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Research outputs:

Effects of control measures on the spread of LA-MRSA among Danish pig herds between 2006 and 2015 – a simulation study

There has been a rapid increase in Danish pig herds testing positive for livestock-associated Methicillin-resistant Staphylococcus aureus (LA-MRSA) since the first screening in 2008. Despite a national action plan to control LA-MRSA in the Danish pig population, 88% of pig herds tested positive in a 2016 cross-sectional study of 57 herds. The national action plan was initiated in April 2015 and aimed to reduce the spread of LA-MRSA among pig herds. However, its success is uncertain. We used a simulation model mimicking the spread of LA-MRSA among pig herds between 2006 and 2015 to evaluate the impact of control strategies if these had been implemented in 2007 or 2010. The strategies were combinations of the following control measures: (1) a reduced number of herds using high-risk antibiotics, (2) a reduced probability of indirect transmission among herds via humans, (3) movement restrictions, and (4) voluntary eradication in 5–7.5% of the herds. Almost all tested control strategies simulated a reduction in the spread of LA-MRSA. The combination of two, three or four intervention strategies showed additive effects and led to larger reductions in the predicted herd prevalence. In addition, the prevalence of LA-MRSA-positive herds at the time when control measures were initiated influenced the effects of the control strategies. Combining the simulated control measures can be considered in future action plans to control LA-MRSA.

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Simulation of transmission and persistence of African swine fever in wild boar in Denmark

African swine fever (ASF) is caused by ASF virus (ASFV) and is currently circulating in the eastern part of Europe posing a serious risk regarding transmission to western European countries. Wild boar is a main driver of the transmission and persistence of ASFV in the endemic infected countries in Europe. Some European countries free from ASF, such as Denmark and the Netherlands, have limited population sizes of wild boar, but have large swine productions. In these countries, the patterns of transmission and persistence of ASFV in the existing wild boar population, in case of introduction of ASFV, are unknown. It is important to get a better understanding of ASFV in these wild boar populations, in order to better manage the existing wild boar population and thereby minimize the risk of virus introduction and transmission to domestic pigs, in case of an ASFV incursion. We created an agent-based spatio-temporal model and simulated the transmission of ASFV within Danish wild boar populations, using actual landscape data. The model was run with 50 and 100 wild boar groups used as initial population sizes, respectively, either distributed across the southern part of the mainland (Jutland) or across both the southern and middle parts of Jutland, where wild boar groups are believed to exist. At first, the model was run without ASFV for 25 years to assess wild boar population dynamics in both regions. Thereafter, ASFV was added to the model 1 year after initiation and run for up to another 4 years. The model predicted that wild boar populations may increase drastically over the next 25 years, if wild boar groups were distributed across both southern and middle Jutland and no mitigation actions were taken, while the population sizes will be restricted, if groups were distributed only across the southern part of Jutland. The density of the population is an important factor affecting the transmission and persistency of the disease. Model results indicated that ASF epidemics in the simulated populations would generally persist for few months. However, due to the high stochasticity of the process, in certain situations the epidemics may last for more than one year, posing a serious risk of ASFV introduction to domestic pigs.

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Vildsvinehegn virker som en del af løsningen

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Contributors: Boklund, A., Chriél, M., Bøtner, A., Hisham Beshara Halasa, T., Mortensen, S.
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Afrikansk svinepest - en alvorlig trussel for hele svinebranchen

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Building the foundation for veterinary register-based epidemiology: A systematic approach to data quality assessment and validation

Epidemiological studies often use data from registers. Data quality is of vital importance for the quality of the research. The aim of this study was to suggest a structured workflow to assess the quality of veterinary national registers. As an example of how to use the workflow, the quality of the following three registers was assessed: the Central Husbandry Register (CHR), the database for movement of pigs (DMP) and the national Danish register of drugs for veterinary use (VetStat). A systematic quantitative assessment was performed, with calculation the proportion of farms and observations with "poor quality" of data. "Poor" quality was defined for each measure (variable) either as a mismatch between and/or within registers, registrations of numbers outside the expected range, or unbalanced in- and outgoing movements. Interviews were conducted to make a complementary qualitative assessment. The proportion of farms and observations within each quality measure varied. This study highlights the importance of systematic quality assessment of register data and suggests a systematic approach for such assessments and validations without the use of primary data.

General information
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Drivers for Livestock-Associated Methicillin-Resistant Staphylococcus Aureus Spread Among Danish Pig Herds - A Simulation Study

To gain insight into the rapid increase in the number of livestock-associated Methicillin-resistant Staphylococcus aureus (LA-MRSA)-positive herds in Denmark, we developed an individual-based Monte Carlo simulation model. We aimed to assess whether transmission of LA-MRSA via pig movements could explain the observed increase in the number of positive herds in Denmark, and to evaluate the effect of other between-herd transmission mechanisms. Pig movements alone were not sufficient to mimic the observed increase in LA-MRSA-positive herds in Denmark in any of the modelled scenarios. The model identified three factors that played important roles in the between-herd spread of LA-MRSA: (1) the within-herd dynamics, (2) the frequency and effectiveness of indirect transmissions, and (3) unexplainable introduction of LA-MRSA to swine herds. These factors can act as starting points for the development of LA-MRSA control programs in pig herds in order to limit the risk of its transmission to humans.

Infection of pigs with African swine fever virus via ingestion of stable flies (Stomoxys calcitrans)

Within Eastern Europe, African swine fever virus (ASFV) has unexpectedly spread to farms with high biosecurity. In an attempt to explain this process, pigs were allowed to ingest flies that had fed on ASFV-spiked blood, which had a realistic titre for an infected pig. Some of the pigs became infected with the virus. Thus, ingestion of blood-sucking flies, having fed on ASFV-infected wild boar before entering stables, represents a potential route for disease transmission.
Modeling the Effects of Duration and Size of the Control Zones on the Consequences of a Hypothetical African Swine Fever Epidemic in Denmark

African swine fever (ASF) is a notifiable infectious disease. The disease is endemic in certain regions in Eastern Europe constituting a risk of ASF spread toward Western Europe. Therefore, as part of contingency planning, it is important to continuously explore strategies that can effectively control an epidemic of ASF. A previously published and well documented simulation model for ASF virus spread between herds was used to examine the epidemiologic and economic impacts of the duration and size of the control zones around affected herds. In the current study, scenarios were run, where the duration of the protection and surveillance zones were reduced from 50 and 45 days to 35 and 25 days or to 35 and 25 days, respectively. These scenarios were run with or without enlargement of the surveillance zone around detected herds from 10 to 15 km. The scenarios were also run with only clinical or clinical and serological surveillance of herds within the zones. Sensitivity analysis was conducted on influential input parameters in the model. The model predicts that reducing the duration of the protection and surveillance zones has no impact on the epidemiologic and economic consequences of the epidemics, while it may result in a substantial reduction in the total economic losses. In addition, the model predicts that increasing the size of the surveillance zone from 10 to 15 km may reduce both the epidemic duration and the total economic losses, in case of large epidemics. The ranking of the control strategies by the total costs of the epidemics was not influenced by changes of input parameters in the sensitivity analyses.

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Risk factors for the occurrence of livestock-associated methicillin-resistant Staphylococcus aureus (LA-MRSA) in Danish pig herds

Livestock-associated methicillin-resistant Staphylococcus aureus (LA-MRSA) is widespread in many European countries including Denmark, where 88% of randomly selected production herds tested positive in 2016. In the present study, we investigated herd-level risk factors for farms being classified as LA-MRSA positive (study 1), in addition to herd-level risk factors for farms changing status from LA-MRSA negative to LA-MRSA positive during a 2-year period (study 2). Risk factors previously identified in other studies were confirmed in study 1: large herd size, herd type (lower risk in herds with sows) and number of pig suppliers. Due to the effect of herd type, data from sow herds (N = 41) and herds without sows (N = 166) were analysed separately. A univariable analysis found that the variables significantly associated with LA-MRSA status for sow herds were: use of wet feed in the sow units; higher weights of piglets at weaning; availability of a delivery room on the farm; cleaning of aisles after pigs were moved; number of pigs per weaner section; number of pigs purchased in the past year, and factors related to rodent control and human traffic in the herd. In herds without sows, the univariable analysis showed that the presence of other species of animal on the farm; negative pressure ventilation; full sectioning; frequent visits from the veterinarian; peroral use of tetracyclines for weaners; number of pigs purchased in the past year, and factors related to rodent control and human traffic in the herd were significantly associated with LA-MRSA status. For herds that changed from LA-MRSA negative to positive (study 2), having a company contract for mouse control, having more than one pig supplier and using group medication in the drinking water were the variables associated with LA-MRSA status. We did not succeed in building a biologically meaningful multivariable model based on any of the datasets and, as observed in similar studies, many of the risk factors identified in the univariable analysis were related to herd size. It was therefore not possible to determine whether it was the size of the herd or related factors that were the causal risk factors for being LA-MRSA positive.

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Short time window for transmissibility of African swine fever virus from a contaminated environment

Since the introduction of African swine fever virus (ASFV) into the Baltic states and Poland in 2014, the disease has continued to spread within these regions. In 2017, the virus spread further west and the first cases of disease were reported in the Czech Republic and Romania, in wild boar and domestic pigs, respectively. To control further spread, knowledge of different modes of transmission, including indirect transmission via a contaminated environment, is crucial. Up until now, such an indirect mode of transmission has not been demonstrated. In this study, transmission via an
environment contaminated with excretions from ASFV-infected pigs was investigated. Following euthanasia of pigs that were infected with an isolate of ASFV from Poland (POL/2015/Podlaskie/Lindholm), healthy pigs were introduced into the pens, in which the ASFV-infected pigs had been housed. Introduction was performed at 1, 3, 5 or 7 days, following euthanasia of the infected pig groups. Pigs, that were introduced into the contaminated environment after 1 day, developed clinical disease within 1 week, and both ASFV DNA and infectious virus were isolated from their blood. However, pigs introduced into the contaminated pens after 3, 5 or 7 days did not develop any signs of ASFV infection and no viral DNA was detected in blood samples obtained from these pigs within the following 3 weeks. Thus, it was shown that exposure of pigs to an environment contaminated with ASFV can result in infection. However, the time window for transmissibility of ASFV seems very limited, and, within our experimental system, there appears to be a rapid decrease in the infectivity of ASFV in the environment.

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Contributors: Olesen, A. S., Lohse, L., Boklund, A., Halasa, T., Belsham, G. J., Rasmussen, T. B., Bøtner, A.
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A mechanistic model for spread of livestock-associated methicillin-resistant Staphylococcus aureus (LA-MRSA) within a pig herd
Before an efficient control strategy for livestock-associated methicillin resistant Staphylococcus aureus (LA-MRSA) in pigs can be decided upon, it is necessary to obtain a better understanding of how LA-MRSA spreads and persists within a pig herd, once it is introduced. We here present a mechanistic stochastic discrete-event simulation model for spread of LA-MRSA within a farrow-to-finish sow herd to aid in this. The model was individual-based and included three different disease compartments: susceptible, intermittent or persistent shedder of MRSA. The model was used for studying transmission dynamics and within-farm prevalence after different introductions of LA-MRSA into a farm. The spread of LA-MRSA throughout the farm mainly followed the movement of pigs. After spread of LA-MRSA had reached equilibrium, the prevalence of LA-MRSA shedders was predicted to be highest in the farrowing unit, independent of how LA-MRSA was introduced. LA-MRSA took longer to spread to the whole herd if introduced in the finisher stable, rather than by gilts in the mating stable. The more LA-MRSA positive animals introduced, the shorter time before the prevalence in the herd stabilised. Introduction of a low number of intermittently shedding pigs was predicted to frequently result in LA-MRSA fading out. The model is a potential decision support tool for assessments of short and long term consequences of proposed intervention strategies or surveillance options for LA-MRSA within pig herds.

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Contributors: Sørensen, A. I. V., Toft, N., Boklund, A., Espinosa-Gongora, C., Græsbøll, K., Larsen, J., Hisham Beshara Halasa, T.
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Associations between Antibacterial Treatment and the Prevalence of Tail-Biting-Related Sequelae in Danish Finishers at Slaughter

Secondary infections as a result of tail biting cause substantial economic losses in pig production and are a subject of concern for animal welfare. The use of first-choice antibacterial agents in the treatment of tail biting in finishing pigs is hypothesized to be negatively correlated with the development of systemic infection. This would be expected to reduce the prevalence of post-mortem pyemic sequelae (such as osteomyelitis and abscesses) in finishers with tail-bite lesions. We performed a register-based study that included three Danish databases, holding information on the purchase of antibacterials at herd level (VetStat), herd demographics (Central Husbandry Register), and relevant observations at slaughter (meat inspection data). We included all finishers from indoor production finisher herds that met the inclusion criterion of at least one slaughtered finisher with a recorded tail-bite observation during 2015 at the single largest Danish abattoir. The final dataset held 1,070 herds with one or more tail-bite observations, from which 14,411 of 2,906,626 finishers (0.50%) had an individual record of a tail bite. Within this group of finishers with tail-bite observations, the recorded tail-biting-related sequelae included osteomyelitis (8.1%), abscesses in the hindquarters (10.5%), abscesses in the forequarters (2.3%), abscesses in the mid-section of the carcass (2.9%), abscesses in the limbs (2.4%), and chronic arthritis (0.5%). Due to a high-herd prevalence (>25%), osteomyelitis and abscesses in the hindquarters were selected for further analysis. The occurrence of osteomyelitis and hindquarter abscesses in individual finishers with tail-bite observations was described using a generalized linear mixed effects model with binomial response and logit link. Herd was included as a random effect, while herd size and various antibacterial treatments were tested for inclusion in the model as fixed effects. The final models indicated a significant association between herd size and both osteomyelitis (p = 0.014) and hindquarter abscesses (p < 0.001), with larger herds (2,001–12,000 registered finisher pigs) showing a reduced risk. Further, a negative association was found between the occurrence of hindquarter abscesses and the use of oral pleuromutilin (p = 0.022). The significant association with herd size highlights the potential importance of management factors in reducing the occurrence of tail-bite lesions in finishing pigs.

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Evaluation of Strategies to Control a Potential Outbreak of Foot-and-Mouth Disease in Sweden

To minimize the potential consequences of an introduction of foot-and-mouth disease (FMD) in Europe, European Union (EU) member states are required to present a contingency plan. This study used a simulation model to study potential outbreak scenarios in Sweden and evaluate the best control strategies. The model was informed by the Swedish livestock structure using herd information from cattle, pig, and small ruminant holdings in the country. The contact structure was based on animal movement data and studies investigating the movements between farms of veterinarians, service trucks, and other farm visitors. All scenarios of outbreak control included depopulation of detected herds, 3 km protection and 10 km surveillance zones, movement tracing, and 3 days national standstill. The effect of availability of surveillance resources, i.e., number of field veterinarians per day, and timeliness of enforcement of interventions, was assessed. With the estimated currently available resources, an FMD outbreak in Sweden is expected to be controlled (i.e., last infected herd detected) within 3 weeks of detection in any evaluated scenario. The density of farms in the area where the epidemic started would have little impact on the time to control the outbreak, but spread in high density areas would require more surveillance resources, compared to areas of lower farm density. The use of vaccination did not result in a reduction in the expected number of infected herds. Preemptive depopulation was able to reduce the number of infected herds in extreme scenarios designed to test a combination of worst-case conditions of virus introduction and spread, but at the cost of doubling the number of herds culled. This likely resulted from a combination of the small outbreaks predicted by the spread model, and the high efficacy of the basic control measures evaluated, under the conditions of the Swedish livestock industry, and considering the assumed control resources available. The results indicate that the duration and extent of FMD outbreaks could be kept limited in Sweden using the EU standard control strategy and a 3 days national standstill.
Mulighederne for en bedre udnyttelse af de økonomiske ressourcer til det veterinære beredskab for mund- og klovsyge

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Contributors: Christensen, T., Denver, S., Boklund, A., Halasa, T.
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Network analysis of pig movements: Loyalty patterns and contact chains of different holding types in Denmark

Understanding animal movements is an important factor for the development of meaningful surveillance and control programs, but also for the development of disease spread models. We analysed the Danish pig movement network using static and temporal network analysis tools to provide deeper insight in the connection between holdings dealing with pigs, such as breeding and multiplier herds, production herds, slaughterhouses or traders. Pig movements, which occurred between 1 January 2006 and 31 December 2015 in Denmark, were summarized to investigate temporal trends such as the number of active holdings, the number of registered movements and the number of pigs moved. To identify holdings and holding types with potentially higher risk for introduction or spread of diseases via pig movements, we determined loyalty patterns, annual network components and contact chains for the 24 registered holding types. The total number of active holdings as well as the number of pig movements decreased during the study period while the holding sizes increased. Around 60-90% of connections between two pig holdings were present in two consecutive years and around one third of the connections persisted within the considered time period. Weaner herds showed the highest level of in-loyalty, whereas we observed an intermediate level of in-loyalty for all breeding sites and for production herds. Boar stations, production herds and trade herds showed a high level of out-loyalty. Production herds constituted the highest proportion of holdings in the largest strongly connected component. All production sites showed low levels of in-going contact chains and we observed a high level of out-going contact chain for breeding and multiplier herds. Except for livestock auctions, all transit sites also showed low levels of out-going contact chains. Our results reflect the pyramidal structure of the underlying network. Based on the considered disease, the time frame for the calculation of network measurements needs to be adapted. Using these adapted values for loyalty and contact chains might help to identify holdings with high potential of spreading diseases and thus limit the outbreak size or support control or eradication of the considered pathogen.

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Preparedness planning for a veterinary crisis is important to be fast and effective in the eradication of disease. For countries with a large export of animals and animal products, each extra day in an epidemic will cost millions of Euros due to the closure of export markets. This is important for the Danish husbandry industry, especially the swine industry, which had an export of €4.4 billion in 2012. The purposes of this project were to (1) develop an iterative tool with the aim of estimating the resources needed during an outbreak of foot-and-mouth disease (FMD) in Denmark, (2) identify areas, which can delay the control of the disease. The tool developed should easily be updated, when knowledge is gained from other veterinary crises or during an outbreak of FMD. The stochastic simulation model DTU-DADS was used to simulate spread of FMD in Denmark. For each task occurring during an epidemic of FMD, the time and personnel needed per herd was estimated by a working group with expertise in contingency and crisis management. By combining this information, an iterative model was created to calculate the needed personnel on a daily basis during the epidemic. The needed personnel was predicted to peak within the first week with a requirement of approximately 123 (65-175) veterinarians, 33 (23-64) technicians, and 36 (26-49) administrative staff on day 2, while the personnel needed in the Danish Emergency Management Agency (responsible for the hygiene barrier and initial cleaning and disinfection of the farm) was predicted to be 174 (58-464), mostly recruits. The time needed for surveillance visits was predicted to be the most influential factor in the calculations. Based on results from a stochastic simulation model, it was possible to create an iterative model to estimate the requirements for personnel during an FMD outbreak in Denmark. The model can easily be adjusted, when new information on resources appears from management of other crisis or from new model runs.
We present two simple, semiquantitative model-based decision tools, based on the principle of first 14 days incidence (FFI). The aim is to estimate the likelihood and the consequences, respectively, of the ultimate size of an ongoing FMD epidemic. The tools allow risk assessors to communicate timely, objectively, and efficiently to risk managers and less technically inclined stakeholders about the potential of introducing FMD suppressive emergency vaccination. To explore the FFI principle with complementary field data, we analyzed the FMD outbreaks in Argentina in 2001, with the 17 affected provinces as the units of observation. Two different vaccination strategies were applied during this extended epidemic. In a series of 5,000 Danish simulated FMD epidemics, the numbers of outbreak herds at day 14 and at the end of the epidemics were estimated under different control strategies. To simplify and optimize the presentation of the resulting data for urgent decisions to be made by the risk managers, we estimated the sensitivity, specificity, as well as the negative and positive predictive values, using a chosen day-14 outbreak number as predictor of the magnitude of the number of remaining post-day-14 outbreaks under a continued basic control strategy. Furthermore, during an ongoing outbreak, the actual cumulative number of detected infected herds at day 14 will be known exactly. Among the number of epidemics lasting >14 days out of the 5,000 simulations under the basic control scenario, we selected those with an assumed accumulated number of detected outbreaks at day 14. The distribution of the estimated number of detected outbreaks at the end of the simulated epidemics minus the number at day 14 was estimated for the epidemics lasting more than 14 days. For comparison, the same was done for identical epidemics (i.e., seeded with the same primary outbreak herds) under a suppressive vaccination scenario. The results indicate that, during the course of an FMD epidemic, simulated likelihood predictions of the remaining epidemic size and of potential benefits of alternative control strategies can be presented to risk managers and other stakeholders in objective and easily communicable ways.

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Transmission of African swine fever virus from infected pigs by direct contact and aerosol routes
In 2014, African swine fever virus (ASFV) was introduced into the Baltic states and Poland. Since then, the disease has continued to spread within these regions, and recently, cases were reported in the Czech Republic and Romania. Currently, there is an increasing risk of ASFV introduction into Western Europe. Hence, there is an urgent need to assess current contingency plans. For this purpose, knowledge of modes-of-transmission and clinical outcome in pigs infected with new European ASFV strains is needed. In the present study, two experiments were conducted in pigs using an isolate of ASFV from Poland (designated here POL/2015/Podlaskie/Lindholm). In both studies, pigs were inoculated intranasally with the virus and contact pigs were exposed to the experimentally infected pigs, either directly (contact within and between pens) or by air. Pigs exposed to the virus by intranasal inoculation, by direct contact to infected animals and by aerosol developed acute disease characterized by viremia, fever and depression. Infectious virus was first detected in blood obtained from the inoculated pigs and then sequentially among the within-pen, between-pen and air-contact pigs. ASFV DNA and occasionally infectious virus was found in nasal-, oral-, and rectal swabs obtained from the pigs, and ASFV DNA was detected in air samples. No anti-ASFV antibodies were detected in sera. In conclusion, the study shows that the currently circulating strain of ASFV can be efficiently transmitted via direct contact and by aerosols. Also, the results provide quantitative transmission parameters and knowledge of infection stages in pigs infected with this ASFV.

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Organisations: National Veterinary Institute, Virology, Epidemiology, National Veterinary Research Institute, Centro de Investigación en Sanidad Animal
A register-based study of the antimicrobial usage in Danish veal calves and young bulls

High antimicrobial usage and multidrug resistance have been reported in veal calves in Europe. This may be attributed to a high risk of disease as veal calves are often purchased from numerous dairy herds, exposed to stress related to the transport and commingling of new animals, and fed a new ration. In this study, we used national register data to characterize the use of antimicrobials registered for large Danish veal calf and young bull producing herds in 2014. A total of 325 herds with veal calf and potentially young bull production were identified from the Danish Cattle database. According to the national Danish database on drugs for veterinary use (VetStat), a total of 537,399 Animal Daily Doses (ADD200) were registered for these 325 herds during 2014. The amount of antimicrobials registered in 2014 varied throughout the year, with the highest amounts registered in autumn and winter. Antimicrobials were registered for respiratory disorders (79%), joints/limbs/CNS disorders (17%), gastrointestinal disorders (3.7%) and other disorders (0.3%). Of the registered antimicrobials, 15% were for oral and 85% for parenteral administration. Long-acting formulations with a therapeutic effect of more than 48h covered 58% of the drugs for parenteral use. Standardized at the herd-level, as ADD200/100 calves/day, antimicrobial use distributed as median [CI95%] for starter herds (n=22): 2.14 [0.19;7.58], finisher herds (n=24): 0.48 [0.00;1.48], full-line herds (n=183): 0.78 [0.05;2.20] and herds with an inconsistent pattern of movements (n=96): 0.62 [0.00;2.24]. Full-line herds are herds, which purchase calves directly from a dairy herd and raise them to slaughter. Furthermore, we performed a risk factor analysis on the 183 herds with a full-line production. Here, we investigated, whether the number of suppliers, the number of calves purchased, the frequency of purchase, the average age at introduction, the average time in the herd and vaccination influenced the amount of antimicrobials used in the herds. The final multivariable regression analysis revealed that the number of calves introduced was positively associated with the antimicrobial use in the herd.
A simulation model for the spread of LA-MRSA within a pig herd

Changes in group treatment procedures of Danish finishers and its influence on the amount of administered antimicrobials
Control of African swine fever epidemics in industrialized swine populations

African swine fever (ASF) is a notifiable infectious disease with a high impact on swine health. The disease is endemic in certain regions in the Baltic countries and has spread to Poland constituting a risk of ASF spread toward Western Europe. Therefore, as part of contingency planning, it is important to explore strategies that can effectively control an epidemic of ASF. In this study, the epidemiological and economic effects of strategies to control the spread of ASF between domestic swine herds were examined using a published model (DTU-DADS-ASF). The control strategies were the basic EU and national strategy (Basic), the basic strategy plus pre-emptive depopulation of neighboring swine herds, and intensive surveillance of herds in the control zones, including testing live or dead animals. Virus spread via wild boar was not modelled.

Under the basic control strategy, the median epidemic duration was predicted to be 21 days (5th and 95th percentiles: 1-55 days), the median number of infected herds was predicted to be 3 herds (1-8), and the total costs were predicted to be €326 million (€256–€442 million). Adding pre-emptive depopulation or intensive surveillance by testing live animals resulted in marginal improvements to the control of the epidemics. However, adding testing of dead animals in the protection and surveillance zones was predicted to be the optimal control scenario for an ASF epidemic in industrialized swine populations without contact to wild boar. This optimal scenario reduced the epidemic duration to 9 days (1–38) and the total costs to €294 million (€257–€392 million). Export losses were the driving force of the total costs of the epidemics.
Economic analysis of activities to prevent foot and mouth disease in Denmark
The latest foot and mouth disease (FMD) epidemic in Denmark dates back to 1982-1983. Hence, Denmark has not experienced an FMD outbreak in more than 30 years. Still this disease poses a serious threat either as a risk of introduction and spread in Denmark or as a risk of a ban on Danish export of pigs, pork, cattle, beef and milk products due to an outbreak in another country within the EU. It is estimated that a middle sized outbreak of FMD would cost around € 1 billion. It is evident that even though the probability of introducing FMD is very low the consequences are devastating for the agricultural sector and society because the expected costs are so enormous. Therefore, the industry and the public authority have implemented a number of mitigating and preventive activities. The costs of FMD and swine fever related activities in Denmark in 2013 were estimated to be approximately € 32 million. The purpose of the present study is to estimate how changes in resources allocated to the FMD related activities may affect the costs of an FMD outbreak. Nine alternative scenarios describing changes in the contingency plan were formulated by a group of experts from the livestock industry, universities and public authorities. A modified version of Davis Animal Disease Simulation model (DADS version 0.05) was used to estimate costs of FMD outbreaks in each of these alternative scenarios. The modified and updated version by the technical university of Denmark (DTU) is called DTU-DADS. The model simulations indicate that some changes in risk-reducing activities may significantly affect expected costs of an outbreak while other changes have no effect. Our results suggest that increased efforts in terms of efficiently restricting low-risk contacts between farms, such as non-professional visitors and trucks, might reduce the size and costs of an FMD outbreak. In addition, simulations indicate that current resources allocated to depopulation and surveillance could – but only to some extent – be reduced without affecting the size and costs of an outbreak.

Evaluation of temporal surveillance system sensitivity and freedom from bovine viral diarrhea in Danish dairy herds using scenario tree modelling
The temporal sensitivity of the surveillance system (TemSSe) for Bovine Viral Diarrhea (BVD) in Danish dairy herds was evaluated. Currently, the Danish antibody blocking ELISA is used to test quarterly bulk tank milk (BTM). To optimize the surveillance system as an early warning system, we considered the possibility of using the SVANOVIR ELISA, as this test has been shown to detect BVD-positive herds earlier than the blocking ELISA in BTM tests. Information from data (2010) and outputs from two published stochastic models were fed into a stochastic scenario tree to estimate the TemSSe. For that purpose we considered: the risk of BVD introduction into the dairy population, the ELISA used and the high risk period (HRP) from BVD introduction to testing (at 90 or 365 days). The effect of introducing one persistently infected (PI) calf or one transiently infected (TI) milking cow into 1 (or 8) dairy herd(s) was investigated. Additionally we estimated the confidence in low (PLow) herd prevalence (}
Experimental pig-to-pig transmission study with a recent European African Swine Fever virus isolate

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Organisations: National Veterinary Institute, Section for Epidemiology, Section for Virology
Contributors: Olesen, A. S., Lohse, L., Boklund, A., Hisham Beshara Halasa, T., Rasmussen, T. B., Bøtner, A.
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Risk factors for antimicrobial use in Danish rosé veal calves. A register-based study

General information
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Organisations: National Veterinary Institute, Section for Epidemiology, SEGES Cattle
Contributors: Fertner, M. E., Boklund, A., Læssøe Martin, H., Toft, N.
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Simulating the epidemiological and economic effects of an African swine fever epidemic in industrialized swine populations

African swine fever (ASF) is a notifiable infectious disease with a considerable impact on animal health and is currently one of the most important emerging diseases of domestic pigs. ASF was introduced into Georgia in 2007 and subsequently spread to the Russian Federation and several Eastern European countries. Consequently, there is a non-negligible risk of ASF spread towards Western Europe. Therefore it is important to develop tools to improve our
understanding of the spread and control of ASF for contingency planning. A stochastic and dynamic spatial spread model (DTU-DADS) was adjusted to simulate the spread of ASF virus between domestic swine herds exemplified by the Danish swine population. ASF was simulated to spread via animal movement, low- or medium-risk contacts and local spread. Each epidemic was initiated in a randomly selected herd – either in a nucleus herd, a sow herd, a randomly selected herd or in multiple herds simultaneously. A sensitivity analysis was conducted on input parameters. Given the inputs and assumptions of the model, epidemics of ASF in Denmark are predicted to be small, affecting about 14 herds in the worst-case scenario. The duration of an epidemic is predicted to vary from 1 to 76 days. Substantial economic damages are predicted, with median direct costs and export losses of €12 and €349 million, respectively, when epidemics were initiated in multiple herds. Each infectious herd resulted in 0 to 2 new infected herds varying from 0 to 5 new infected herds, depending on the index herd type.

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Web of Science (2016): Indexed yes
Original language: English
Keywords: African swine fever, Between herds, Model, Simulation, Spread
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Simulate the spread of African swine fever (ASF) within a pig unit and the impact of unit size on ASF spread, a simulation model was created. In the model, an animal can be in one of the following stages: susceptible, latent, subclinical, clinical, or recovered. Animals can be infectious during the subclinical stage and are fully infectious during the clinical stage. ASF virus (ASFV) infection through residues of dead animals in the slurries was also modeled in an exponentially fading-out pattern. Low and high transmission rates for ASFV were tested in the model. Robustness analysis was carried out in order to study the impact of uncertain parameters on model predictions. The results showed that the disease may fade out within the pig unit without a major outbreak. Furthermore, they showed that spread of ASFV is dependent on the infectiousness of subclinical animals and the residues of dead animals, the transmission rate of the virus, and importantly the unit size. Moreover, increasing the duration of the latent or the subclinical stages resulted in longer time to disease fade out. The proposed model is a simple and robust tool simulating the spread of ASFV within a pig house taking into account dynamics of ASFV spread and the unit size. The tool can be implemented in simulation models of ASFV spread between herds.

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Original language: English
The costs of preventive activities for exotic contagious diseases - A Danish case study of foot and mouth disease and swine fever: a Danish case study of foot and mouth disease and swine fever

The present paper provides an overview of the costs of preventive activities, currently undertaken in Denmark, related to foot and mouth disease (FMD) and classical and African swine fever (SF). Only costs held between outbreaks were included. Costs were divided into public costs and costs paid by the pig and cattle industries, respectively. Data were retrieved from multiple sources such as databases, legal documents, official statistics, yearly reports and expert opinions. As no previous studies have assessed such costs, data collection and estimation procedures were discussed and decided upon in a group of experts from universities, industry, and public authorities. The costs of each preventive activity were related to the type of activity, the number of times the activity was carried out and the share of costs that could be associated with FMD or SF. Uncertainty about parameters was incorporated in the analysis by assuming that the FMD/SF shares of costs as well as total costs for each activity could take on a most likely as well as a minimum and maximum value. A high degree of transparency was prioritized in the cost analysis, which enables reproducibility and easy access to conducting sensitivity analyses. A total of 27 FMD/SF preventive activities were identified. The estimated median (minimum-maximum) of total costs amounted to (sic)32 (18-50) million in 2013. The single most costly FMD/SF related activity, amounting to (sic)8 (5-13) million or 26% of total costs, was a national legal requirement to clean lorries immediately after transportation of live animals. The distribution of costs between stakeholders was estimated to be as follows: pig industry 63%, cattle industry 27%, and the public authorities 10%. Most of the activities focused on reducing the probability of spreading FMD/SF, while only a few activities were directed mainly towards reducing the probability of introduction. Legally required FMD/SF activities (mainly based on EU legislation) accounted for 60% of the activities, while FMD/SF related measures agreed on at sector level and measures implemented due to individual initiatives, such as farmer's investment in specially built delivery facilities, each accounted for 20%. (C) 2016 Elsevier B.V. All rights reserved.

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Towards control of LA-MRSA - Simulation modeling of LA-MRSA spread between pig farms

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Changing medication method influences total amount of administered antimicrobials

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Organisations: National Veterinary Institute, Section for Epidemiology
Contributors: Fertner, M. E., Boklund, A., Toft, N.
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Dødelig sygdom på fremmarch: Afrikansk svinepest

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Improving the Effect and Efficiency of FMD Control by Enlarging Protection or Surveillance Zones
An epidemic of foot-and-mouth disease (FMD) in a FMD-free country with large exports of livestock and livestock products would result in profound economic damage. This could be reduced by rapid and efficient control of the disease spread. The objectives of this study were to estimate the economic impact of a hypothetical FMD outbreak in Denmark based on changes to the economic assumptions of the model, and to investigate whether the control of an FMD epidemic can be improved by combining the enlargement of protection or surveillance zones with pre-emptive depopulation or emergency vaccination. The stochastic spatial simulation model DTU-DADS was used to simulate the spread of FMD in Denmark. The control strategies were the basic EU and Danish strategy, pre-emptive depopulation, suppressive or protective vaccination, enlarging protection or surveillance zones, and a combination of pre-emptive depopulation or emergency vaccination with enlarged protection or surveillance zones. Herds are detected either based on basic detection through the appearance of clinical signs, or as a result of surveillance in the control zones. The economic analyses consisted of direct costs and export losses. Sensitivity analysis was performed on uncertain and potentially influential input parameters. Enlarging the surveillance zones from 10 to 15 km, combined with pre-emptive depopulation over a 1-km radius around detected herds resulted in the lowest total costs. This was still the case even when the different input parameters were
changed in the sensitivity analysis. Changing the resources for clinical surveillance did not affect the epidemic consequences. In conclusion, an FMD epidemic in Denmark would have a larger economic impact on the agricultural sector than previously anticipated. Furthermore, the control of a potential FMD outbreak in Denmark may be improved by combining pre-emptive depopulation with an enlarged protection or surveillance zone.

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**Bibliographical note**
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**Persistent Spatial Clusters of Prescribed Antimicrobials among Danish Pig Farms - A Register-Based Study**
The emergence of pathogens resistant to antimicrobials has prompted political initiatives targeting a reduction in the use of veterinary antimicrobials in Denmark, especially for pigs. This study elucidates the tendency of pig farms with a significantly higher antimicrobial use to remain in clusters in certain geographical regions of Denmark. Animal Daily Doses/100 pigs/day were calculated for all three age groups of pigs (weaners, finishers and sows) for each quarter during 2012-13 in 6,143 commercial indoor pig producing farms. The data were split into four time periods of six months. Repeated spatial cluster analyses were performed to identify persistent clusters, i.e. areas included in a significant cluster throughout all four time periods. Antimicrobials prescribed for weaners did not result in any persistent clusters. In contrast, antimicrobial use in finishers clustered persistently in two areas (157 farms), while those issued for sows clustered in one area (51 farms). A multivariate analysis including data on antimicrobial use for weaners, finishers and sows as three separate outcomes resulted in three persistent clusters (551 farms). Compared to farms outside the clusters during this period, weaners, finishers and sows on farms within these clusters had 19%, 104% and 4% higher use of antimicrobials, respectively. Production type, farm type and farm size seemed to have some bearing on the clustering effect. Adding these factors as categorical covariates one at a time in the multivariate analysis reduced the persistent clusters by 24.3%, 30.5% and 34.1%, respectively.

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Contributors: Fertner, M. E., Sanchez, J., Boklund, A., Stryhn, H., Dupont, N., Toft, N.
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Preventing foot and mouth disease - how are the costs divided between the public authorities and the pig and cattle industries in Denmark?

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Simulator bruges i kampen mod plasmacytose

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Organisations: National Veterinary Institute, Section for Epidemiology, Copenhagen Fur
Contributors: Boklund, A., Hisham Beshara Halasa, T., Chriél, M., Struve, T., Østergaard, J., Clausen, J.
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Simulering af kontrolforanstaltninger til bekæmpelse af plasmacytose i minkfarme

General information
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Organisations: National Veterinary Institute, Section for Epidemiology, National Food Institute, Kopenhagen Diagnostics

Simulering af tiltag til bekæmpelse af plasmacytose i mink

General information
Publication status: Published
Organisations: National Veterinary Institute, Section for Epidemiology
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Place of publication: Aarhus N
Publisher: Kopenhagen Fur
Research output: Chapter in Book/Report/Conference proceeding – Annual report year: 2015 – Research

Weaner production with low antimicrobial usage: a descriptive study

Background: Health, productivity and antimicrobial use in the production of pigs are expected to be interrelated to some extent. Previous studies on register-based data have investigated these correlations with a subsequent large variation residing at the farm level. In order to study such farm factors in more detail we designed an elaborate interview-guide. By in-depth interviews of farmers with well-managed 7-30 kg (weaner) productions we sought to describe a set of common key-factors characterizing their management practices. Identification of such common practices could be used in follow-up projects, investigating whether identified factors really are characteristic for good-practicing farmers.

Results: Eleven farms were selected for a farm visit and in-depth interview. Participating farms used less antimicrobials than the national median (8.2 animal daily doses/100 weaners/day), had a mortality below the national average (2.9%) and an average daily weight gain above the national average (443 g/day). Similarities were observed among participating farms, including the sectioning of farms, use of all-in-all-out procedures with subsequent cleaning, purchasing 7 kg weaners from only one source, as well as active participation in management by a committed farm owner. Most farmers had a specific point of focus in their management, and were convinced that this was the reason for their success. This included; feeding, treatment strategy, refurbishment of facilities and presence in the shed.

Conclusion: According to register data, participating farms were alike; in the good league regarding use of antimicrobials, mortality and daily growth. However, on-farm interviews elucidated more heterogeneity among farmers than expected. Most of the farmers had a specific point of focus, which they considered to be crucial for their good results. These results indicate the importance of non-registerable factors, highlighting the value of qualitative study techniques in the understanding of human actions. Further studies on the effect of various farmer types are recommended.

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Organisations: National Veterinary Institute, Section for Epidemiology, University of Copenhagen
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Peer-reviewed: Yes

Publication information
A Comparison between Two Simulation Models for Spread of Foot-and-Mouth Disease

Two widely used simulation models of foot-and-mouth disease (FMD) were used in order to compare the models’ predictions in term of disease spread, consequence, and the ranking of the applied control strategies, and to discuss the effect of the way disease spread is modeled on the predicted outcomes of each model. The DTU-DADS (version 0.100), and ISP (version 2.001.11) were used to simulate a hypothetical spread of FMD in Denmark. Actual herd type, movements, and location data in the period 1st October 2006 and 30th September 2007 was used. The models simulated the spread of FMD using 3 different control scenarios: 1) A basic scenario representing EU and Danish control strategies, 2) pre-emptive depopulation of susceptible herds within a 500 meters radius around the detected herds, and 3) suppressive vaccination of susceptible herds within a 1,000 meters radius around the detected herds. Depopulation and vaccination started 14 days following the detection of the first infected herd. Five thousand index herds were selected randomly, of which there were 1,000 cattle herds located in high density cattle areas and 1,000 in low density cattle areas, 1,000 swine herds located in high density swine areas and 1,000 in low density swine areas, and 1,000 sheep herds. Generally, DTU-DADS predicted larger, longer duration and costlier epidemics than ISP, except when epidemics started in cattle herds located in high density cattle areas. ISP supported suppressive vaccination rather than pre-emptive depopulation, while DTU-DADS was indifferent to the alternative control strategies. Nonetheless, the absolute differences between control strategies were small making the choice of control strategy during an outbreak to be most likely based on practical reasons.

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Organisations: National Veterinary Institute, Section for Epidemiology, Department of Applied Mathematics and Computer Science, Statistics and Data Analysis, Dynamical Systems
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Web of Science (2014): Indexed yes
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Bibliographical note
Impact of clinical surveillance during a foot-and-mouth disease epidemic

The objectives of this study were to assess, whether the current surveillance capacity is sufficient to fulfill EU and Danish regulations to control a hypothetical foot-and-mouth disease (FMD) epidemic in Denmark, and whether enlarging the protection and/or surveillance zones could reduce epidemic duration, number of infected herds and the economic losses from an epidemic.

The stochastic spatial simulation model DTU-DADS was enhanced to include simulation of surveillance of herds within the protection and surveillance zones and the model was used to model spread of FMD between herds. A queuing system was included in the model, and based on a daily surveillance capacity of 450 herds per day, it was decided whether herds appointed for surveillance would be surveyed on the current day or added to the queue. The model was run with a basic scenario representing the EU and Danish regulations, which includes a 3 km protection and 10 km surveillance zone around detected herds. In alternative scenarios, the protection zone was enlarged to 5 km, the surveillance zone was enlarged to 15 or 20 km, or a combined enlargement of the protection and surveillance zones was modelled. Sensitivity analysis included changing 1) surveillance capacity to 200, 350 or 600 herds per day, 2) frequency of repeated visits for herds in overlapping surveillance zones from every 14 days to every 7, 21 and 30 days, and 3) the size of the zones combined with a surveillance capacity increased to 600 herds per day.

The results showed that the default surveillance capacity is sufficient to survey herds within one week of the zones establishment, as the regulations demand. Extra resources for surveillance did not reduce the costs of the epidemics, but fewer resources could result in larger epidemics and costs. Furthermore, enlarging the surveillance zone may result in shorter epidemic duration, and lower number of affected herds, while enlargements of the protection zone resulted in lower economic losses when epidemics were large. Given the assumptions, enlarging the surveillance zone did not reduce the economic losses.

Persistent spatial clusters of prescribed porcine antimicrobials

General information
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Quantitative assessment of the risk of introduction of bovine viral diarrhea virus in Danish dairy herds

A quantitative risk assessment was carried out to estimate the likelihood of introducing bovine viral diarrhea virus (BVDV) in Danish dairy herds per year and per trimester, respectively. The present study gives important information on the impact of risk mitigation measures and sources of uncertainty due to lack of data. As suggested in the Agreement on the
Application of Sanitary and Phytosanitary Measures (SPS Agreement), the OIE Terrestrial Animal Health Code was followed for a transparent science-based risk assessment. Data from 2010 on imports of live cattle, semen, and embryos, exports of live cattle, as well as use of vaccines were analyzed. Information regarding the application of biosecurity measures, by veterinarians and hoof trimmers practicing in Denmark and in other countries, was obtained by contacting several stakeholders, public institutions and experts. Stochastic scenario trees were made to evaluate the importance of the various BVDV introduction routes. With the current surveillance system, the risk of BVDV introduction was estimated to one or more introductions within a median of nine years (3–59). However, if all imported animals were tested and hoof trimmers always disinfected the tools used abroad, the risk could be reduced to one or more introductions within 33 years (8–200). Results of this study can be used to improve measures of BVD surveillance and prophylaxis in Danish dairy herds.

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Web of Science (2014): Impact factor 2.167
Web of Science (2014): Indexed yes
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Resource estimations in contingency planning for FMD
Based on results from a stochastic simulation model, it was possible to create a simple model in excel to estimate the requirements for personnel and materiel during an FMD outbreak in Denmark. The model can easily be adjusted, when new information on resources appears from management of other crisis or from new model runs.

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Resource Estimations in Contingency Planning for Foot-And-Mouth Disease
Introduction
Preparedness planning for a veterinary crisis is important to be fast and effective in the eradication of disease. For countries with a large export of animals and animal products, each day in an epidemic will cost millions of euros due to the closure of export markets. This is important for the Danish swine industry, which had an export of €4.4 billion in 2012.
Materials and methods
The purposes of this project were to: 1) estimate the resources needed during an outbreak of FMD in Denmark, 2) identify areas, which can delay the control of the disease, and 3) develop an iterative tool, which can easily be updated, when knowledge is gained from other veterinary crises or during an outbreak of FMD.

A stochastic simulation model was developed in InterSpread Plus to simulate spread of FMD in Denmark. The personnel and resource needs was estimated using results from this model.

Results

We estimated that the need for personnel would peak on day 7 with a requirement of approximately 170 veterinarians, 70 technicians and 45 administrative staff. However, the need for personnel in the Danish Emergency Management Agency (responsible for the hygiene barrier and initial cleaning and disinfection of the farm) would peak already on day 4 with a requirement for almost 500 persons, mostly recruits.

On average, 53000 animals were culled during the simulated epidemics, leading to a daily need for rendering capacity of up to 210 tons for swine and 379 tons for ruminants.

Discussion

Based on results from a stochastic simulation model, it was possible to create a simple model in excel to estimate the requirements for personnel and materiel during an FMD outbreak in Denmark. The model can easily be adjusted, when new information on resources appears from management of other crisis or from new model runs.

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Resource Estimations in Contingency Planning for Foot-And-Mouth Disease

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A stochastic simulation model was developed in InterSpread Plus to simulate spread of FMD in Denmark. The personnel and resource needs was estimated using results from this model.

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Success factors in weaner production - with limited antimicrobials, high health and productivity. Case studies from Denmark

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The Impact of Resources for Clinical Surveillance on the Control of a Hypothetical Foot-and-Mouth Disease Epidemic in Denmark.
The objectives of this study were to assess whether current surveillance capacity is sufficient to fulfill EU and Danish regulations to control a hypothetical foot-and-mouth disease (FMD) epidemic in Denmark, and whether enlarging the protection and/or surveillance zones could minimize economic losses. The stochastic spatial simulation model DTU-DADS was further developed to simulate clinical surveillance of herds within the protection and surveillance zones and used to model spread of FMD between herds. A queuing system was included in the model, and based on daily surveillance capacity, which was 450 herds per day, it was decided whether herds appointed for surveillance would be surveyed on the
The model was run with a basic scenario representing the EU and Danish regulations, which includes a 3 km protection and 10 km surveillance zone around detected herds. In alternative scenarios, the protection zone was enlarged to 5 km, the surveillance zone was enlarged to 15 or 20 km, or a combined enlargement of the protection and surveillance zones was modelled. Sensitivity analysis included changing surveillance capacity to 200, 350 or 600 herds per day, frequency of repeated visits for herds in overlapping surveillance zones from every 14 days to every 7, 21 and 30 days, and the size of the zones combined with a surveillance capacity increased to 600 herds per day.

The results showed that the default surveillance capacity is sufficient to survey herds on time. Extra resources for surveillance did not improve the situation, but fewer resources could result in larger epidemics and costs. Enlarging the protection zone was a better strategy than the basic scenario. Despite that enlarging the surveillance zone might result in shorter epidemic duration, and lower number of affected herds, it resulted frequently in larger economic losses.

Assessment of confidence in freedom from Aujeszky's disease and classical swine fever in Danish pigs based on serological sampling—Effect of reducing the number of samples

Confirming freedom from disease is important for export of animals and animal products. In Denmark, an intensive surveillance program is in place for Aujeszky's disease (AD) and classical swine fever (CSF), including 34,974 blood samples tested for AD and 37,414 samples tested for CSF (2008 figures). In the current system, 3.5% of sows and boars for export or slaughter are tested for both diseases, as well as all boars before entering boar stations. Furthermore, nucleus herds are tested every third month for classical swine fever.

We investigated, whether the sample size could be reduced without compromising the posterior probability of freedom (PostPFree) from AD and CSF by use of a scenario tree model. Conventional herds and sows or boars were defined as risk factors (compared to SPF1 herds and finisher pigs), with a relative risk of 2 and 5, respectively. The probability of introduction was modeled as a distribution (0.0042:0.0083; 0.05), and the within-herd and between-herd design prevalence were set to 0.05 and 0.01, respectively.

If 50 and 75% of the test results from exported or slaughtered sows and boars were simulated to be removed at random, while the blood samples from boar stations were kept constant (reflecting a total reduction of 28 or 43%) the PostPFree from AD was reduced from 0.989 after 1 year testing to 0.980 or 0.971, respectively. Similarly, the confidence of freedom from CSF was reduced from 0.989 to 0.982 or 0.969, when the number of serological samples from abattoirs and export sows and boars is reduced by 50 or 75%, respectively (reflecting a total reduction of 34 or 51%), and further to 0.978 or 0.963 if sampling in nucleus herds was stopped (reflecting a total reduction of 41 or 59%).

The results show that a reduction in the sampling size of Danish sows will have limited effect on the PostPFree from AD and CSF, and that sampling in nucleus herds for CSF adds little to the PostPFree from CSF.
Comparing control strategies against foot-and-mouth disease: Will vaccination be cost-effective in Denmark?

Recent outbreaks of foot-and-mouth disease (FMD) in Europe have highlighted the need for assessment of control strategies to optimise control of the spread of FMD. Our objectives were to assess the epidemiological and financial impact of simulated FMD outbreaks in Denmark and the effect of using ring depopulation or emergency vaccination to control these outbreaks. Two stochastic simulation models (InterSpreadPlus (ISP) and the modified Davis Animal Disease Simulation model (DTU-DADS)) were used to simulate the spread of FMD in Denmark using different control strategies. Each epidemic was initiated in one herd (index herd), and a total of 5000 index herds were used. Four types of control measures were investigated: (1) a basic scenario including depopulation of detected herds, 3km protection and 10km surveillance zones, movement tracing and a three-day national standstill, (2) the basic scenario plus depopulation in ring zones around detected herds (Depop), (3) the basic scenario plus protective vaccination within ring zones around detected herds, and (4) the basic scenario plus protective vaccination within ring zones around detected herds. Disease spread was simulated through direct animal movements, medium-risk contacts (veterinarians, artificial inseminators or milk controllers), low-risk contacts (animal feed and rendering trucks, technicians or visitors), market contacts, abattoir trucks, milk tanks, or local spread. The two simulation models showed different results in terms of the estimated numbers. However, the tendencies in terms of recommendations of strategies were similar for both models. Comparison of the different control strategies showed that, from an epidemiological point of view, protective vaccination would be preferable if the epidemic started in a cattle herd in an area with a high density of cattle, whereas if the epidemic started in an area with a low density of cattle or in other species, protective vaccination or depopulation would have almost the same preventive effect. Implementing additional control measures either 14 days after detection of the first infected herd or when 10 herds have been diagnosed would be more efficient than implementing additional control measures when more herds have been diagnosed. Protective vaccination scenarios would never be cost-effective, whereas depopulation or suppressive vaccination scenarios would most often be recommended. Looking at the median estimates of the cost-benefit analysis, depopulation in zones would most often be recommended, although, in extreme epidemics, suppressive vaccination scenarios could be less expensive. The vast majority of the costs and losses associated with a Danish epidemic could be attributed to export losses.
Decisions on control of foot-and-mouth disease informed using model predictions

The decision on whether or not to change the control strategy, such as introducing emergency vaccination, is perhaps one of the most difficult decisions faced by the veterinary authorities during a foot-and-mouth disease (FMD) epidemic. A simple tool that may predict the epidemic outcome and consequences would be useful to assist the veterinary authorities in the decision-making process. A previously proposed simple quantitative tool based on the first 14 days outbreaks (FFO) of FMD was used with results from an FMD simulation exercise. Epidemic outcomes included the number of affected herds, epidemic duration, geographical size and costs. The first 14 days spatial spread (FFS) was also included to further support the prediction. The epidemic data was obtained from a Danish version (DTU-DADS) of a pre-existing FMD simulation model (Davis Animal Disease Spread – DADS) adapted to model the spread of FMD in Denmark. The European Union (EU) and Danish regulations for FMD control were used in the simulation. The correlations between FFO and FFS and the additional number of affected herds after day 14 following detection of the first infected herd were 0.66 and 0.82, respectively. The variation explained by the FFO at day 14 following detection was high (P-value < 0.001). This indicates that the FFO may take a part in the decision of whether or not to intensify FMD control, for instance by introducing emergency vaccination and/or pre-emptive depopulation, which might prevent a “catastrophic situation”. A significant part of the variation was explained by supplementing the model with the FFS (P-value < 0.001). Furthermore, the type of the index-herd was also a significant predictor of the epidemic outcomes (P-value < 0.05). The results of the current study suggest that national veterinary authorities should consider to model their national situation and to use FFO and FFS to help planning and updating their contingency plans and FMD emergency control strategies.
Decisions on foot-and-mouth disease control informed by model prediction

The predictive capability of the first fortnight incidence (FFI), which is the number of detected herds within the first 14 days following detection of the disease, of the course of a foot-and-mouth disease (FMD) epidemic and its outcomes were investigated. Epidemic outcomes included the number of affected herds, epidemic duration, geographical size, and costs. The first fourteen days spatial spread (FFS) was also included to support the prediction. The epidemic data were obtained from a Danish version (DTU-DADS) of the Davis Animal Disease Spread simulation model. The FFI and FFS showed good correlations with the epidemic outcomes. The predictive capability of the FFI was high. This indicates that the FFI may take a part in the decision of whether or not to boost FMD control, which might prevent occurrence of a large epidemic in the face of an FMD incursion. The prediction power was improved by supplementing the models with information on FFS and characteristics of the index-herd. Results presented here will contribute to improve preparedness of Denmark to early control of a hypothetical FMD epidemic.

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Simulated effects of changes in herd sizes and densities with regard to fmd outbreaks in Denmark

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Comparison of different control strategies on FMD in Denmark

The purpose of this study was to compare different control strategies that could be used in Denmark during an outbreak of FMD, based on epidemiological, ethical and economic parameters. Nearly a hundred different control strategies and more than 30 sensitivity analyses were run, changing between depopulation (Depop), suppressive (VacToKill) and protective (VacToLive) vaccination with different times for implementation and different zone sizes. It is therefore obvious that not all results can be included here; neither will all results be presented at the seminar. However, we have done our best to extract the essence of the results. All results will be presented in the final project report, which will be available on request to the authors.
Comparing epidemiological outputs showed that extra control measures will always reduce the average duration and size of an epidemic. However, the variations in duration and size of epidemics are large, and if epidemics are small, extra control measures may not always be necessary. Comparing depopulation to suppressive and protective vaccination shows that from an epidemiologic point of view, vaccination will be beneficial. However, comparing the economy of the
epidemics, it is shown that vaccination is more expensive compared to depopulation. Results from 1000 epidemics starting in cattle herds in cattle dense areas. Epidemiological results from ISP presented as medians and 5-95 percentiles (brackets), economical as means. The size, duration and costs of epidemics vary much with the type of index herd (starting points). Furthermore, not only economy, but also ethical and political issues will also play an important role in decision making. Therefore, it is important to keep in mind that this work will not give the answer as to which strategy to use during an epidemic, but can be used as a decision support tool. Sometimes, even though one strategy will be predicted to be cheaper, the second cheapest strategy might reduce the number of killed animals so much that it will become a better option.

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Consequence of changes in herd size and densities for the contingency planning
The objective of the current work was to evaluate whether the effects and control of foot-and-mouth disease (FMD) spread would differ following the structural changes to the Danish agricultural sector from now until 2030. Following the predicted structural changes, a new farm file was created, representing active farms in 2030. Index herds were randomly selected from the created farm file. The farm file contains information about the herd ID, coordinates, number of animals and movement rates. DTU-DADS and ISP were used to simulate the spread of FMD in Denmark in 2030. Following discussions with the industry, low risk contacts are assumed to increase with increasing herd size, and thus the number of low risk contacts was increased by 50%. All other input values were assumed to stay the same. Four different control scenarios were run: 1) A basic scenario representing current EU and Danish control strategies, 2) pre-emptive depopulation of susceptible herds in a radius of 0.5, 1, 1.5 and 3 km around the detected herds, 3) suppressive vaccination in a radius of 1, 2, 3, and 5 km around the detected herds 4) protective vaccination in similar radiuses to suppressive vaccination. Depopulation and vaccination started after detecting 10 infected herds. Compared to the current situation, future FMD outbreaks are, based on median values, predicted to be shorter and cheaper. Nonetheless, we also predicted that extreme epidemics would be larger and more expensive. Epidemiologic results predict that pre-emptive depopulation and protective vaccination are good choices to control the disease in future populations. However, economically, protective vaccination is predicted to be too expensive in Denmark, and thus pre-emptive depopulation and suppressive vaccination are better options to control FMD in the future. It is also important to mention that enlarging the depopulation and vaccination zones might not be a good option, because direct costs would increase and resources problems might arise leading to larger economic damage.

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Monte Carlo simulation can be defined as a representation of real life systems to gain insight into their functions and to investigate the effects of alternative conditions or actions on the modeled system. Models are a simplification of a system. Most often, it is best to use experiments and field trials to investigate the effect of alternative conditions or actions on a specific system. Nonetheless, field trials are expensive and sometimes not possible to conduct, as in case of foot-and-mouth disease (FMD). Instead, simulation models can be a good and cheap substitute for experiments and field trials. However, if simulation models would be used, good quality input data must be available.

To model FMD, several disease spread models are available. For this project, we chose three simulation model; Davis Animal Disease Spread (DADS), that has been upgraded to DTU-DADS, InterSpread Plus (ISP) and the North American Animal Disease Spread Model (NAADSM). The models are rather data intensive, but in varying degrees. They generally demand data on the farm level, including farm location, type, number of animals, and movement and contact frequency to other farms.

To be able to generate a useful model of FMD spread that can provide useful and trustworthy advises, there are four important issues, which the model should represent: 1) The herd structure of the country in question, 2) the dynamics of animal movements and contacts between herds, 3) the biology of the disease, and 4) the regulations attached to the occurrence of the disease. Model inputs are usually given in distributions to represent biological variability as well as uncertainty. Subsequently, model outputs are usually given as distributions, sometimes with wide ranges.

Use of modeling will help us to gain insight to a system as well as support decision making. However, several other factors affect decision making such as, ethics, politics and economics. Furthermore, the insight gained when models are build leads to point out areas where knowledge is lacking.

Influence of livestock markets on the spread of FMD
The purpose of this study was to investigate, whether cattle markets would influence the duration, size and economic consequences of a potential FMD epidemic in Denmark.

The spread of FMD was simulated using the InterSpread Plus. For movements of cattle to and from markets, we modeled the frequency of movements to markets for the individual herd and categorized herds that could receive contacts from markets. The epidemics were initiated in herds with market contacts. In a basic market scenario, we used the individual herds' probability of moving animals to markets, while in a control scenario we reduced all probabilities of movements to markets to zero, to reflect a situation with no markets. Each scenario was initiated in 386 different herds (index), and for each index herd, the model was run 100 times. The number of extra contacts generated through a market was set to 3.5 and the probability of transmission from markets was modeled as a normal distribution with a mean of 0.415 and a standard deviation of 0.06. This probability was a combination of the risk from purchase of animals from markets and the indirect contact from visitors on markets. Danish markets would be closed as soon as FMD is detected. Therefore, markets were only active during the first three weeks of the epidemic, as time from infection to first detection was assumed to be 21 days.

The results show an effect of markets on the size, duration and costs of a FMD epidemic (Table 1); the median duration of epidemics is 1 week longer, and 28 more herds are detected with FMD. In the scenarios with markets, the epidemics included a larger area compared to scenarios without markets. It is also shown that epidemics with markets are more expensive compared to epidemics without markets.
Input parameters and scenarios, including economic inputs

Geographical locations of the farms are the core in these models. We used geographical data, number of animals and specification of herd types for the 50,853 herds in the Danish Husbandry Register (CHR) in 2007. For each herd, the daily probability of moving animals, to another herd or to the abattoir, was calculated as the sum of all registered movements off the herd in the period from October 1, 2006 to September 30, 2007 divided by 365. Swine movements originated from the Movement database for swine and cattle and sheep movements from the Danish Cattle database.

From an infected herd, disease was simulated to spread via direct contacts (movements of animals), indirect contacts (trucks and persons) and local spread (mice, birds, airborne spread in limited distances). Furthermore, in some scenarios airborne spread was included.

For all contact types, when a contact was simulated to take place, a receiving herd needed to be found. The distance, in which the receiving herd should be found, was calculated from movement data for animals and from data from trucks and abattoirs for movements to slaughter and milk tankers. For persons visiting herds, we used a combination of expert opinions, data from other countries and survey data. Local spread was simulated within a distance of three kilometers around infected herds, with a decreasing probability of spread with increasing distance.

All epidemics were simulated to be detected on day 21. When an epidemic was detected, a three day national stand still was initiated. Furthermore, infected herds were depopulated and a 3 km detection zone and a 10 km surveillance zone were implemented around all infected herds. Within the protections zones, all herds were simulated to be clinically surveyed twice, first within 7 days after implementing the zone, and second 21 days later.

Sheep within the zone were simulated to be tested. Within the surveillance zone, all herds were simulated to be clinically surveyed within 7 days, and sheep within the zone were simulated to be tested within 7 days and again before lifting the zone. Herds, which had received animals from an infected herd, were simulated to be traced and depopulated. Herds delivering animals to an infected herd were simulated to be traced and surveyed.

In the alternative scenarios, extra control measures were added to the basic measures. Extra measures were depopulation or vaccination in ringzones of varying radii around infected herds. In alternative scenarios, we tested the effect of depopulating in zones of 500, 1000 and 1500 meters from infected herds. Depopulation was started on day 14 after detection of the first herd, or after detecting 10, 20, 30 or 50 infected herds. In some scenarios, we excluded hobby-type farms1

In the vaccination scenarios, herds within the vaccination zone were simulated to be vaccinated 14 days after detection of the first herd or when 10, 20, 30 or 50 herds were infected. All herds within the zones were simulated to be vaccinated. We used vaccination zones of either a 1, 2, 3 or 5 km. In some scenarios, hobby herds were not vaccinated. In one scenario, no sheep were vaccinated, and in another scenario no swine were vaccinated. From depopulation in zones. The resources for depopulation were estimated to 4,800 swine and 2,000 ruminants a day. Resources for depopulation in zones was shared with depopulation of infected and depopulation of traced herds, however zone depopulation would be number three on the resource list. All herds depopulated in zones would be tested before slaughter. The probability of detection was assumed to be 50% from day 0 to day 8 after the herd was infected, and increased to 1 after day 8.

The costs of an epidemic were divided into direct and indirect costs. The direct costs consisted of surveillance, depopulation, cleaning and disinfection, empty stable, compensation, national standstill, and vaccination costs. The indirect costs included losses incurred from restrictions on exports to EU and non-EU countries. The total costs were calculated as the sum of the direct and indirect costs. Costs were calculated per iteration, and summaries were thereafter calculated.
Meta-analysis on the efficacy of foot-and-mouth disease emergency vaccination

The objectives of this study were to provide a summary quantification of the efficacy of FMD emergency vaccination based on a systematic review and a meta-analysis of available literature, and to further discuss the suitability of this review and meta-analysis to summarize and further interpret the results. Peer-reviewed, symposium, and unpublished studies were considered in the analysis.

Clinical protection and virological protection against foot and mouth disease were used as parameters to assess the efficacy of emergency vaccination. The clinical protection was estimated based on the appearance of clinical signs including FMD lesions and fever, while the virological protection parameter was estimated based on the outcome of laboratory tests that were used to diagnose FMD infection. A meta-analysis relative risk was calculated per protection parameter. Results of the meta-analyses were examined using publication bias tests.

In total, 31 studies were included in the analyses, of which 26 were peer-reviewed studies, 1 was a symposium study and 4 were unpublished studies. Cattle, swine and sheep were well protected against clinical disease and foot-and-mouth disease infection following the use of emergency vaccine. Fortunately, no significant bias that would alter the conclusions was encountered in the analysis.

Meta-analysis showed to be a useful tool to summarize literature results from a systematic review of the efficacy of foot and mouth disease emergency vaccination.
Model's comparison

Three popular disease spread simulation models were used to simulate the spread of foot-and-mouth disease (FMD) in Denmark. The models’ predictions in term of disease spread, consequence, and the ranking of the applied control strategies were compared. The original Davis Animal Disease Spread (DADS version 0.05) was adapted to DTU-DADS, and this model as well as InterSpread Plus (ISP version 2.001.11) and the North American Animal Disease Spread Model (NAADSM version 3.0.81) were all used to simulate hypothetical spread of FMD in Denmark. Data on Danish herds were used including herd type, movements, and location in the period 1st October 2006 to 30th September 2007.

The three models to the highest possible extend set up to simulate the same epidemics in 3 different control scenarios: 1) A basic scenario representing EU and Danish control strategies, 2) pre-emptive depopulation of susceptible herds in a 500 meters radius around the detected herds, and 3) suppressive vaccination of susceptible herds in a 1,000 meters radius around the detected herds. Depopulation and vaccination started either 14 days following the detection of the first infected herd or following detection of 50 infected herds. Five thousand index herds were selected randomly in which there were 1,000 cattle herds located in high density cattle area and 1,000 in low density cattle area, 1,000 swine herds located in high density swine area and 1,000 in low density swine area, and 1,000 sheep herds.

Generally, NAADSM predicted the largest, longest duration and costliest epidemics. DTU-DADS predicted larger, longer duration and costlier epidemics than ISP, except when epidemics started in cattle herds located in high density cattle area. ISP predicted suppressive vaccination to be less costly than depopulation, while the least costly control strategy predicted by DTU-DADS differed depending on the species and density area of the index herd. It was not possible to run the depopulation scenarios in the NAADSM due to limitations in the model.

Running several models in parallel gives better insight in disease spread, limits typing and coding errors and improves understanding of modeled processes. The chosen control strategy might depend on the chosen model.

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Optimizing the control of foot-and-mouth disease in Denmark by simulation: Meta-analysis on the efficacy of foot-and-mouth disease emergency vaccination

General information
Publication status: Published
Organisations: National Veterinary Institute, Section for Epidemiology
Contributors: Hisham Beshara Halasa, T., Boklund, A., Enæe, C.
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Optimizing the control of foot-and-mouth disease in Denmark by simulation: Foot-and-mouth disease simulation modeling

General information
Publication status: Published
Optimizing the control of foot-and-mouth disease in Denmark by simulation: Comparison of foot-and-mouth disease simulation models

General information
Publication status: Published
Organisations: National Veterinary Institute, Section for Epidemiology, Department of Informatics and Mathematical Modeling, DTU Data Analysis, Mathematical Statistics
Contributors: Hisham Beshara Halasa, T., Boklund, A., Stockmarr, A., Enøe, C., Christiansen, L. E.
Publication date: 2012
Media of output: Power Point Presentation

Optimizing the control of foot-and-mouth disease in Denmark by simulation: Comparison of different control strategies on FMD in Denmark

General information
Publication status: Published
Organisations: National Veterinary Institute, Section for Epidemiology, Department of Informatics and Mathematical Modeling, Mathematical Statistics
Contributors: Boklund, A., Hisham Beshara Halasa, T., Christiansen, L. E., Enøe, C.
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Optimizing the control of foot-and-mouth disease in Denmark by simulation: Influence of livestock markets on spread of FMD

General information
Publication status: Published
Organisations: National Veterinary Institute, Section for Epidemiology, Department of Informatics and Mathematical Modeling, Mathematical Statistics
Contributors: Boklund, A., Hisham Beshara Halasa, T., Christiansen, L. E., Enøe, C.
Publication date: 2012
Media of output: Power Point Presentation
Predicting the structural development in Danish livestock and how it affects control strategies against FMD

The purpose of this study was to assess if the optimal control strategy against foot-and-mouth disease (FMD) spread is invariant to structural development in Danish livestock until 2030. The DTU-DADS model as presented by Halasa et al. uses demographic information of all farms including their location, size, and production type. The main challenge was to predict the demographic data.

Based on data for all herds with animals susceptible to FMD in the Central Husbandry Registry from 1999 to 2010 and supplementary data for swine herds from Danish Agriculture & Food Council (2002 to 2009), all farms were classified by production type and size each year. A total of 88 classes were used. For each species group (cattle, swine, and sheep and goat) a transition probability matrix (TPM) was estimated based on the ten year to year transitions. It was hypothesized that there might be regional differences. This was assessed by dividing Denmark into 7 regions, counting all transitions per region, and comparing these counts to the country wide counts using a Chisq test. Due to the regionalization, some of the less populated size categories were merged to reduce noise. All regions were found to have significantly different TPMs. These TPMs were used in a Markov chain to predict the distribution of farms in year 2030. However, the predictions were unrealistic as far too many farms opened – since all closed farms were allowed to reopen. It was decided to make the closed state a terminal state and make an independent prediction of how many farms should open each year. The best model was a log-linear model for each region. The combined result is a reduction from 51,031 herds in 2007 to 14,126 farms in 2030 with larger average size.

Simple decision tools to help optimize the control strategy 2 weeks into a Danish FMD epidemic

The choice of whether or not to apply emergency vaccination is one of the most difficult decisions facing the authorities when foot-and-mouth disease (FMD) breaks out in a free country (Barnett et al. 2002). A simple quantitative tool has been proposed using the first 14-days incidence (FFI) of outbreaks by 12 regional foci in the 2001 UK epidemic to predict the duration and the cumulative number of outbreaks at the end of the epidemic (Huber et al. 2006). Contingency planning should include provision for emergency vaccination and must address the complex decisions of not
only when, where, and how to apply vaccine, but also its economic consequences. Computer modelling may be a useful aid to cost benefit and decision support systems in this context (Barnett et al. 2002). We used a modified FFI procedure to analyze data from a series of 5,000 FMD simulations with current Danish population data at the national level and the basic EU control strategy using a modified DADS model (DTU-DADS).

The primary independent variable in regressions and correlations was the number of outbreaks detected during the first 14 days of the epidemic. The dependent variables were the number of outbreaks detected after day 14, the epidemic duration after day 14 and the size of the affected region at the end of the epidemic.

Statistically significant positive correlations were found in all regression analyses of the data. There was, however, a high degree of variation (Fig. 1), which is to be expected, since we simulated 5000 different epidemics, while the original publication analyzed regional variations in field data from one and the same epidemic (Hutber et al. 2006).

We also simplified the presentation of the results for operational use during a potential outbreak, using a 2-by-2 table format to estimate predictive values by applying selected cut-off- values for both the dependent and the independent variables (Table 1).

Emergency vaccination should be considered during an outbreak if the predicted cumulative size, duration or cost of the epidemic appears alarming (EU 2003, Kitching et al. 2005, Hagerman et al. 2010). The overall results from our project support this conclusion when comparing the expected outcomes from applying the basic control measures, emergency vaccination after day 14 and zonal culling after day 14, respectively (Boklund et al., in prep.)

Conclusion: Our results indicate that predicting the final outcome of an epidemic from the number of outbreaks by day 14 and modifications hereof might be useful in informing decisions two weeks into the epidemic about the potential introduction of control strategies based on emergency vaccination or zonal culling.
Simulation of the influence of Danish cattle markets on a Foot-and-Mouth epidemic

During the epidemic of Foot-and-Mouth disease (FMD) in the United Kingdom in 2001, live animal markets had large influence on the spread of the disease. The culture of and behavior around markets are expected to be different between countries. During the last decade, the number of animals traded through markets in Denmark has decreased and only few cattle markets are left.

The purpose of this study was to investigate, whether cattle markets would influence the duration, size and economic consequences of a potential FMD epidemic in Denmark.

The spread of FMD was simulated using the stochastic and spatial disease-spread InterSpread Plus, version 2.001.11. From Danish databases, we collected data movements of animals. These were used to model movements of animals for each individual herd. For movements of cattle to and from markets, we modeled the frequency of movements to markets for the individual herd and categorized herds that could receive contacts from markets. The epidemics were initiated in herds with market contacts. In a basic market scenario, we used the individual herds' probability of moving animals to markets, while in a control scenario we reduced all probabilities of movements to markets to zero, to reflect a situation with no markets. Each scenario was initiated in 100 different herds (index), and for each index herd, the model was run 100 times. The number of extra contacts generated through a market was set to 3.5 and the probability of transmission from markets was modeled as a normal distribution with a mean of 0.415 and a standard deviation of 0.06. This probability was a combination of the risk from purchase of animals from markets and the indirect contact from visitors on markets. Danish markets would be closed as soon as FMD is detected. Therefore, markets were only active during the first three weeks of the epidemic, as time from infection to first detection was modeled as 21 days.

The results was described as epidemic duration (from first detection day to last detection day), number of detected herds and infected area, direct costs (costs of surveillance visits, tests, slaughter etc.) and indirect losses due to the epidemic (export losses).

The results show an effect of markets on the size and duration of a FMD epidemic (Table 1); the median duration of epidemics is 1 week longer, and 28 more herds are detected with FMD. In the scenarios with markets, the epidemics included a larger area compared to scenarios without markets. Economic results will be described in the final paper. Markets can influence spread of other diseases as well. Little is known about the influence of markets on spread of other diseases. Even though FMD is more contagious than many other diseases, the markets effect on spread of other diseases might be more prominent, as the activity of markets is not influenced by the presence of endemic diseases.

Simuleringsstudier af konsekvenser af mund- og klovesyge i Danmark

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Organisations: National Veterinary Institute, Division of Veterinary Diagnostics and Research, Section for Veterinary Epidemiology and public sector consultancy, Section for Epidemiology
Contributors: Boklund, A., Hisham Beshara Halasa, T., Enøe, C.
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Event: Abstract from Kvægkonference 2012, Bredsten, Denmark.
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Meta-analysis on the efficacy of foot-and-mouth disease emergency vaccination

The objectives of this study were to provide a summary quantification of the efficacy of FMD emergency vaccination based on a systematic review and a meta-analysis of available literature, and to further discuss the suitability of this review and meta-analysis to summarize and further interpret the results. Peer-reviewed, symposium, and unpublished studies were considered in the analysis. Clinical protection and virological protection against foot and mouth disease were used as parameters to assess the efficacy of emergency vaccination. The clinical protection was estimated based on the appearance of clinical signs including FMD lesions and fever, while the virological protection parameter was estimated based on the outcome of laboratory tests that were used to diagnose FMD infection. A meta-analysis relative risk was calculated per protection parameter. Results of the meta-analyses were examined using publication bias tests. In total, 31 studies were included in the analyses, of which 26 were peer-reviewed studies, 1 was a symposium study and 4 were unpublished studies. Cattle, swine and sheep were well protected against clinical disease and foot and mouth disease infection following the use of emergency vaccine. Fortunately, no significant bias that would alter the conclusions was encountered in the analysis. Meta-analysis can be a useful tool to summarize literature results from a systematic review of the efficacy of foot and mouth disease emergency vaccination.

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Organisations: National Veterinary Institute, The Pirbright Institute
Contributors: Hisham Beshara Halasa, T., Boklund, A., Cox, S., Enøe, C.
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ISI indexed (2011): ISI indexed yes
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Svinepestovervågningen i Danmark - kan vi gøre det bedre?

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Publication status: Published
Organisations: National Veterinary Institute, Danish Veterinary and Food Administration, Landbrug og Fødevarer
Contributors: Lohse, L., Uttenthal, Å., Hansen, M. S., Boklund, A., Enøe, C., Sten, M., Jan, D., Nielsen, J.
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Comparing the epidemiological and economic effects of control strategies against classical swine fever in Denmark
In 2006, total Danish pork exports were valued at (sic) 3.8 billion, corresponding to approximately 5% of the total Danish exports, and an outbreak of a notifiable disease would have dramatic consequences for the agricultural sector in Denmark. Several outbreaks of classical swine fever (CSF) have occurred in Europe within the last decade, and different control strategies have been suggested. The objective of this study was to simulate the epidemiological and economic consequences of such control strategies in a CSF epidemic under Danish conditions with respect to herd demographics and geography and to investigate the effect of extra biosecurity measures on farms. We used InterSpread Plus to model the effect of nine different control strategies: the minimum measures required by the EU plus depopulation of contact herds (EUplus), extra depopulation of neighbouring herds, extra surveillance within the protection and surveillance zones, extra biosecurity in SPF herds—or in all herds, vaccination of all pigs in the 1 or 2 km zones using live vaccine as a protective measure (vaccination-to-kill), vaccination of all weaners and finishers in the 1 or 2 km zones using an E2 marker vaccine as a suppressive measure (vaccination-to-live). Each epidemic was simulated to start in four different index herds: production herds located in low, medium and high pig density areas, respectively; and a nucleus herd in an area of high pig density. For each control strategy and index case, we calculated the size and duration of the epidemic, the number of depopulated and/or vaccinated herds and animals, the control costs borne by the public and the pig industry, respectively, as well as the loss of exports associated with the epidemic. The simulations showed that the EUplus strategy is the most effective of the evaluated strategies with respect to limiting the size, duration and cost of the epidemic, regardless of the index case. However, regarding the number of slaughtered animals, the vaccination-to-live strategies appeared to be more effective. Epidemics become larger and last longer if the index case is a nucleus herd. This implies that biosecurity in nucleus herds is extremely important to avoid transmission of CSF to these herds. Simulations showed that a Danish CSF epidemic will be moderate in most cases and will include fewer than 10 cases and last less than 2 weeks on average. However, for some iterations, long-lasting and large epidemics were observed. Irrespective of the size and duration, an epidemic is expected to be very costly due to the export losses.

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Organisations: Section for Veterinary Epidemiology and public sector consultancy, Division of Veterinary Diagnostics and Research, National Veterinary Institute, Sektion for Ekotiske Virussygdomme, Division of Virology
Contributors: Boklund, A., Toft, N., Alban, L., Uttenhal, Å.
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Peer-reviewed: Yes

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Scopus rating (2009): SJR 1.021 SNIP 1.338
Web of Science (2009): Indexed yes
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Research output: Contribution to journal › Journal article – Annual report year: 2009 › Research › peer-review

Emergency vaccination for classical swine fever will not be cost-effective for countries with a large export
In 2008, total Danish pork exports were evaluated at €3.6 billion, corresponding to approximately 5% of the total Danish exports. An outbreak of a notifiable disease might, there-fore, have a dramatic consequence for the agricultural sector in Denmark. The objective of this study was to simulate the epidemiological and economic consequences of such control strategies under Danish conditions with respect to herd demographics and geography as well as to investigate the effect of extra biosecurity on farms. We used InterSpread Plus to model the effect of nine different control strategies: the minimum measures required by the EU plus depopulation of contact herds (EUplus), extra depopulation of neighbouring herds, extra surveillance of neighbouring herds, extra surveil-lance within the protection and surveillance zones, extra biosecurity in SPF herds – or in all herds, vaccination of all pigs in the 1 or 2 km zones as a protective measure (vaccination-to-kill), vaccination of all weaners and finishers in the 1 and 2 km zones as a suppressive measure (vaccination-to-live). Each epidemic was simulated to start in four different index herds: production herds located in low, medium and high pig density areas, respectively; and a nu-cleus herd in an area of high pig density. For each control strategy and index case, we calcu-lated the size and duration of the epidemic, the number of depopulated and/or vaccinated herds and animals, the control costs borne by the public and the pig industry, respectively, as well as the loss of exports associated with the epidemic. The simulation showed that the EUplus strategy is the most effective of the
evaluated strategies with respect to limiting size, duration and costs of the epidemic, regardless of the index case. However, regarding the number of slaughtered animals, the vaccination-to-live strategy appeared to be more effective. Epidemics become larger and longer if the index case is a nucleus herd. This implies that biosecurity in nucleus herds is extremely important to avoid transmission of CSF to these herds. In the Netherlands in 1997-98, many herds were involved in a large epidemic (Elbers et al., 1999). However, many epidemics include a smaller number of infected herds, as was the case in Germany in the 1990s (Fritzemeier et al., 2000) and in England in 2000 (Mackinnon, 2001). Simulations showed that a Danish CSF epidemic will be moderate in most cases and will include fewer than ten cases and last less than 2 weeks on average. However, for some iterations, long-lasting and large epidemics were observed. Irrespective of the size and duration, an epidemic is expected to be very costly due to the export losses. Elbers, A.R.W., Stegeman, A., Moser, H., Ekker, H.M., Smak, J.A., Plumers, F.H., 1999. The classical swine fever epidemic 1997-1998 in The Netherlands: descriptive epidemiology. Prev. Vet. Med., 42, 157-184. Fritzemeier, J., Teuffert, J., Greiser-Wilke, I., Staubach, Ch., Schlüter, H., Moennig, V., 2000. Epidemiology of classical swine fever in Germany in the 1990s. Vet. Microbiol. 77, 29-41. Mackinnon, J.D., 2001. Some clinical and epidemiological aspects of the outbreak of Classical Swine Fever in East Anglia in 2000, State Vet.J., 11, 2-7.

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Contributors: Boklund, A., Toft, N., Alban, L., Uttenthal, Å.
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Nød vaccination ikke rentabelt i et land med stor ekspport

General information
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Contributors: Boklund, A., Toft, N., Alban, L., Uttenthal, Å.
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Peer-reviewed: Unknown

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Simulating the spread of classical swine fever virus between a hypothetical wild-boar population and domestic pig herds in Denmark
Denmark has no free-range wild-boar population. However, Danish wildlife organizations have suggested that wild boar should be reintroduced into the wild to broaden national biodiversity. Danish pig farmers fear that this would lead to a higher risk of introduction of classical swine fever virus (CSFV), which could have enormous consequences in terms of loss of pork exports. We conducted a risk assessment to address the additional risk of introducing and spreading CSFV due to the reintroduction of wild boar. In this paper, we present the part of the risk assessment that deals with the spread of CSFV between the hypothetical wild-boar population and the domestic population. Furthermore, the economic impact is assessed taking the perspective of the Danish national budget and the Danish pig industry. We used InterSpreadPlus to model the differential classical swine fever (CSF) risk due to wild boar. Nine scenarios were run to elucidate the effect of: (a) presence of wild boar (yes/no), (b) locations for the index case (domestic pig herd/wild-boar group),

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Organisations: Sektion for Eksotiske Virussygdomme, Division of Virology, National Veterinary Institute, Danish Meat Association
Contributors: Boklund, A., Goldbach, S. G., Uttenthal, Å., Alban, L.
Wildrisk: Classical swine fever and wild boar in Denmark: A risk analysis

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Publication status: Published
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WILDRISK_2005.pdf
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Biosecurity in 116 Danish fattening swineherds: descriptive results and factor analysis
Biosecurity measures are important for the herd's protection against diseases and also to provide nationwide protection against the introduction of exotic diseases. In this paper, we describe the farmers’ choices and routines regarding biosecurity in Danish fattening herds. Overall, 116 Danish swine fattening herds in three areas of different pig density were interviewed. Of these herds, 78% purchased weaners from one sow herd only, whereas 10% purchased from >5 sow herds during 1 year. Large herds (>500 finishers) purchased weaners more often than smaller herds (<500 finishers). Only two swine producers purchased weaners from a market. Almost all herds (95%) received weaners from one sow herd at one time, and only one herd received from >5 sow herds in one batch. Twenty-one percent did not use an effective barrier between the loading area and the stables when delivering pigs for slaughter. Entry rooms (in which clothing and boots are changed) were common at the farm, and the numbers of visitors were generally low (3.10). A site scoring high on factor 1 was a large SPF herd, which received weaners from a single source, had biosecurity requirements for the transport vehicles, and had a high level of biosecurity for visitors. A site scoring high on factor 2 was a multi-site farm, which had personnel working on more than one of the sites, only received weaners from one sow herd, had delivering herds placed close to the participating site, and transported animals themselves. A site scoring high on factor 3 was a site which hired commercial transport for slaughter, was situated far from the abattoir and had a high level of biosecurity when loading pigs. A production site scoring high on factor 4 was a large site, which used all-in/all-out management, washed and disinfected between each group, and purchased many weaners.
Biosecurity in 121 Danish sow herds
Herds are under constant risk of introducing new pathogens from different sources. In this article we describe biosecurity practices in Danish sow herds. Between December 1, 1999 and February 29, 2000, 121 sow units were interviewed regarding biosecurity on the site. The questionnaire contained 62 questions. The 121 units were situated in three areas with different swine densities. Sow units were described by their sizes (units with >110 sows were regarded as large herds) and health status (SPF herds or conventional herds). Of the 121 sow herds, 63 (52%) sold weaners. Most sow units (71%) used delivery facilities for the picking up of weaners, but half of these did not have a barrier between the loading area and the stable while loading. In 19% of the units, weaners were picked up directly from the stable, and in 10% the truck driver had access to the stables. Most units required the vehicle to be cleaned (16%) or cleaned and disinfected (48%) before the transport; large sites and SPF sites more often required stricter biosecurity measures, for example a quarantine period before the transport of weaners.

Risk factors for infection of sow herds with porcine reproductive and respiratory syndrome (PRRS) virus
In 1992, the porcine reproductive and respiratory syndrome virus (PRRSV) of European type (PRRSV-EU) was introduced in Denmark. By 1996, the virus had spread to approximately 25% of the Danish herds. In January 1996, a modified-live vaccine based on the American type of the virus (PRRSV-US) was used in replacement boars for Danish artificial insemination (AI) centres and from July 1996, the vaccine was used in PRRSV-EU infected herds for prevention of disease. Soon after vaccine introduction, PRRSV non-infected herds experienced outbreaks of disease due to infection with PRRSV-US. In this study, we investigated the risk factors (biosecurity level, animals, exposure from PRRSV-US-infected neighbour herds, semen, herd size, pig density and herd density) for infection with PRRSV-US in a cohort of 1071 sow herds; we used a nested case-control study. The retrospective observation period lasted from June 1996 (when they all were noninfected) to October 1997. Seventy-three non-vaccinated, closed sow herds became infected with the vaccine...
strain during this period. Each case herd was matched with two control herds from the cohort (controls had not been infected at the time of infection in the case herds). The data were analysed using a Cox-regression model. The hazard of infection increased significantly with exposure from PRRSV-US-infected neighbouring herds, purchase of animals from herds incubating PRRSV-US infection, increasing herd size and purchase of semen from boars at PRRSV-US-infected AI centres. The results are consistent with the modified-live vaccine strain spread to other herds by trade with animals and semen and by neighbour (area) transmission. We suggest that virus spread by aerosols was a frequent mode of transmission.

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Organisations: National Veterinary Institute
Contributors: Mortensen, S., Stryhn, H., Søgaard, R., Boklund, A., Stärk, K. D. C., Christensen, J., Willeberg, P.
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Web of Science (2002): Indexed yes
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Research output: Contribution to journal › Journal article – Annual report year: 2002 › Research › peer-review

Projects:

Veterinary epidemiology with emphasis on the association between spatial proximity, contact structures, antibiotic consumption and antibiotic resistance
Birkegård, A. C., PhD Student, National Veterinary Institute
Toft, N., Main Supervisor
Hisham Beshara Halasa, T., Supervisor
Boklund, A., Examiner
Dewulf, J., Examiner
Nielsen, S. S., Examiner
Samfinansieret - Andet
01/12/2013 → 20/12/2017
Award relations: Veterinary epidemiology with emphasis on the association between spatial proximity, contact structures, antibiotic consumption and antibiotic resistance
Project: PhD

Undersøgelse af sammenhænge mellem sundhed, velfærd og antibiotikaforbrug hos danske husdyr
Førtørn, M. E., PhD Student, National Veterinary Institute
Toft, N., Main Supervisor
Boklund, A., Supervisor
Christiansen, L. E., Supervisor
Jensen, V. F., Examiner
Pedersen, K. S., Examiner
Dewulf, J., Examiner
Stege, H., Supervisor
Technical University of Denmark
15/12/2011 → 17/11/2016
Award relations: Undersøgelse af sammenhænge mellem sundhed, velfærd og antibiotikaforbrug hos danske husdyr
Project: PhD
Development of a herd- and cow-specific decision support tool for control of mastitis
Gussmann, M. K., PhD Student, National Veterinary Institute
Hisham Beshara Halasa, T., Main Supervisor
Toft, N., Supervisor
Boklund, A., Examiner
Denwood, M., Examiner
Rajala-Schultz, P. J., Examiner
Nielsen, S. S., Supervisor
Samfinansieret - Andet
01/07/2015 → 30/09/2018
Award relations: Development of a herd- and cow-specific decision support tool for control of mastitis
Project: PhD

Investigation of transmission dynamics and virulence of new European African Swine Fever Virus strains
Olesen, A. S., PhD Student, National Veterinary Institute
Rasmussen, T. B., Main Supervisor
Boklund, A., Supervisor
Betner, A., Supervisor
Jungersen, G., Examiner
Dixon, L., Examiner
Mortensen, S., Examiner
Samfinansieret - Andet
01/08/2015 → 21/03/2019
Award relations: Investigation of transmission dynamics and virulence of new European African Swine Fever Virus strains
Project: PhD

Simulation modeling of LA-MRSA dispersal and control between swine herds
Schulz, J., PhD Student, National Veterinary Institute
Hisham Beshara Halasa, T., Main Supervisor
Boklund, A., Supervisor
Toft, N., Supervisor
Jensen, V. F., Examiner
Baekbo, P., Examiner
Selhorst, T., Examiner
Offentlig finansiering
01/05/2015 → 21/02/2019
Award relations: Simulation modeling of LA-MRSA dispersal and control between swine herds
Project: PhD

The spread and control of LA-MRSA within Danish pig herds
Sørensen, A. I. V., PhD Student, National Veterinary Institute
Hisham Beshara Halasa, T., Main Supervisor
Boklund, A., Supervisor
Toft, N., Supervisor
Kirkeby, C. T., Examiner
Wagenaar, J. A., Examiner
Larsen, J., Supervisor
Mortensen, S., Examiner
Offentlig finansiering
01/04/2015 → 20/06/2018
Award relations: The spread and control of LA-MRSA within Danish pig herds
Project: PhD

Investigation of transmission dynamics and virulence of new African Swine Fever Virus strains
Olesen, A. S., PhD Student, Section for Public sector service and commercial diagnostics, National Veterinary Institute
Betner, A., Supervisor, Section for Public sector service and commercial diagnostics, National Veterinary Institute
Boklund, A., Supervisor, National Veterinary Institute, Section for Epidemiology
Rasmussen, T. B., Main Supervisor, National Veterinary Institute, Section for Virology
01/08/2015 → 31/07/2018
Project: Research
**Styrkelse af det videnmæssige beredskab overfor svinepest**
Utenthal, Å., Project Manager, National Veterinary Institute, Division of Virology
Lohse, L., Project Participant, National Veterinary Institute, Division of Virology
Nielsen, J., Project Participant, National Veterinary Institute, Division of Virology
Rasmussen, T. B., Project Participant, National Veterinary Institute, Division of Virology
Enøe, C., Project Participant, National Veterinary Institute, Division of Virology
Mortensen, S., Contact Person, National Veterinary Institute, Division of Virology
Boklund, A., Contact Person, National Veterinary Institute, Division of Virology
Project ID: 22001_2008
Forskningsprojekter - Andre ministerier og styrelser: DKK3,496,000.00
01/04/2008 → 31/03/2011
Keywords: husbandry animal diseases, Classical Swine Fever virus, Diagnostics, Immuno-pathogenesis
Award relations: Styrkelse af det videnmæssige beredskab overfor svinepest
Project: Research

**Activities:**

**Risk assessment of a spread of a pathogen: simulation models**
Period: 6 Dec 2018
Anette Boklund (Guest lecturer)
National Veterinary Institute
Epidemiology

**Description**
Venice, Italy

**Related external organisation**
BTSF
Belgium
Activity: Talks and presentations › Guest lectures, external teaching and course activities at other universities

**Spørgeskema som redskab og metode til udvikling og udforskning af sygepleje**
Period: 26 Oct 2018 → 9 Nov 2018
Anette Boklund (Lecturer)
Section for Epidemiology
National Veterinary Institute

**Related external organisation**
Aarhus University
Inge Lehmanns Gade 10, 8000, Aarhus C, Denmark
Activity: Talks and presentations › Guest lectures, external teaching and course activities at other universities

**Ramt af svinepest**
Period: 24 Oct 2018
Anette Boklund (Guest lecturer)
Bertel Strandbygaard (Guest lecturer)
Jan Dahl (Guest lecturer)
Carsten Aagaard (Guest lecturer)
Sten Mortensen (Guest lecturer)
Tina Birk Jensen (Guest lecturer)
National Veterinary Institute
Epidemiology
Virology
Degree of recognition: National

Related event

Svinekongressen
23/10/2018 → 24/10/2018
Herning, Denmark
Activity: Talks and presentations › Conference presentations

Risk assessment of a spread of a pathogen: simulation models
Period: 10 Oct 2018
Anette Boklund (Guest lecturer)
National Veterinary Institute
Epidemiology

Description
Utrecht, Netherlands

Related external organisation

BTSF
Belgium
Activity: Talks and presentations › Guest lectures, external teaching and course activities at other universities

ASF-STOP meeting
Period: 3 Jul 2018
Anette Boklund (Guest lecturer)
National Veterinary Institute
Epidemiology
Degree of recognition: International

Related event

ASF-STOP
03/07/2018 → 04/07/2018
Lisabon, Portugal
Activity: Talks and presentations › Conference presentations

Risk assessment of a spread of a pathogen: simulation models
Period: 20 Jun 2018
Anette Boklund (Guest lecturer)
National Veterinary Institute
Epidemiology

Description
Riga, Latvia

Related external organisation

BTSF
Belgium
Activity: Talks and presentations › Guest lectures, external teaching and course activities at other universities

Risk assessment of a spread of a pathogen: simulation models
Period: 8 Feb 2018
Anette Boklund (Guest lecturer)
National Veterinary Institute
**Epidemiology**

**Description**
Tallin, Estonia

**Related external organisation**
BTSF
Belgium
Activity: Talks and presentations › Guest lectures, external teaching and course activities at other universities

**Vet-TWIN workshop, Pulawy, Poland**
Anette Boklund (Guest lecturer)

National Veterinary Institute

**Description**
Workshop on use of simulation models for contingency planning

**Related external organisation**
National Veterinary Research Institute
Pulawy, Poland
Activity: Talks and presentations › Guest lectures, external teaching and course activities at other universities

**Spørgeskema som redskab og metode til udvikling og udforskning af sygepleje**
Period: 22 Sep 2017 → 6 Oct 2017
Anette Boklund (Lecturer)

Section for Epidemiology
National Veterinary Institute

**Related external organisation**
Aarhus University
Inge Lehmanns Gade 10, 8000, Aarhus C, Denmark
Activity: Talks and presentations › Guest lectures, external teaching and course activities at other universities

**Biostatistik for sygeplejersker**
Period: 21 Sep 2016 → 16 Dec 2016
Anette Boklund (Lecturer)

Section for Epidemiology
National Veterinary Institute

**Related external organisation**
Aarhus University
Inge Lehmanns Gade 10, 8000, Aarhus C, Denmark
Activity: Talks and presentations › Guest lectures, external teaching and course activities at other universities

**Biostatistik for sygeplejersker**
Anette Boklund (Lecturer)

Section for Epidemiology
National Veterinary Institute
Related external organisation

Aarhus University  
Inge Lehmanns Gade 10, 8000, Aarhus C, Denmark  
Activity: Talks and presentations › Guest lectures, external teaching and course activities at other universities

Expert group for swine fever (External organisation)  
Period: 19 Oct 2015 → …  
Anette Boklund (Participant)  
National Veterinary Institute  
Section for Epidemiology  
Description  
National expert group for swine fever (CSF & ASF)

Related external organisation  
Expert group for swine fever  
Activity: Membership › Membership of committees, commissions, boards, councils, associations, organisations, or similar

CoVetLab  
Period: 24 Jun 2015  
Anette Boklund (Speaker)  
Section for Epidemiology  
National Veterinary Institute  
Description  
Workshop for France and Belgium in CoVetLab region  
Workshop of DTU-DADS preparation of data

Related event  
CoVetLab: Preparation of data for modelling  
24/06/2015 → 25/12/2015  
Copenhagen, Denmark  
Activity: Talks and presentations › Guest lectures, external teaching and course activities at other universities

Better Training for Safer FoodInitiative: Monte Carlo Simulation Modeling  
Period: 23 Apr 2015  
Anette Boklund (Lecturer)  
Section for Epidemiology  
National Veterinary Institute  
Related external organisation  
EU-finansieret  
Berlin, Germany  
Activity: Talks and presentations › Guest lectures, external teaching and course activities at other universities

Making models useful in contingency planning  
Period: 12 Jan 2015  
Anette Boklund (Lecturer)  
Section for Epidemiology  
National Veterinary Institute  
Description
EUFMD Webinar

Internet
Links:
https://eufmd.rvc.ac.uk/course/view.php?id=47

Related event

EuFMD e-Learning
12/01/2015 → 12/01/2015
Denmark
Activity: Talks and presentations › Guest lectures, external teaching and course activities at other universities

Danish Veterinary and Food Administration (External organisation)
Period: 30 Nov 2014 → …
Anette Boklund (Chairman)
National Veterinary Institute
Section for Epidemiology

Description
Ekspertgruppe for Mund- og klovesyge

Ekspertgruppe nedsat af FVST

Related external organisation

Danish Veterinary and Food Administration
Mørkhøj Bygade 19, 2860, Søborg, Denmark
Activity: Membership › Membership of committees, commissions, boards, councils, associations, organisations, or similar

Vidensformer og forskningsmetode: Biostatistik
Anette Boklund (Lecturer)
Section for Epidemiology
National Veterinary Institute

Related external organisation

Aarhus University
Inge Lehmanns Gade 10, 8000, Aarhus C, Denmark
Activity: Talks and presentations › Guest lectures, external teaching and course activities at other universities

EU Working Group
Anette Boklund (Invited speaker)
National Veterinary Institute
Section for Epidemiology

Description
European Commission, Working Group on animal Health contingency planning and emergency preparedness

Related event

16/10/2014 → 17/10/2014
Grange, Ireland
Activity: Talks and presentations › Conference presentations
EU-FMD
Period: 3 Oct 2014
Anette Boklund (Invited speaker)
National Veterinary Institute
Section for Epidemiology

Related event
EU-FMD: To vaccinate or not to vaccinate: using modelling to evaluate FMD control
29/09/2014 → 03/10/2014
Franscati, Italy
Activity: Talks and presentations › Conference presentations

8th Annual Meeting of Epizone
Period: 24 Sep 2014
Anette Boklund (Organizer)
National Veterinary Institute
Section for Epidemiology

Related event
8th Annual Meeting of Epizone: Primed for tomorrow
Copenhagen, Denmark
Activity: Attending an event › Participating in or organising a conference

Spørgeskema som redskab og metode til udvikling og udforskning af sygepleje
Period: 9 Sep 2014 → 14 Oct 2014
Anette Boklund (Lecturer)
Section for Epidemiology
National Veterinary Institute

Description
Kursus for sygeplejersker på kandidat-uddannelsen

Related external organisation
Aarhus University
Inge Lehmanns Gade 10, 8000, Aarhus C, Denmark
Activity: Talks and presentations › Guest lectures, external teaching and course activities at other universities

Spørgeskema som redskab og metode til udvikling og udforskning af sygepleje
Period: 1 Oct 2013 → 15 Nov 2013
Anette Boklund (Lecturer)
Section for Epidemiology
National Veterinary Institute

Description
Kursus for sygeplejersker på kandidat-uddannelsen

Related external organisation
Aarhus University
Inge Lehmanns Gade 10, 8000, Aarhus C, Denmark
Activity: Talks and presentations › Guest lectures, external teaching and course activities at other universities
Comparing control strategies against foot-and-mouth disease: will vaccination be cost-effective in Denmark?
Period: 30 Aug 2013
Anette Boklund (Lecturer)
National Veterinary Institute
Section for Epidemiology

Related event
Disease Control and Dynamics – In a One Health Setting
26/08/2013 → 30/08/2013
Frederiksberg, Denmark
Activity: Talks and presentations › Conference presentations

Comparing control strategies against foot-and-mouth disease: will vaccination be cost-effective in Denmark?
Period: 18 Jun 2013
Anette Boklund (Lecturer)
National Veterinary Institute
Section for Epidemiology

Related event
Aktualitetsdag
18/06/2013 → …
Herning, Denmark
Activity: Talks and presentations › Conference presentations

NOSOVE
Period: 14 Jan 2013 → 17 Jan 2013
Anette Boklund (Participant)
National Veterinary Institute
Section for Epidemiology

Related event
NOSOVE
14/01/2013 → 17/01/2013
Copenhagen, Denmark
Activity: Attending an event › Participating in or organising workshops, courses, seminars etc.