weeks	6 weeks
1	14,9	14,9	3,7	3,7	**14,9**	**0,0**	**0,0**	0,0	0,0
2	14,9	29,9	3,7	7,4	**29,9**	**0,0**	**0,0**	0,0	0,0
3	14,9	44,8	3,7	11,1	**44,8**	**0,0**	**0,0**	14,9	0,0
4	14,9	59,7	3,7	14,7	**59,7**	**0,0**	**0,0**	29,9	0,0

5	14,9	74,7	3,7	18,4	**74,7**	**0,0**	**0,0**	44,8	0,0
6	14,8	88,5	3,7	22,1	**88,8**	**0,7**	**0,2**	59,1	0,0
7	14,8	103,3	3,7	25,8	**103,6**	**0,0**	**0,0**	73,9	14,8
8	-	-	-	-	**0.0**	**77,8**	**25,8**	-	-

*Part of the MRZ is allowed to transport animals again, this figures represents the part of the transportable animals, that theoretically should be exported. Under the Relaxation Strategy this can only take place at the end of the MR.
** The net surplus is shown for the total area that was struck by MR, i.e. the net surplus of the relaxed part of the MRZ is still included in the figure

Table C.7 Moderate outbreak in a DPLAeq under Early lifting (numbers are in thousands)

Week	Production	Cumulative production	**Net surplus	Cumulative net surplus	**Locked piglets**	**Released piglets**		Exceeded buffer capacity	
						Place inside MRZ	***Export Need**	2 weeks	6 weeks
1	14,9	14,9	3,7	3,7	**14,9**	**0,0**	**0,0**	0,0	0,0
2	14,9	29,9	3,7	7,4	**29,9**	**0,0**	**0,0**	0,0	0,0
3	14,9	44,8	3,7	11,1	**44,8**	**0,0**	**0,0**	14,9	0,0
4	14,9	59,7	3,7	14,7	**59,7**	**0,0**	**0,0**	29,9	0,0
5	14,9	74,7	3,7	18,4	**74,7**	**0,0**	**0,0**	44,8	0,0
6	14,8	88,5	3,6	21,8	**88,5**	**0,7**	**0,2**	59,0	0,0
7	14,8	103,3	3,6	25,5	**103,3**	**0,0**	**0,0**	73,8	14,8
8	-	-	-	-	**0,0**	**77,8**	**25,5**	-	-

* Piglets can be transported outside the MRZ from the farms that have reached the end of MR
** Only the net surplus of the farms under MR are shown, i.e. the surplus of the farms of the early lifted part is no longer included from the week of lifting onwards

Table C.8 Large outbreak in a DPLAeq under Relaxation (numbers are in thousands)

Week	Productio n	Cumulativ e	**Net surplus	Cumulativ e net	**Locked piglets**	**Released piglets**		Exceeded buffer capacity	
						Place inside MRZ	***Export Need**	2 weeks	6 week
1	13,1	13,1	2,1	2,1	**13,1**	**0,0**	**0,0**	0,0	0,0
2	13,1	26,1	2,1	4,2	**26,1**	**0,0**	**0,0**	0,0	0,0
3	13,1	39,2	2,1	6,3	**39,2**	**0,0**	**0,0**	13,1	0,0
4	29,2	68,4	7,1	13,4	**68,4**	**0,0**	**0,0**	26,1	0,0
5	29,2	97,5	7,1	20,5	**97,5**	**0,0**	**0,0**	39,2	0,0
6	29,2	126,7	7,1	27,7	**126,7**	**0,0**	**0,0**	68,4	0,0
7	29,2	155,9	7,1	34,8	**155,9**	**0,0**	**0,0**	97,5	13,1
8	16,1	80,7	7,1	42,0	**97,4**	**76,7**	**14,6**	48,4	0,0
9	16,0	96,0	7,1	49,1	**115,6**	**0,0**	**0,6**	64,0	0,0
10	16,0	112,0	7,1	56,2	**133,8**	**0,0**	**0,0**	80,0	16,0
11	-	-	-	-	**0.0**	**77,6**	**56,2**	26,0	-

*Part of the MRZ is allowed to transport animals again, this figures represents the part of the transportable animals, that theoretically should be exported.
Under the Relaxation Strategy this can only take place at the end of the MR.
** The net surplus is shown for the total area that was struck by MR, i.e. the net surplus of the relaxed part of the MRZ is still included in the figure

Table C.9 Large outbreak in a DPLAeq under Early Lifting (numbers are in thousands)

Week	Production	Cumulative production	**Net surplus	Cumulative net surplus	**Locked piglets**	**Released piglets**		Exceeded buffer capacity	
						Place inside MRZ	***Export Need**	2 weeks	6 weeks
1	13,1	13,1	2,1	2,1	**13,1**	**0,0**	**0,0**	0,0	0,0
2	13,1	26,1	2,1	4,2	**26,1**	**0,0**	**0,0**	0,0	0,0
3	13,1	39,2	2,1	6,3	**39,2**	**0,0**	**0,0**	13,1	0,0
4	29,2	68,4	7,1	13,4	**68,4**	**0,0**	**0,0**	26,1	0,0
5	29,2	97,5	7,1	20,5	**97,5**	**0,0**	**0,0**	39,2	0,0
6	29,2	126,7	7,1	27,7	**126,7**	**0,0**	**0,0**	68,4	0,0
7	29,2	155,9	7,1	34,8	**155,9**	**0,0**	**0,0**	97,5	13,1
8	16,1	80,7	5,0	25,2	**80,7**	**76,7**	**14,6**	48,4	0,0
9	16,0	96,0	4,9	29,5	**96,0**	**0,0**	**0,6**	64,0	0,0
10	16,0	112,0	4,9	34,4	**112,0**	**0,0**	**0,0**	80,0	16,0
11	-	-	-	-	**0.0**	**77,6**	**34,4**	-	-

* Piglets can be transported outside the MRZ from the farms that have reached the end of MR
** Only the net surplus of the farms under MR are shown, i.e. the surplus of the farms of the early lifted part is no longer included from the week of lifting onwards

Appendix D: Maps of the simulated outbreaks

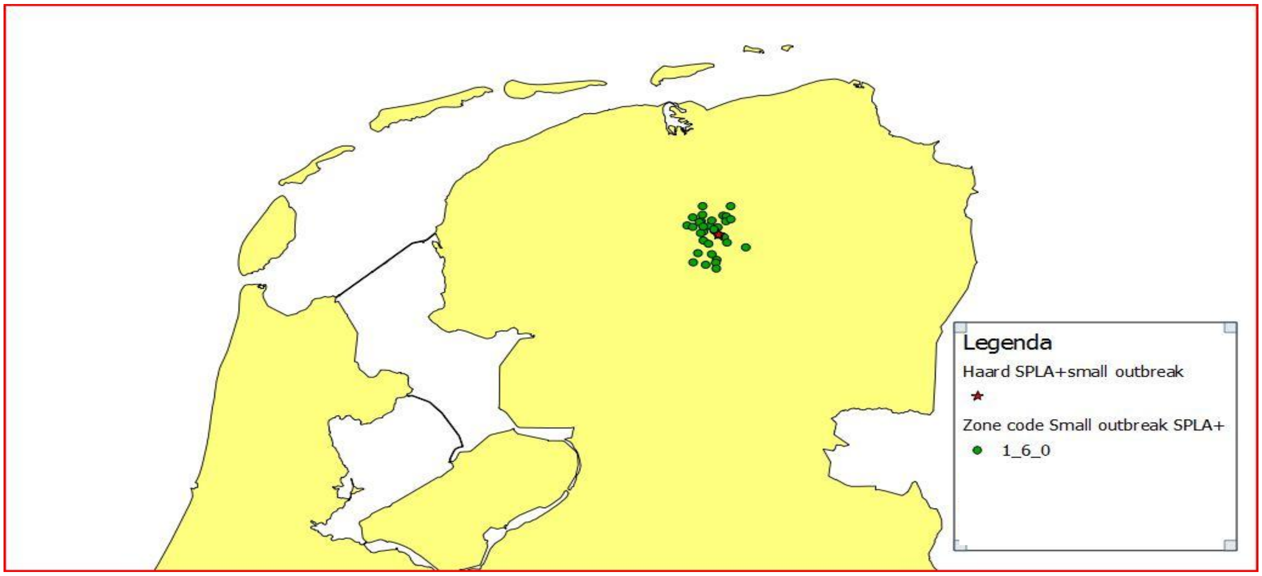


Figure D.1 Map of the small outbreak in a SPLA+

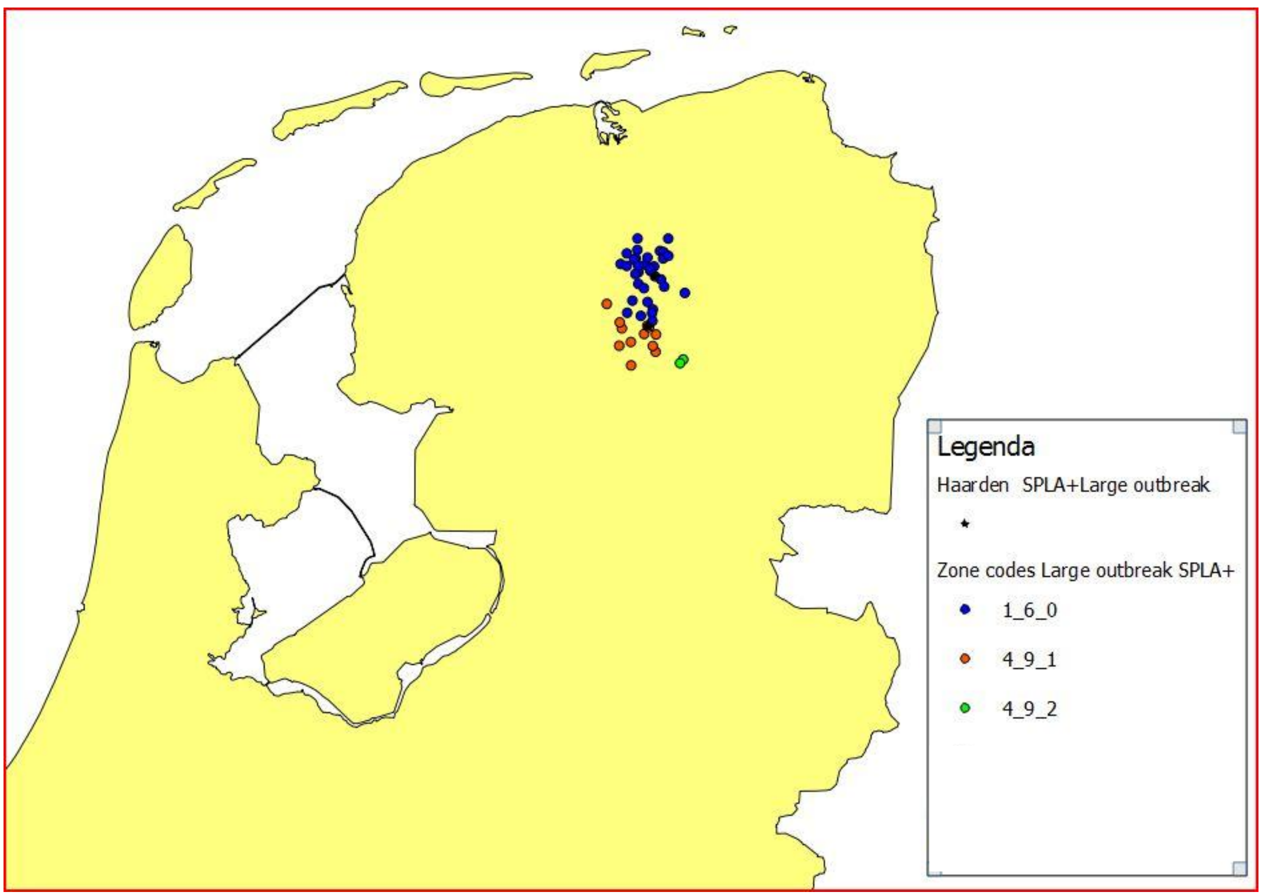


Figure D 2 Map of large outbreak in a SPLA+

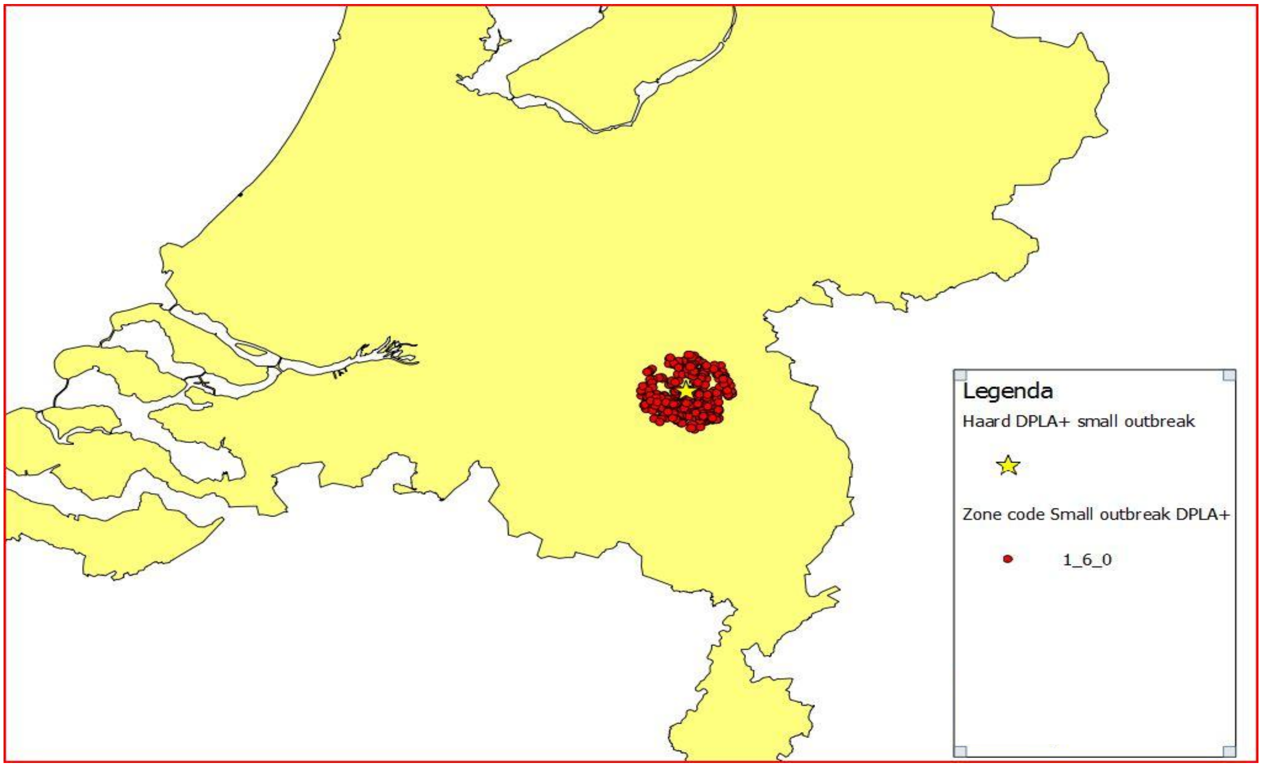


Figure D. 3 Map of the small outbreak in a DPLA+

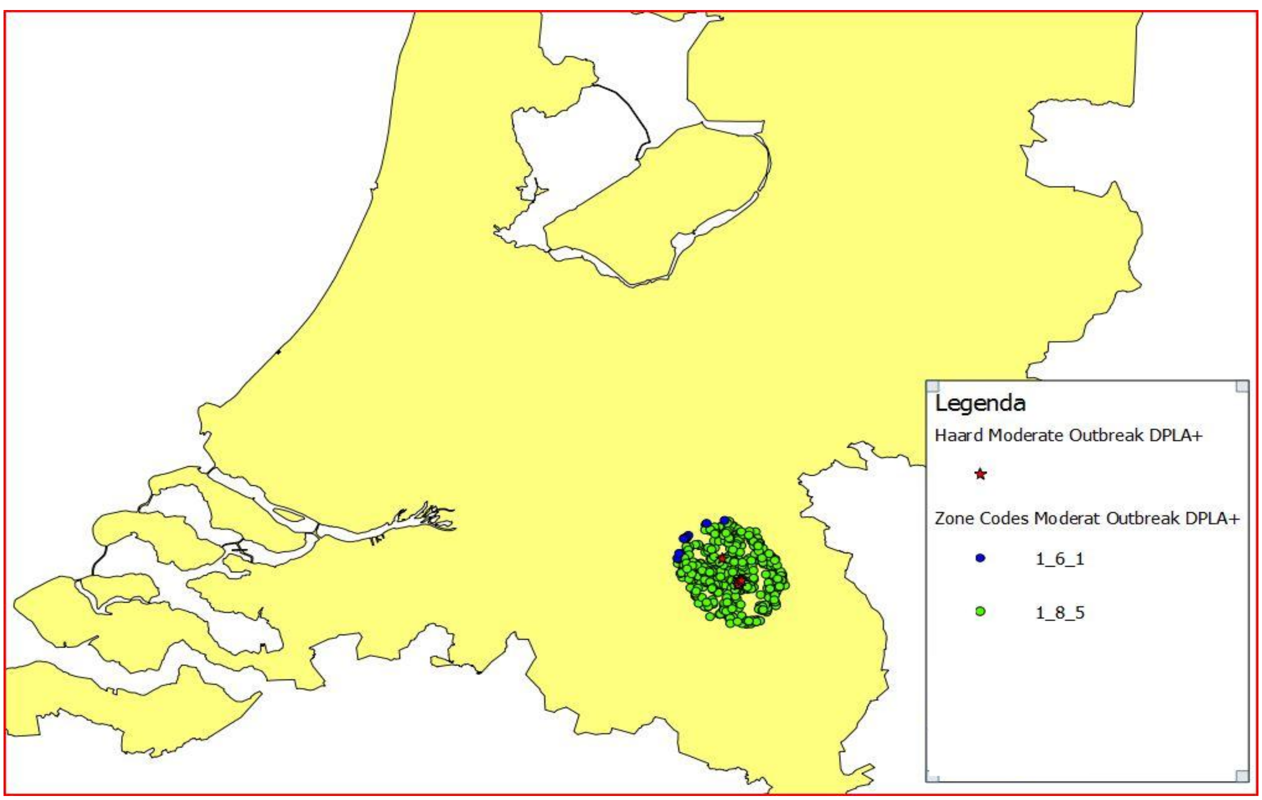


Figure D.4 Map of the moderate outbreak in a DPLA+

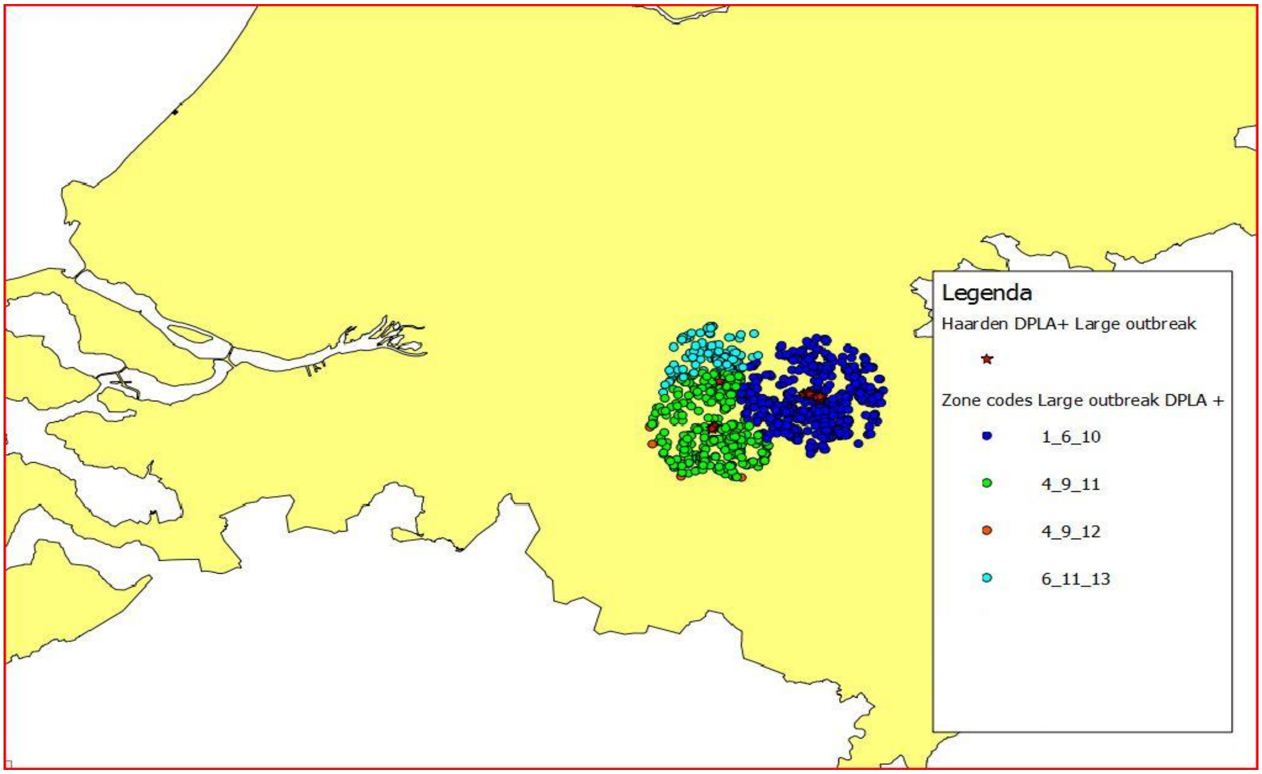


Figure D. 5 Map of the large outbreak in a DPLA+

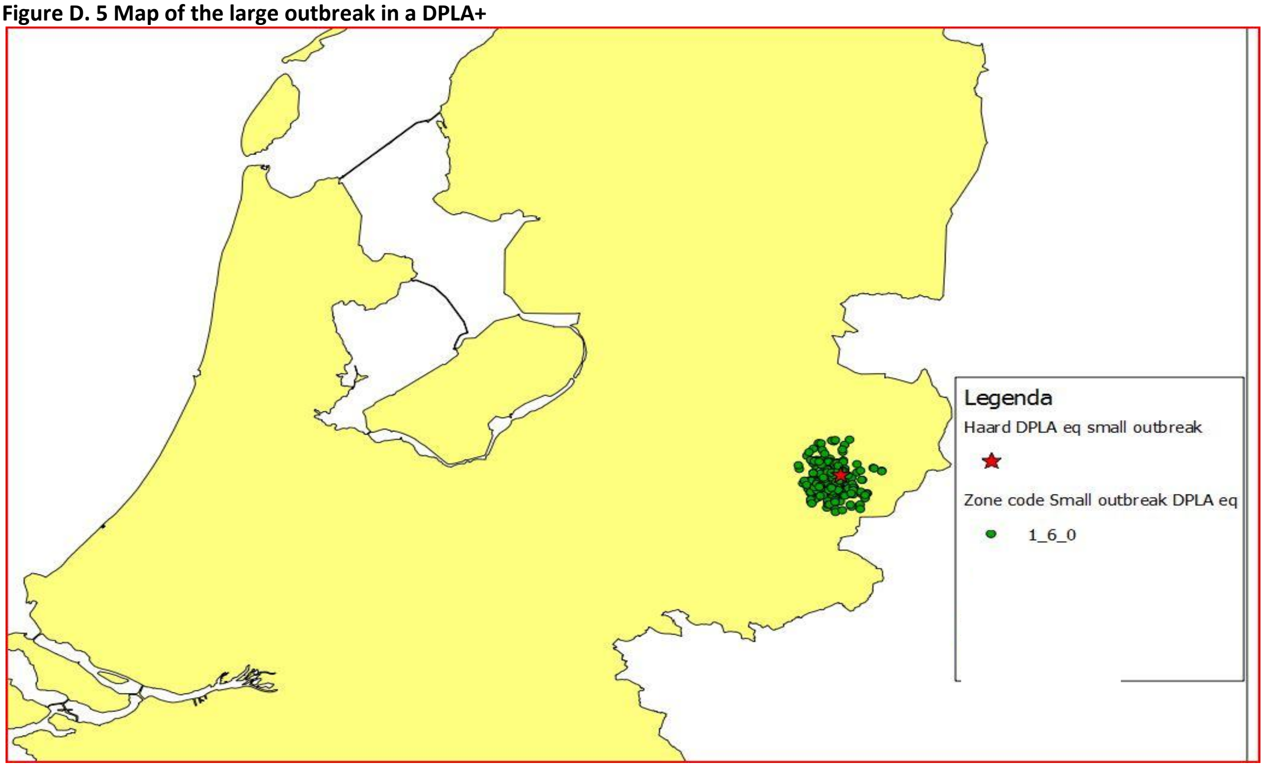


Figure D.6 Map of the small outbreak in a DPLAeq

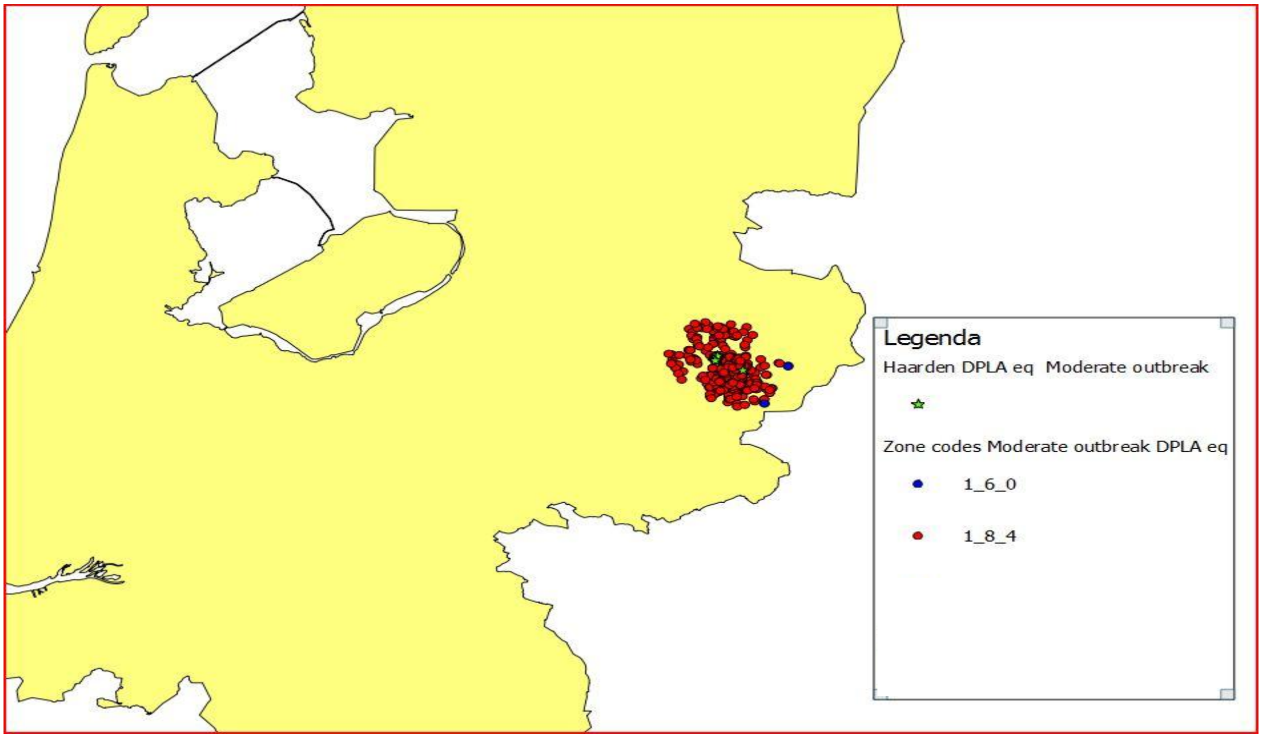


Figure D.7 Map of the moderate outbreak in a DPLAeq

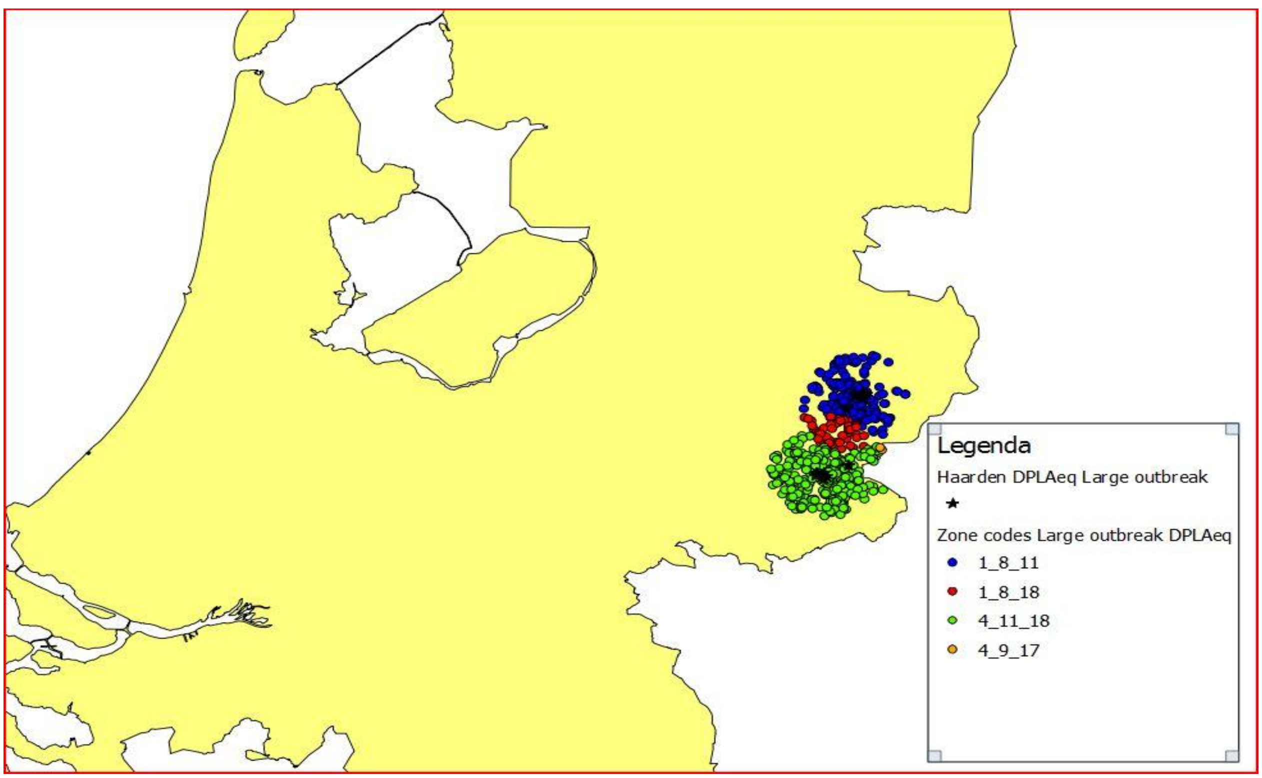


Figure D.8 Map of the large outbreak in a DPLAeq